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Model 2308 Portable Device Battery/Charger Simulator

User's Manual

2308-900-01 Rev. A / July 2008

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Model 2308 Portable Device Battery/Charger Simulator User's Manual

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product warranty may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

Keithley Instruments products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the user documentation.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions, or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the user documentation.

The symbol on an instrument shows that it can source or measure 1000V or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The symbol on an instrument shows that the surface may be hot. Avoid personal contact to prevent burns.

The symbol indicates a connection terminal to the equipment frame.

If this symbol is on a product, it indicates that mercury is present in the display lamp. Please note that the lamp must be properly disposed of according to federal, state, and local laws.

The **WARNING** heading in the user documentation explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in the user documentation explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits - including the power transformer, test leads, and input jacks - must be purchased from Keithley Instruments. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. Other components that are not safety-related may be purchased from other suppliers as long as they are equivalent to the original component (note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., a data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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Section 1
Getting Started

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Overview

This manual describes Keithley Instruments Model 2308 Portable Device Battery/Charger Simulator, which is designed specifically for development and high-speed production testing of DC battery-operated products.

Applications

Development and high speed testing of DC battery-operated products, such as:

- Cellular handsets
- Cellular components like RFIC power amplifiers
- Other high-volume precision electrical components.

Performance features

Key features and benefits include:

- The Model 2308 is a specialized power supply that has a very fast recovery to large, near instantaneous load current transitions. Conventional power supplies do not have this capability. The Model 2308 is designed specifically to respond to large load changes and very short pulsed loads with small transient voltage drop and a very fast recovery time. Typical devices that have these types of characteristic loads are mobile phones, wireless communication modules, and other portable, battery operated devices. The Model 2308 can maintain a near-constant output, even under quickly-changing load conditions.
- The power supply can measure a wide range of load currents. It can resolve down to 0.1 μA and measure up to 5 A. It has fast measurement capability as well and can measure load current pulses as narrow as 50 μsec.
- The Model 2308 can simulate the output of a battery. Its programmable output resistance can simulate a battery's internal resistance so that the voltage output looks exactly like that of a battery's output.
- The two channels can also sink current so that one channel (the battery channel) simulates a discharged battery, while the other channel (the charger channel) can be used to simulate a charger.

NOTE	Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, Channel 1 refers to the battery channel, Channel 2 refers to the charger channel.

Contact information

If you have any questions after reviewing this information, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-348-3735 (U.S. and Canada

Specifications

Full Model 2308 specifications are included on the Model 2308 Portable Device Battery/ Charger Simulator Product Information CD-ROM.

Inspection

The power supply was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit.

NOTE	There may be a protective film over the display lens, which can be removed.

Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. The following items are included with every order:

- Model 2308 Portable Device Battery/Charger Simulator with line cord
- Quick Disconnect Connector (2)
- Accessories as ordered
- Certificate of calibration
- Product Information CD-ROM that contains PDFs of Model 2308 User's Manual and Model 2308 Quick Start Guide

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into the manual.

Options and accessories

The following options and accessories are available for the power supply.

- 2306-DISP remote display unit
- Low inductance coaxial cable (SC-182)
- Single fixed rack mount kit (P/N 4288-1)
- Dual fixed rack mount kit (P/N 4288-2)
- IEEE-488 Interface for PCI bus (P/N KPCI-488LP)
- USB to GPIB adapter interface (P/N KUSB-488A)
- Double shielded premium GPIB cable, 0.5 m (1.6 ft) (P/N 7007-05)
- Double shielded premium GPIB cable, 1 m (3.2 ft) (P/N 7007-1)
- Double shielded premium GPIB cable, 2 m (6.5 ft) (P/N 7007-2)
- Double shielded premium GPIB cable, 3 m (10 ft) (P/N 7007-3)
- Double shielded premium GPIB cable, 4 m (13 ft) (P/N 7007-4)

Power supply overview

The Model 2308 power supply (see *Figure 1-1*) can simulate a battery channel (#1) or a charger channel (#2). *Figure 1-1* and *Figure 1-2* show the Model 2308 front and rear panels.

Figure 1-1
Model 2308 front panel

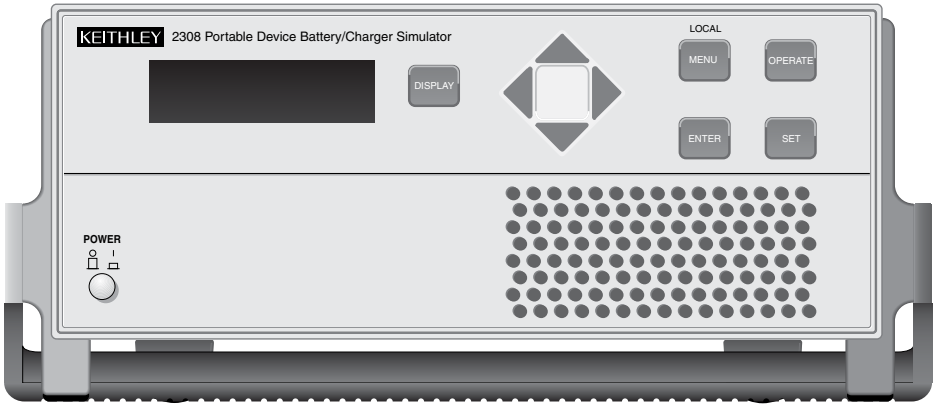
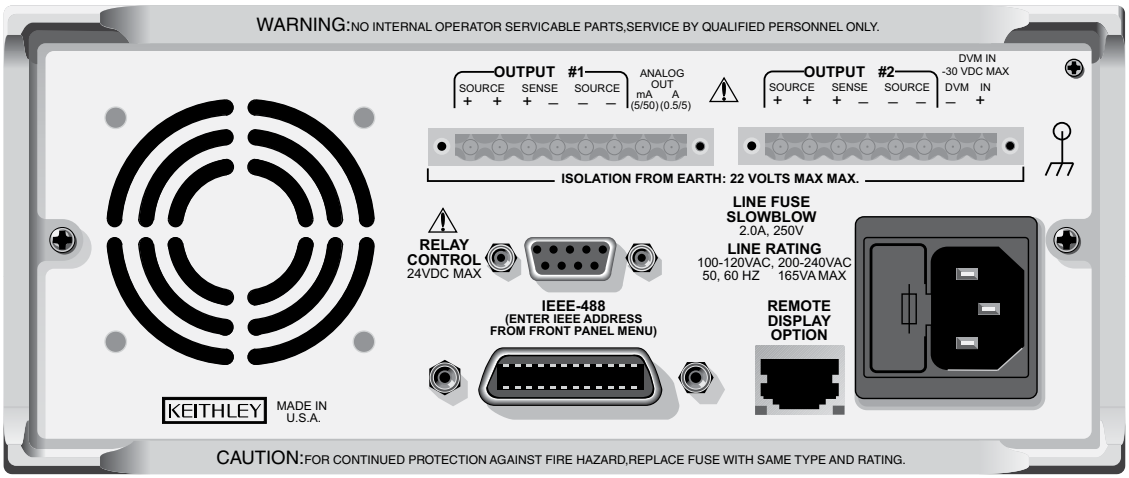


Figure 1-2
Model 2308 rear panel



NOTE	The output from each channel is isolated from the other channel.

CAUTION	Allow for adequate ventilation around the front and rear-panel openings to prevent the unit from overheating which may degrade performance.

Make sure that the maximum combined channel output is not exceeded. Also, do not exceed 3 A when using the power supply as a sink. For output voltages exceeding 5 V, the maximum sink current is less than 3 A (derate the maximum sink current 0.2 A for each volt over 5 V).

NOTE	When using the power supply as a sink (negative polarity), the power supply is dissipating rather than sourcing power (see *Sink operation*).

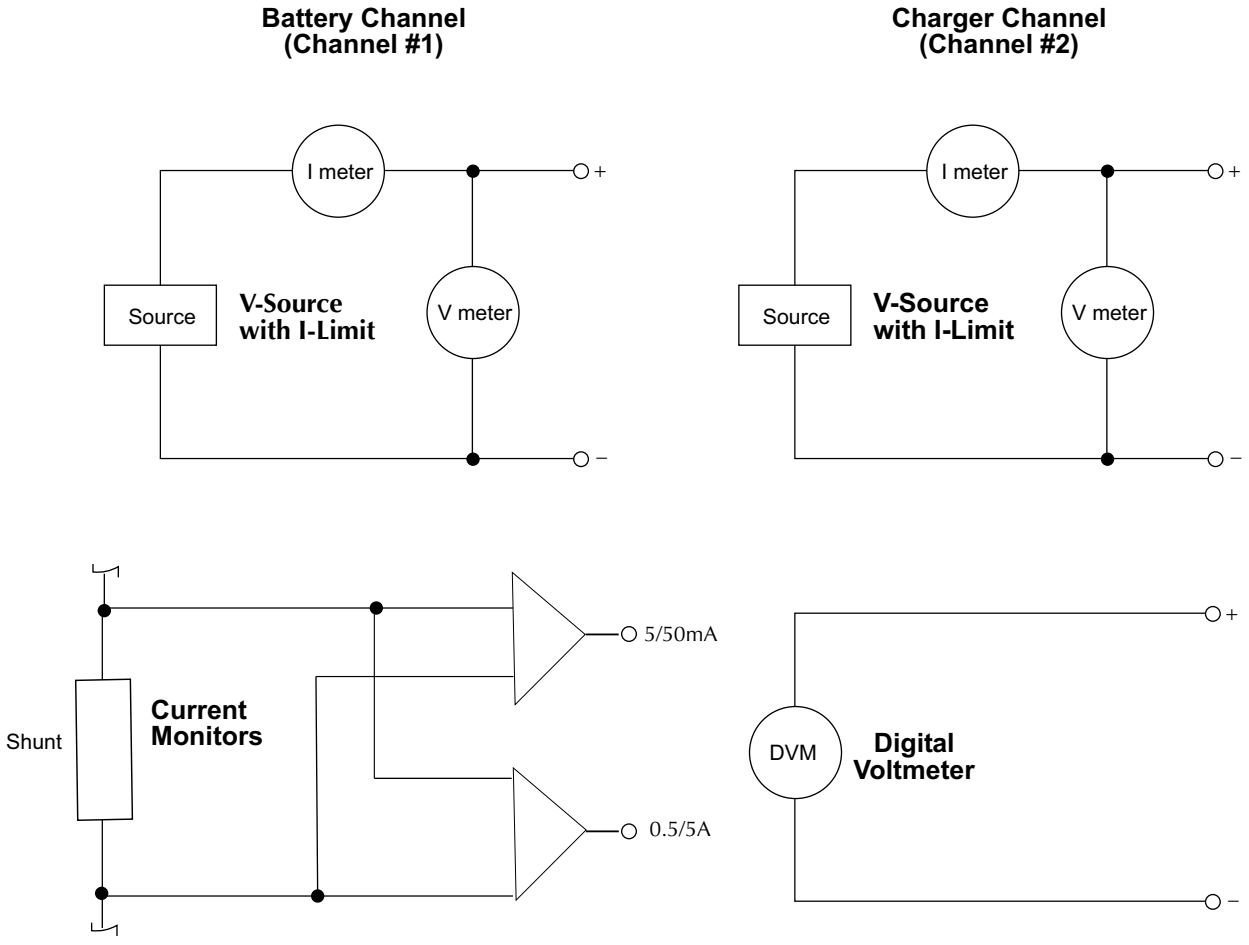
A simplified diagram of the power supply is shown in *Figure 1-3*. Note that it can read back the output voltage (V_{meter}) and current (I_{meter}). Display resolution for voltage readback is 1mV.

The battery channel (#1) has four current ranges: 5 A, 500 mA, 50 mA and 5 mA. The charger has 5 A and 5 mA. The resolution on 5 A is 100 μA, and on 5 mA is 0.1 μA. The 500 mA is 10 μA and 50 mA is 1μA.

The power supply also has a digital voltmeter (DVM - on the charger channel only) that is independent of the power supply circuit. The DVM can measure up to +30 V (1 mV resolution). The power supply has analog output pins that allow acquisition of the load current waveform for in-depth analysis on the battery channel only (see *Analog output* for more information).

When used with a pulsed load, the power supply can read back peak current, idle current, and average current (see *Section 3* for details). A long integration (up to 60 seconds) function is provided to measure average current of a low frequency pulse (long period) or a series of pulses (see *Section 4* for details).

Figure 1-3
Simplified power supply diagram

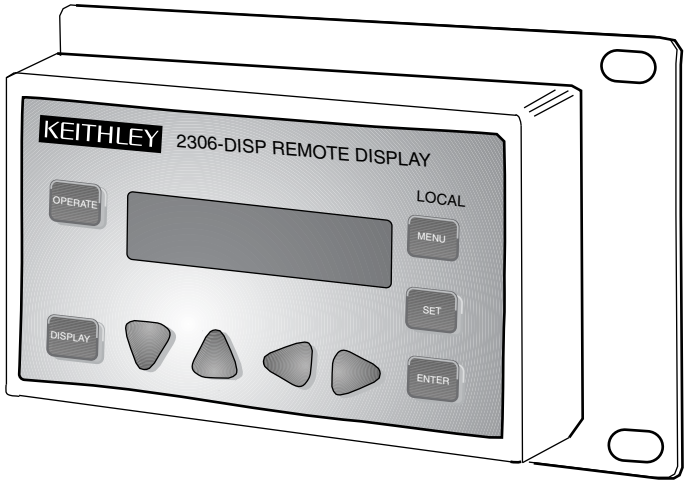


Remote display option

If you are mounting the power supply in a location where the display cannot be seen or the controls are not easily accessible, use this option (see *Figure 1-4*). This remote display module

includes all front-panel instrument controls/features (with the exception of power). All features and menus work as described for the Model 2308. A 9-foot cable attaches the remote display to the rear-panel of the power supply, allowing the unit to be operated remotely.

Figure 1-4
Model 2306-DISP Remote display option



Plug the remote display module into the rear-panel connector labeled REMOTE DISPLAY OPTION (see rear panel in *Figure 1-2*). When plugged in, the main display module is disabled with the following message displayed:

REMOTE PANEL

ENABLED

When the remote display module is unplugged, control returns to the main display module.

NOTE	When using the remote display, VFD BRIGHTNESS may not appear in the main menu (dependent on the firmware revision in the unit). When connecting or disconnecting the remote display, allow a few seconds for the power supply to recognize the action. Fast, repeated connects/disconnects of the remote display may cause the power supply to hang or appear to hang. Disconnecting the remote display and waiting a few seconds to reconnect it may clear the problem. If not, cycling power on the power supply clears the condition.

Power-up

Line power connection

The power supply operates from a line voltage in the range of 100-120VAC/200-240VAC at a frequency of 50 or 60 Hz, 165 V AC. Line voltage and frequency are automatically sensed, therefore there are no switches to set. Check to see that the line power in your area is compatible. Use the `:SYSTem::LFRequency?` query (see *Section 10*) to read the line frequency.

Perform the following steps to connect the power supply to the line power and turn it on:

WARNING	***The power cord supplied with the Model 2308 contains a separate ground for use with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.***

1. Before plugging in the power cord, make sure the front-panel power switch is in the off (0) position.
2. Connect the female end of the supplied power cord to the AC receptacle on the rear panel.
3. Turn on the power supply by pressing the front-panel power switch to the on (1) position.

Power-up sequence

On power-up, the power supply performs self-tests on its RAM and EPROM. After a blinking cursor appears on line one, RAM tests are completed. After a blinking cursor appears on line two, EPROM self tests are completed.

NOTE	If a problem develops while the instrument is under warranty, return it to Keithley Instruments for repair. If the instrument passes the self tests, the following information is briefly displayed: • **Top Line** - The model number and the IEEE-488 address are displayed (The factory default GPIB address is 16). • **Bottom Line** - Firmware revision levels are displayed for the main board and the display board. Also displayed is the detected line frequency.

After displaying the above information, any errors that occurred during the startup sequence will be displayed. Then, the instrument goes to the default settings (*RST) or saved power-up settings (SAV0-3) with the output off (see *Default settings*). Any missed error messages may be viewed over the bus using the `:SYST:ERR?` command (see *Error queue*).

Fuse replacement

A rear-panel fuse protects the power line input of the power supply.

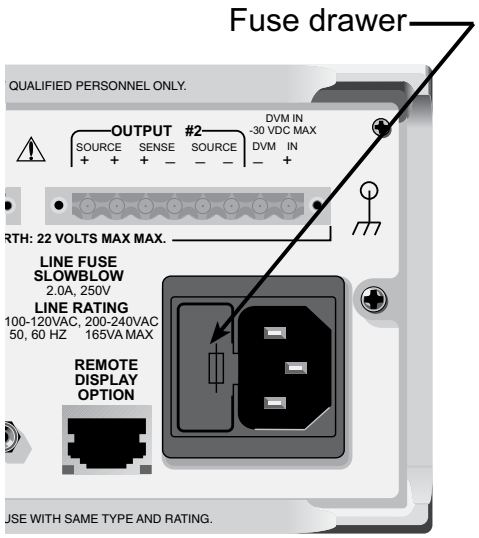
To replace the line fuse:

1. Power off the unit and remove line cord.
2. The fuse drawer is located on the left side of the AC receptacle (see *Figure 1-5*). On the right side of the fuse drawer is a small tab. At this location, use a screwdriver to pry the fuse drawer open.
3. Slide the fuse drawer out to gain access to the fuse. Note that the fuse drawer does not pull all the way out of the power module.
4. Snap the fuse out of the drawer and replace it with the same type (250 V, 2.0 A, 5 × 20 mm time lag). The Keithley Instruments part number is FU-81.

CAUTION	For continued protection against fire or instrument damage, only replace the fuse with the type and rating listed. If the instrument repeatedly blows fuses, locate and correct the cause of the problem before replacing the fuse.

5. Push the fuse drawer back into the power module.

Figure 1-5
Fuse drawer location



Display modes

For voltage and current readings, there are five display modes described as follows:

- **SINGLE V AND I DISPLAY** - This display mode is used to read back the actual output voltage and current on a single channel. The active channel dictates if the single channel being displayed is for the battery or charger channel. This display mode is the RST default (see *Section 2* for details).
- **DUAL V AND I DISPLAY** - This display mode is used to read back the actual output voltage and current for both channels simultaneously. The top display line shows the voltage and current readings for the battery channel while the bottom line shows the charger channel

readings. The # symbol indicates the active channel (see *Section 2* for details). For both channels, the output state is indicated by:

- 0 (zero) if the output is OFF for that channel.
- l (lowercase L) if the output is ON for that channel..

NOTE	With DUAL V AND I DISPLAY mode enabled, there is no indicator on the front panel about voltage protection or current limit state. See *Section 2* for more information on voltage protection and current limit.

- **PULSE CURRENT** - This mode is used to display high, low, or average pulse-current measurements (see *Section 3* for details)
- **LONG INTEGRATION** - This mode is used to display average current measurements of a pulse or pulses measuring periods between 850 msec to 60 sec (60 Hz line frequency) and 840 msec to 60 sec (50 Hz line frequency) (see *Section 4* for details).
- **DVM INPUT** (charger channel only) - This mode is used to display the DC voltage applied to the DVM input of the power supply (see *Section 2* for details).

Use the SAVE SETUP item of the MENU to save the selected display mode in memory, and use the POWER ON SETUP item to specify the power-on setup (*Setups - Save, Power-on, and Recall* for details). The Dual V and I display cannot be saved. A reset will not change this setting. Recalling a setup may change the setting. If setup recalling has a channel function set to something other than voltage or current then this setting is disabled otherwise the setting is left unchanged.

Selecting (enabling) Dual V and I will switch the function to voltage for each channel unless the function is already voltage or current. Dual V and I will be disabled if you change the display mode on either channel to be Pulse Current, Long Integration, or DVM Input (Channel #2 only).

To select a display mode:

1. Press the **DISPLAY** key.
2. Press the ▲ or ▼ keys to scroll to the desired display mode.

Table 1-1
Display Modes

Battery channel (#1)	Charger channel (#2)
• SINGLE V AND I • DUAL V AND I • LONG INTEGRATION • PULSE CURRENT	• SINGLE V AND I • DUAL V AND I • LONG INTEGRATION • PULSE CURRENT • DVM INPUT

3. Press the ◄ or ► keys to select Channel **#1** or **#2**.

NOTE	Switching back to the original active channel will display the initial setting for that channel.

4. With the desired mode and active channel displayed, press **ENTER**.

Examples of the display modes are shown in *Table 1-2*.

NOTE To select **PULSE CURRENT** high (**HI**), low (**LO**) or average (**AVG**) readings, use the ▲ or ▼ keys to select the desired pulse measurement after selecting pulse current as the display mode.

Table 1-2
Display mode examples

Display mode	Samples for battery channel (#1)	Samples for charger channel (#2)	Reference
SINGLE V AND I:	6.116V #1 ON 1.2058 A	6.116 V #2 ON 1.2058 A	*Section 2*
DUAL V AND I:	2.97V 25.7m 1# 0.00V 0.00A 0	2.97V 25.7m 1 1.00V 0.17A 1#	*Section 2*
DVM input:	N/A (charger channel only)	DVM INPUT #2 OFF 5.321 V	*Section 2*
Pulse current:	PULSE HI #1 ON 2.1947 A	PULSE HI #2 ON 2.1947 A	*Section 3*
	PULSE LO #1 ON 0.2147 A	PULSE LO #2 ON 0.2147 A	
	PULSE AVG #1 ON 1.1495 A	PULSE AVG #2 ON 1.1495 A	
Long integration:	LONG INT #1 ON 1.0236 A	LONG INT #2 ON 1.0236 A	*Section 4*

NOTE **#1** or **#2** indicates the active channel. **ON** indicates that the output is turned on. With the output turned off, **OFF** is displayed (see *Section 2* for details on outputting current and voltage).

NO PULSE is displayed if the output is OFF or pulses are not detected (output ON) for pulse current and long integration display modes only.

When a change is made that affects the readings being taken, dashes are displayed instead of readings. The dashes remain until a valid reading for the new condition is taken.

Default settings

The power supply can be set to power-on with the factory default conditions (RST defaults) or to one of four user-saved setup conditions (SAV0 to SAV3). The factory default conditions are listed in *Table 1-3*.

Table 1-3
Factory defaults (RST)

Setting	Reset (RST) default	
	Battery channel (#1)	**Charger channel (#2)**
Output value settings:		
Voltage (V)	0.000V	0.000V
Current (A)	0.2500A	0.2500A
Output state (operate)	OFF	OFF
Voltage protection	8 V, clamp off	8 V, clamp off
Display type	Single V and I	Single V and I
GPIB address*	No effect (factory set to 16)	
Current range	5 A (Auto Range OFF)	5 A (Auto Range OFF)
Integration rate	1.00 PLC	1.00 PLC
Average readings	1	1
Power on setup*	No effect (factory set to RST)	
Current limit mode	LIM	LIM
Auto Zero State	ON (applies to both channels)	
Output relay one* Output relay two* Output relay three* Output relay four*	No effect (after power cycle, set to zero)	
VFD brightness*	Over bus: 1 From display: FULL BRIGHTNESS	
Output bandwidth	LOW	LOW
Output impedance	0.00 Ω	Not Applicable
Pulse current:		
High time	33 µsec	33 µsec
Low time	33 µsec	33 µsec
Average time	33 µsec	33 µsec
Digitize time	33 µsec	33 µsec
Timeout	1.000 sec	1.000 sec
Average readings	1	1
Trigger delay	0.00000 sec	0.00000 sec
Trigger level:	0	0
Step	Off	
Step Initial	2 sec	
Step Sequence	0	
Step Length	0	
Step Skip	0	
Step up	1	
Step down	1	
Step time	200µs	
Step timeout	2ms	
Step delay	0	
Long integration:		
Integration time	1 second	1 second

*Global settings (not channel-specific).

Table 1-3
Factory defaults (RST)

Setting	Reset (RST) default	
	Battery channel (#1)	**Charger channel (#2)**
Pulse timeout	16 seconds	16 seconds
Trigger edge	RISING	RISING
Trigger level	Same as "Trigger level" under Pulse Current (above)	Same as "Trigger level" under Pulse Current (above)

*Global settings (not channel-specific).

Setups - Save, Power-on, and Recall

Setups are configured by SAVE SETUP, POWER ON SETUP and RECALL SETUP items of the MENU (which is accessed by pressing the **MENU** key). When a setup is saved, all settings that are channel-specific settings will be saved to that setup. Saving/recalling a setup has no effect on Global Settings (see Global settings in *Table 1-3*). Similarly, recalling a setup loads only the channel-specific parameters from that setup.

NOTE *Table 1-4* shows the menu structure. Rules to navigate the menu follow the table.

The setup MENU items are explained as follows:

- **SAVE SETUP** - Save the present power supply setup to a memory location; SAV0-SAV3.
- **RECALL SETUP** - Return the power supply to the RST defaults (*Table 1-3*), or to one of four user-saved setups; RST, SAV0-SAV3.
- **POWER-ON SETUP** - Select the setup to use at power-up; RST, SAV0-SAV3.

When powering up or recalling the SAV0, SAV1, SAV2, or SAV3 setup, the output will be OFF regardless of the operate state when the setup was saved. For example, if the output is ON when the setup is saved as SAV0, the power supply will power up with the output OFF for the SAV0 power-on setup.

NOTE For GPIB operation, the setups are saved and recalled using the `*SAV`, `*RCL`, and `*RST` commands (see *Section 8* or details). The power-on setup is selected using the `SYSTem:POSetup` command (see *Section 10*).

Menu

Many aspects of operation are configured from the menus summarized in *Table 1-4*. Use the rules following the table to navigate through the menu structure.

NOTE The menu key is used to access the menu structure. However, if in remote for IEEE-488 bus operation ("R" displayed below "ON/OFF") the menu key returns the instrument to LOCAL operation.

Table 1-4
Main MENU structure

Menu item	Description	Ref
GPIB ADDRESS	Set primary address (0 to 30)	Sect. 6
CURRENT RANGE #1/#2	Select current range: Battery channel (#1) / Charger channel (#2) 5 A / 5 A 500 mA / 5 mA 50 mA / AUTO 5 mA AUTO	Sect. 2
NPLC RATE #1/#2	Set integration rate in NPLC (0.002 to 10)	Sect. 2
AVER READINGS #1/#2	Set average reading count (1 to 10)	Sect. 2
SAVE SETUP	Save present setup in memory (SAV0–SAV3)	Note 1
RECALL SETUP	Recall setup from memory (RST, SAV0–SAV3).	Note 1
POWER ON SETUP	Select power-on setup (RST, SAV0–SAV3)	Note 1
CALIBRATE UNIT	Calibrate unit (see *Calibration*)	Sec. 13
VOLT PROTECT #1/#2	Set voltage protection range (0–8 V) and clamp (ON/OFF)	Sect. 2
CURR LIM MODE #1/#2	Select current limit mode (LIMit or TRIP)	Note 2
AUTO ZERO STATE	Set auto zero state (ON/OFF)	Sect. 9
OUTPUT RELAYS	Close (1) or open (0) relay control circuitry	Sect. 5
REVISION NUMBER	Display firmware revision levels	Note 2
SERIAL NUMBER	Display serial number of the power supply	Note 3
VFD BRIGHTNESS	Set VFD display's brightness level (OFF, FULL, 3/4, 1/2, 1/4)	Sect. 10
OUT BANDWIDTH #1/#2	Set bandwidth (HIGH, LOW)	Sect. 2
OUT IMPEDANCE #1	Set battery channels impedance (0–1 Ω)	Sect. 2
PULSE CURRENT #1/#2	Pulse-current configuration.	Sect. 3
HIGH TIME	Set high time integration rate (in µsec.).	
LOW TIME	Set low time integration rate (in µsec.).	
AVERAGE TIME	Set average time integration rate (in µsec.).	
AUTO TIME	Set pulse integration rates automatically.	
PULSE TIMEOUT	Set pulse timeout (default is 1.000 second, incremented in 1ms steps)	
AVERAGE READINGS	Set average reading count (1 to 100).	
TRIGGER DELAY	Set trigger delay in seconds (0 to 100 msec).	
TRIGGER LEVEL	Sets pulse current trigger level in Amps for the 5 A, 500 mA, 50 mA, or 5 mA current ranges: Battery channel (#1) / Charger channel (#2) A(5.0) 0–5A in 5 mA steps / A(5.0) 0–5 A in 5 mA steps mA(500) 0–500 mA in 0.5 mA steps mA (50) 0-50 mA in 0.05 mA steps mA (5) 0-5 mA in 0.005 mA steps	

The main menu structure is accessed by pressing the **MENU** key on the front panel.
Notes:
1. See *Default settings* in this section to save and recall setups.
2. Revision Number displays the firmware revision level for the microcontroller and the display.
3. Serial Number displays the serial number of the power supply.

Table 1-4
Main MENU structure

Menu item	Description	Ref
LONG INTEGRAT #1/#2	Long integration configuration.	Sect. 4
INTEGRATION TIME	Manually set integration time (up to 60 sec).	
AUTO TIME	Automatically set integration time.	
PULSE TIMEOUT	Set the "NO PULSE" timeout period (1 to 63 sec).	
TRIGGER EDGE	Select trigger edge (rising, falling, or neither).	
TRIGGER LEVEL	Sets long integration trigger level in Amps for the 5 A, 500 mA, 50 mA, or 5 mA current ranges: Battery channel (#1) / Charger channel (#2) A (5.0) 0–5 A in 5 mA steps / A (5.0) 0–5 A in 5 mA steps mA (500) 0–500 mA in 0.5 mA steps mA (50) 0-50 mA in 0.05 mA steps mA (5) 0-5 mA in 0.005 mA steps	

The main menu structure is accessed by pressing the **MENU** key on the front panel.
Notes:
1. See *Default settings* in this section to save and recall setups.
2. Revision Number displays the firmware revision level for the microcontroller and the display.
3. Serial Number displays the serial number of the power supply.

Getting around the MENU

- Press the **MENU** key to activate the menu.
- Press the ▲ or ▼ keys to scroll through the primary menu items.
- Press the ◄ or ► keys to toggle between Channel **#1** and Channel **#2**.

NOTE If a channel number is not shown, the ◄ or ► keys presses will be ignored. Also the ◄ or ► keys presses will be ignored if a submenu only exists on the battery channel (not on the charger channel).

- The active channel may be changed in the main menu, and the top submenus for pulse current and long integration. The active channel cannot be changed in all other submenus.
- Select the displayed primary menu item by pressing **ENTER**. With **PULSE CURRENT** or **LONG INTEGRATION** selected, use the ▲ or ▼ keys to display the secondary items (again, pressing **ENTER** selects the displayed item).

NOTE Before pressing enter, make sure the desired channel is active. If **ENTER** is pressed with the incorrect channel selected, press the **MENU** key (to cancel changes), use the ◄ or ► keys to scroll to the desired channel, and then press **ENTER** to select the displayed primary menu item.

- Display and change settings and selections (for a menu item) using the edit keys (▲, ▼, ◄, or ► keys):
  – For a setting, use ◄ or ► keys to place the cursor on the desired digit, then use the ▲ or ▼ keys to increase or decrease the value (unless noted otherwise).
  – Rapid jump to minimum or maximum: To rapidly jump to the maximum value, increment the most significant digit (the left further-most digit in the selection setting). If the most

significant digit is not displayed, place the cursor on that digit's menu location and increment from there. To rapidly jump to the minimum value, decrement the most significant digit menu location. To find the most significant digit for a setting, press the ◄ key until the cursor stops moving.

– For a selection, use the ▲ or ▼ keys to scroll to the desired option (unless noted otherwise).

- With the desired setting or selection displayed, press **ENTER** for it to take effect. Pressing **MENU** will cancel the edit operation.
- Use the **MENU** key to exit the **MENU** structure.

SCPI programming

SCPI programming information is integrated with front-panel operation throughout this manual. SCPI commands are listed in tables, and additional information that pertains exclusively to remote operation is provided after each table. Also, the SCPI tables may reference other sections of this manual.

Except for *Section 11*, all SCPI tables in this manual are abridged. That is, they exclude most optional command words and query commands. Optional command words and query commands are summarized as follows.

Optional Command Words - In order to be in conformance with the IEEE-488.2 standard, the power supply accepts optional command words. Any command word that is enclosed in brackets ([ ]) is optional and does not have to be included in the program message.

Query Commands - Most command words have a query form (exceptions are noted). A query command is identified by the question mark (?) that follows the command word. A query command requests (queries) the programmed status of that command. When a query is sent and the power supply is addressed to talk, the response message is sent to the computer.

To send a SCPI command as a query, append a "?" to the fundamental form of the command (make sure to add the "?" immediately following the command on the same line). For complete details, see *Programming syntax*.

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Section 2

Basic Power Supply Operation

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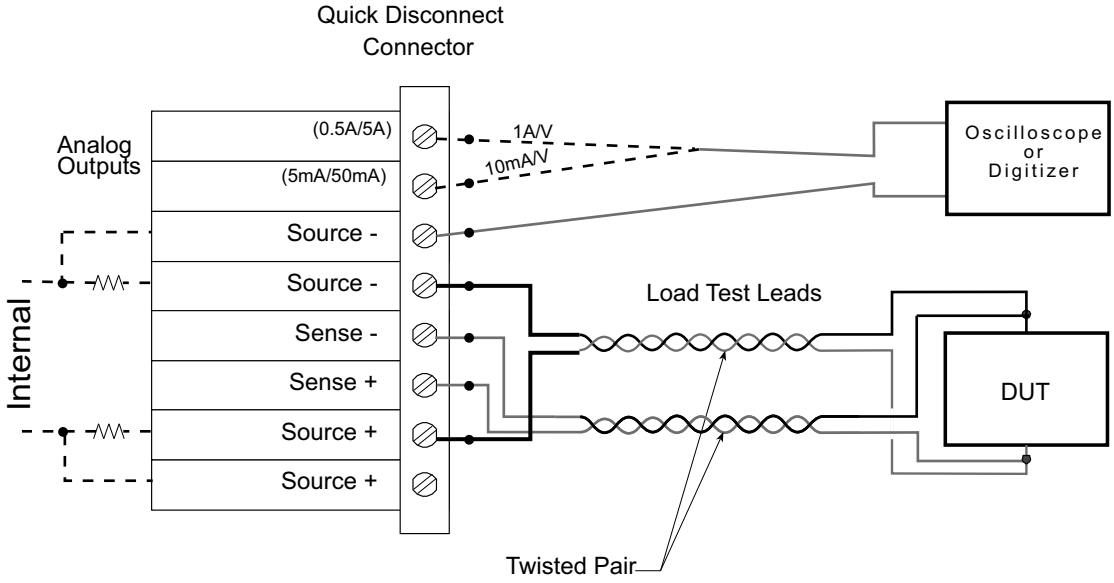
Test connections

WARNING	***When installing a unit into a test system, make sure the external power sources do not apply voltage to the power supply in excess of its maximum limits. Failure to do so could result in personal injury or death.***
	The source and measurement connections are provided with overvoltage protection rated up to 500 V for 50 µs. Do not connect sources that produce transient voltages greater than 500 V or the protection provided by the equipment may be degraded.

Test connections to the power supply are made at the rear panel using a quick disconnect connector (see rear panel in *Figure 1-1* for connector location). Use up to #14 AWG wire for the screw terminals of the connector. Once the connector is wired up, plug it into the rear panel and tighten the captive retaining screws.

Figure 2-1 and *Figure 2-2* show optimum remote 4-wire connections for device-under-test (DUT) preferred connection (*Figure 2-1*) and fastest transient response connection (*Figure 2-2*).

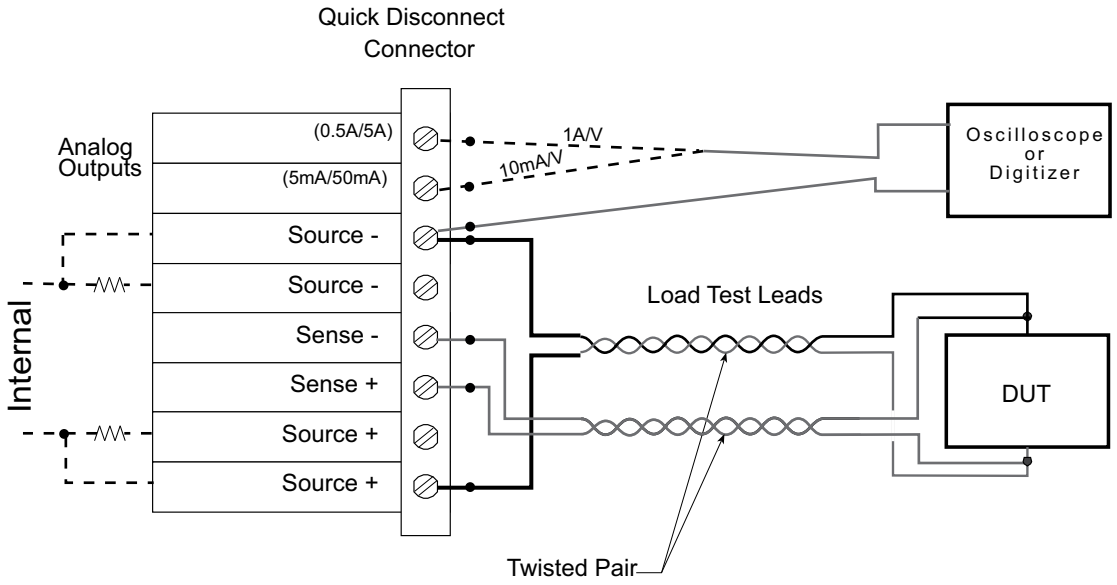
Figure 2-1
Battery channel preferred connection (maximum stability)



NOTE Twist source leads together and twist sense leads together for optimum performance.

The analog outputs provide a voltage output based on the measured current as follows:
0.5/5 A Output referenced to Source - : 1 A/V (each volt out represents 1A)
5/50 mA Output referenced to Source - : 10 mA/V (each volt out represents 10 mA)

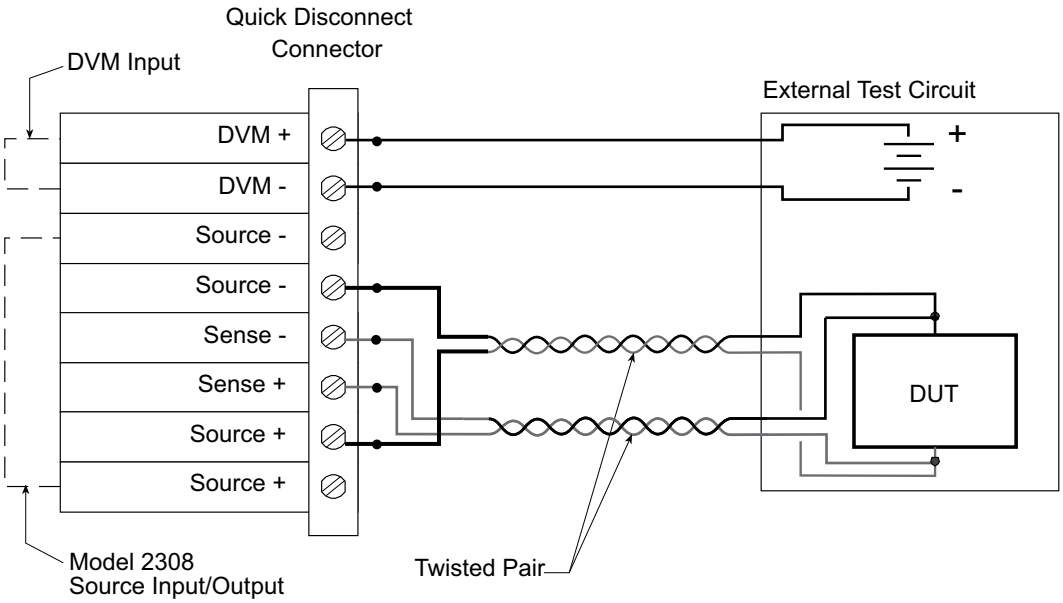
Figure 2-2
Battery channel fastest transient response connection



NOTE Twist source leads together and twist sense leads together for optimum performance.

The analog outputs provide a voltage output based on the measured current as follows:
0.5/5 A Output referenced to Source - : 1 A/V (each volt out represents 1A)
5/50 mA Output referenced to Source - : 10 mA/V (each volt out represents 10 mA)

Figure 2-3
Charger channel 4-wire remote sense connection from the DUT to the ouput



NOTE	Twist Source leads together and twist Sense leads together for optimum performance.

Remote sense

As shown in *Figure 2-1* the Model 2308 battery and charger channels are intended to be operated with remote sense leads (4 wire connection). The Sense+ and Sense- pins provide output voltage sensing. Without these terminals connected, the power supply operates without voltage feedback and therefore supplies an unregulated voltage. This unregulated voltage value can be up to +18 V or down to -5 V. Use voltage protection to turn off the output and protect against the extremes (refer to *Setting voltage protection value*).

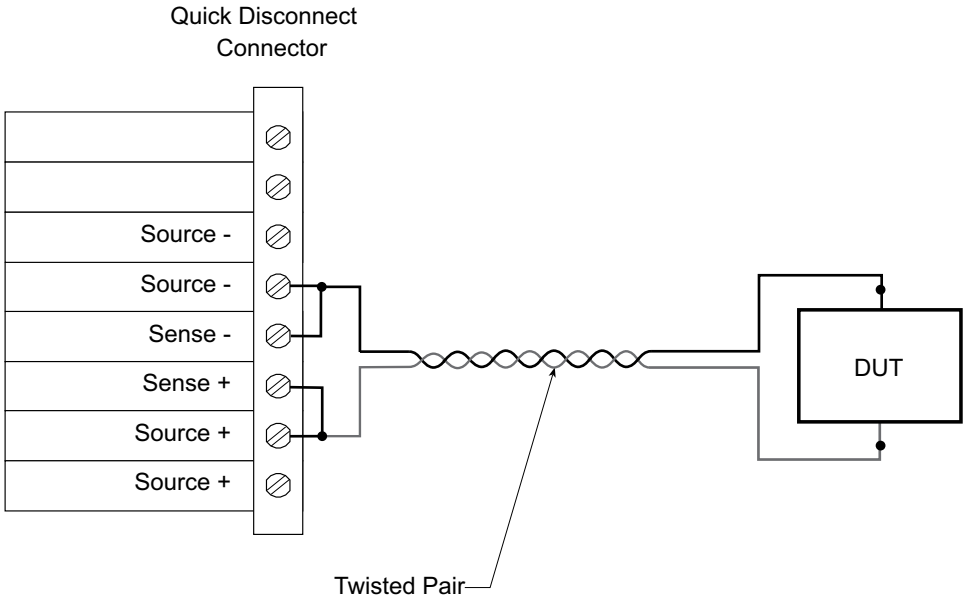
Connect the sense inputs to the supply as close as possible to the load's source inputs through twisted pair leads (refer to *Figure 2-1*). This is necessary to achieve the maximum transient performance of the supply.

CAUTION	Do NOT connect the sense inputs and supply outputs at the rear of the supply! Connecting the sense leads in this fashion will severely compromise the performance of Model 2308 with dynamic loads when using 4-wire sense.

Local sense

The Model 2308 battery and charger channels can be connected to operate with local sense leads (2-wire connection) as shown in *Figure 2-4*. In this connection scheme, the sense inputs and supply outputs are connected at the rear of the supply.

Figure 2-4
Local Sense Connections (battery channel and charger channel)



RFI considerations

NOTE	Twist Source leads together for optimum performance.

Operating the power supply in high Radio Frequency Interference (RFI) environments may result in improper operation. For that reason, keep RFI to a minimum when operating the unit. Additional shielding can be used to reduce RFI to an acceptable level.

Outputting voltage and current

Setting voltage protection value

NOTE	The voltage protection value (VPT) is channel-specific. The number after the number sign (#) indicates the channel affected by editing.

Voltage protection value (VPT) is provided for the battery and charger channels. This function monitors the SOURCE + pins (see *Figure 2-1* or *Figure 2-4*) with respect to the Model 2308's internal ground and will shut off the output voltage for either channel when the protection voltage range (which equals the set voltage ± protection voltage) set by the user is exceeded. This voltage is typically not the same voltage as at the device under test due to lead impedance and internal sense resistor losses.

The VPT message will appear on the lower line of the display after the current reading indicator (A or mA). The message will clear when the output it turned back ON, unless the condition causing a the VPT message still exist. The VPT message takes precedence over the current limit messages. See *Selecting current limit mode* for more information on the current limit messages. The VPT message will not appear if the display mode is set to DUAL V AND I.

VPT circuitry is useful in protecting the load from a high positive voltage if one of the remote sensing leads is disconnected. When in VPT mode, the output is held in the Operate OFF position until an Operate ON command is received (VPT will be displayed until the output is turned back on). The voltage protection feature has a clamp setting, which can be turned ON or OFF. If ON, protection voltage values below 0 volts (-0.6 volts) are not allowed. If OFF, protection voltage can go negative to the extent of the set voltage - protection voltage.

For example: If PROT=4 V, and SET =6 V, VPT range is from +2 V to +10 V. If the SET voltage is changed to 2 V and protection clamp set to OFF, the range would equal -2 V to +6 V. However, if protection clamp is set to ON, the range would equal -0.6 V to +6 V.

NOTE	*Table 1-3* shows the menu structure. Rules to navigate the menu follow the table.

CAUTION	Electrostatic Discharge (ESD) to the output connector pins may cause the VPT circuitry to turn the output off. Use proper ESD handling precautions before making any contact with the output connector pins or wires connected to the pins.

To set the VPT value from the front panel:

1. Press the **MENU** key to access the main menu.
2. Press the ▲ or ▼ keys to scroll to **VOLT PROTECT**.
3. Press the ◄ or ► keys to select Channel **#1** or **#2**.
4. Press **ENTER** to select.
5. Press the ▲, ▼, ◄, or ► keys to scroll to the desired VPT value and to select **cOFF** (voltage protection clamp OFF) or **cON** (voltage protection clamp ON).

NOTE	Setting changes can be canceled by pressing the **MENU** key.

6. Press **ENTER** to save your settings and return to the main menu.

Selecting proper current range

NOTE	The current range value is channel-specific. The number after the number sign (#) indicates the channel affected by editing.

Power supply current ranges are listed in *Table 2-1*. When auto range is selected, the instrument will automatically go to the most sensitive range to perform the measurement. The current range setting may be the same or different for each channel.

Table 2-1
Current ranges

Power supply	Current ranges
battery channel (#1)	5 A, 500 mA, 50 mA, 5 mA or AUTO
charger channel (#2)	5 A, 5 mA, or Auto

NOTE	*Table 1-3* shows the menu structure. Rules to navigate the menu follow the table.

To select the CURRENT RANGE from the front panel:

1. Press the **MENU** key to access the main menu.
2. Press the ▲ or ▼ keys to scroll to **CURRENT RANGE**.
3. Press the ◄ or ► keys to select Channel **#1** or **#2**.
4. Press **ENTER** to select.
5. Press ▲ or ▼ keys to scroll to the desired current range value (see *Table 2-1*).

NOTE	Setting changes can be canceled by pressing the **MENU** key.

6. Press **ENTER** to save your settings and return to the main menu.

Selecting current limit mode

NOTE	The current limit mode setting is channel-specific. The number after the number sign (#) indicates the channel affected by editing.

If the current limit is reached, the output will either turn off (TRIP) or stay on (LIM). The two current limit modes (LIM or TRIP) are explained as follows:

LIM mode - If **LIM** mode selected, the output will remain on when the current limit is reached. The "LIM" message will appear on the lower line of the display after the current reading indicator (A or mA). The message will clear when the limit condition is cleared.

The power supply may or may not be taken out of current limit by decreasing the output voltage or increasing the current limit value, depending on how the circuit is connected. However, increasing the current limit may compromise protection for the DUT.

While in the current limit, the power supply is operating as a constant-current source. As long as the limit condition exists, the power supply output current will remain constant. The output voltage is probably less than the programmed value when sourcing current, and probably greater than the programmed value when sinking current. The LIM message will not appear if the display mode is set to DUAL V AND I.

TRIP mode - If **TRIP** mode selected, the output will turn off when the current limit is reached. The "TRIP" message will appear on the lower line of the display after the current reading indicator (A or mA). The message will clear when the output is turned back on, unless it trips again because of a current limit condition. The TRIP message will not appear if the display mode is set to DUAL V AND I.

NOTE	See *Table 1-3* for an illustration of the menu structure. Rules to navigate the menu follow the table.

To select the CUR LIM MODE from the front panel:

1. Press the **MENU** key to access the main menu.
2. Press the ▲ or ▼ keys to scroll to **CUR LIM MODE**.
3. Press the ◄ or ► keys to select Channel **#1** or **#2**.
4. Press **ENTER** to select.
5. Press the ▲ or ▼ keys to scroll to the desired current limit mode (**LIM** or **TRIP**).

NOTE	Setting changes can be canceled by pressing the **MENU** key.

6. Press **ENTER** to save your settings and return to the main menu.

Editing output voltage and current limit values

NOTE	Output voltage and current limit values are channel-specific. The number after the number sign (#) indicates the channel affected by editing.

Current limit is a feature that protects the load from damage under overload conditions. The current limit setting indicates the maximum amount of current allowed to flow through the system. The setting applies to any of the current range settings.

The current limit setting for the 5 A and AUTO range selections are "remembered." For the following examples, assume the current limit setting on the 5 A range is 3 A. Selecting the 5 mA, 50 mA or 500 mA range on the battery channel, or 5 mA on the charger channel defaults the current limit setting to 1A since that is the maximum allowable setting on those ranges. Switching back to the 5 A range or enabling auto ranging reinstates the 3 A limit. If the current limit value on the 5 amps range is ≤1 A, the limit on the 500 mA, 50 mA, or 5 mA ranges will be the same when switching from the 5 A range to that range.

NOTE	See *Table 1-3* for an illustration of the menu structure. Rules to navigate the menu follow the table.

To edit voltage and current values from the front panel:

NOTE	The following steps assume that the appropriate current range is already selected along with current limit mode and voltage protection.

1. Press the **SET** key to select the output settings mode. A blinking cursor appears in the voltage field of the display.
2. Press the ▲, ▼, ◄, or ► keys to scroll to the desired output voltage value.
   - The cursor position (blinking digit) is controlled by the ◄ or ► keys.
   - With the cursor positioned on a digit, increment or decrement the value using the ▲ or ▼ keys.
3. Press **SET** to move the blinking cursor to the current limit field.
4. Press the ▲, ▼, ◄, or ► keys to scroll to the desired current limit.
5. Press **SET** to exit from output settings mode.

Once in Set Mode (enter Set Mode by pressing the **SET** key), the active channel cannot be changed. If Set Mode was inadvertently entered or entered in on the wrong channel, press the SET key until the blinking cursor disappears to exit Set Mode (once out of Set Mode, active channel switching is enabled).

Editing voltage and current values using the SET key cannot be canceled with the MENU key (the values are immediately committed). Enter the old values by repeating the editing procedure and manually using the ▲, ▼, ◄, or ► keys to scroll to the desired output voltage or current value(s).

SET key: This key is active in any front-panel menu or display mode - if not already in the output settings mode, the SET key will select it.

Pressing the **SET** key to exit the output settings mode returns the instrument to the previous display mode or front-panel menu.

V and I DACs are updated in real time - if the output is on, the output is updated immediately when a value is altered.

If the display mode is set to DUAL V AND I, then entering SET mode will cause the display to exit back into the SINGLE V AND I mode for the active channel. If dual is desired, select dual after exiting set mode (see *V and I display modes (Single or Dual)*).

Editing shortcuts

The following editing shortcuts can be used when the output is OFF:

- Output voltage can be quickly set to the maximum value by incrementing the tens digit (MSD). Note that if the tens digit is zero, it is not displayed. Place the cursor to the left of the units digit.
- Output voltage can be quickly set to zero (0.000 V) by decrementing the first leading zero of the reading. If there is no leading zero, decrement the tens digit.
- Current limit can be quickly set to its maximum value by incrementing the units digit (MSD).

- Current limit on either range can be quickly set to the minimum value (0.006 A) by decrementing the first leading zero of the reading. If there is no leading zero, decrement the units digit.

Editing restrictions

The following editing restrictions are in effect when the output is ON:

- You cannot increment a digit that would display a value that jumps to the maximum. For example, for the value 14.200 V, you cannot increment the "1" or the "4" since the resultant value would exceed 15.000 V.
- When decrementing a digit, only that digit and digits to the left are affected. The digits to the right of the cursor are not changed.

Using the OPERATE key

NOTE	Pressing the **OPERATE** key is channel-specific. The number after the number sign (#) indicates the channel affected by the OPERATE key.

Use the **OPERATE** key to control power supply output. This key toggles the output ON and OFF for the active channel even if output status is not displayed. To display the output status for the active channel, place the unit in readings or set mode (the output status is not shown in display type menu, main menu, or submenus). When output status is displayed, ON or OFF will appear in the upper right hand corner of the display.

NOTE	DVM measurements can be performed with the output OFF on the charger channel.

Output bandwidth

The battery and charger channel's output bandwidth control has HIGH and LOW settings. The HIGH setting will result in the fastest response with dynamic loads but, could be unstable with certain loads. The LOW setting mode will have a slower response but will be stable for most loads.

Testing the performance of the battery charger circuitry in a handset does not require the high bandwidth performance in Channel 1 or Channel 2 of the Model 2308. Since a charger circuit is a voltage regulated circuit, it resembles a high capacitance load to the output of the Model 2308. For this type of application, the LOW bandwidth output mode provides increased stability and eliminates oscillations that may occur.

The bandwidth can be user-programmed at any time. However, if the output is OFF, the output bandwidth is automatically set to LOW as summarized in *Table 2-2*.

Table 2-2
Output bandwidth channel setting

Output	Bandwidth
ON	LOW or HIGH (user selectable)
OFF	LOW

NOTE	The following steps assume that the appropriate current range is already selected along with current limit mode and voltage protection.

To set output bandwidth from the front panel:

1. Press the **MENU** key to access the main menu.
2. Press ▲ or ▼ keys to scroll to **OUT BANDWIDTH**.
3. Press ◄ or ► keys to select Channel **#1** or **#2**.
4. Press **ENTER** to select.
5. Press the ▲ or ▼ keys to scroll to the desired bandwidth setting (**HIGH** or **LOW**).

NOTE	Setting changes can be canceled by pressing the **MENU** key.

6. Press **ENTER** to save your settings and return to the main menu.

Output impedance

Keithley Instruments Model 2308 has a variable output impedance feature on the battery channel (#1). This output impedance setting allows the performance of the battery channel to closely model a real battery's performance with a dynamic load. When setting the output impedance to a certain value (R_I), the output voltage drop will be proportional to the output current (see the voltage drop equation below). The output voltage will be reduced by the voltage drop.

Voltage drop equation:

$$V_{drop}(t) = R_I \times I(t)$$

NOTE	For a more detailed discussion of output impedance and the performance with various types of loads, see Applications Note 2191 on the Product Information CD-ROM.

Changing the battery channel's output impedance

The Model 2308 output impedance can be checked or changed with the output on or off. The output impedance is selectable from 0.00 Ω to 1.00 Ω in 10 mΩ steps (default is 0Ω).

NOTE	The following steps assume that the appropriate current range is already selected along with current limit mode and voltage protection.

To set output impedance from the front panel:

1. Press the **MENU** key to access the main menu.
2. Press the ▲ or ▼ keys to scroll to **OUT IMPEDANCE #1** (Channel #1 only feature).
3. Press **ENTER** to select.

4. Press ▲, ▼, ◄, or ► keys to scroll to the desired output impedance value.

NOTE Setting changes can be canceled by pressing the **MENU** key.

5. Press **ENTER** to save your settings and return to the main menu.

SCPI programming - outputting voltage and current

The commands to output voltage and current are summarized in *Table 2-3* (a listing following the table contains specific command notes). The programming example ("Outputting and reading back V and I") located at the end of this section demonstrates how to use these commands.

NOTE Brackets [ ] indicate optional (and default) command parameters.

Table 2-3
SCPI command summary - outputting voltage and current

Commands	Description	Default

`SENSe[1]`
`:CURRent`
`:RANGe`
`[:UPPer] <n>`
`:AUTO <b>`
	SENSe[1] subsystem for battery channel (#1):
	Current function:
	Set current measurement range:
	Specify expected current in amps: 0 to 5.
	Enable or disable auto range.
		
		5.0
		OFF

`SENSe2`
`:CURRent`
`:RANGe`
`[:UPPer] <n>`
`:AUTO <b>`
	SENSe2 subsystem for charger channel (#2):
	Current function:
	Set current measurement range:
	Specify expected current in amps: 0 to 5.
	Enable or disable auto range.
		
		5.0
		OFF

`[SOURce[1]]`
`:VOLTage <n>`
`:PROTection <NRf>`
`:STATe? <b>`
`:CLAMp <b>`
`:CURRent <n>`
`:TYPe <name>`
`:STATe?`
	[SOURce1] subsystem for battery channel (#1):
	Set voltage amplitude in volts: 0 to 15 (1mV resolution).
	Sets VPT (voltage protection) range (0–8V).
	Query state of VPT - no associated command.
	Sets VPT clamp mode ON or OFF.
	Set current limit value in amps: 0.006 to 5 (100µA res)
	Select current limit type: LIMit or TRIP.
	Query state of current limit - no associated command.
		
		0.0
		8V
		
		OFF
		0.25
		LIM

`SOURce2`
`:VOLTage <n>`
`:PROTection <NRf>`
`:STATe? <b>`
`:CLAMp <b>`
`:CURRent <n>`
`:TYPe <name>`
`:STATe?`
	SOURce2 subsystem for charger channel (2):
	Set voltage amplitude in volts: 0 to 15 (1 mV resolution).
	Sets VPT range (0–8V).
	Query state of VPT - no associated command.
	Sets VPT clamp mode ON or OFF.
	Set current limit value in amps: 0.006 to 5 (100 µA res).
	Select current limit type: LIMit or TRIP.
	Query state of current limit - no associated command.
		
		0.0
		8V
		
		OFF
		0.25
		LIM

`OUTPut[1]`
`[:STATe] <b>`
`:BANDwidth <name>`
`:IMPedance <NRf>`
	OUTPut [1] subsystem for battery channel (#1):
	Turn the power supply output ON or OFF.
	Specifies output bandwidth (HIGH or LOW).
	Specifies output impedance (0–1 Ω in 10 mΩ steps).
		
		OFF
		LOW
		0

`OUTPut2`
`[:STATe] <b>`
`:BANDwidth <name>`
	OUTPut2 subsystem for charger channel (#2):
	Turn the power supply output ON or OFF.
	Specifies output bandwidth (HIGH or LOW).
		
		OFF
		LOW

Table 2-3
SCPI command summary - outputting voltage and current (cont.)

Commands	Description	Default
:BOTHOUTON :BOTHOUTOFF	Turns both power supply channels ON. Turns both power supply channels OFF.	

Command notes (outputting voltage and current)

`SENSe[1]:CURRent:RANGe <n>` Applies to battery channel (#1)
`SENSe2:CURRent:RANGe <n>` Applies to charger channel (#2)

After specifying a current value, the instrument will go to the most sensitive range to accommodate that reading. For example, if you are expecting a maximum current reading of 750mA, you can let <n> = 0.75 (or 750e-3) to select the 5A range. Using the `:RANGe` command to manually select a current range disables auto range. Another way to select a range is to use the MINimum, MAXimum, and DEFault parameters as follows:

`SENS:CURR:RANG MIN` Select the low current range (5mA) for battery channel (#1) .

`SENS2:CURR:RANG MAX` Select the high current range (5A) for charger channel (#2).

`SENS2:CURR:RANG DEF` Select the default current range for charger channel (#2).

The response for `:RANGe?` query returns the selected range value, which can be 5.0000 A, 0.5000 A, 0.0500 A, or 0.0050 A on the battery channel. Charger channel returns are 5.0000 A or 0.0050 A.

`SENSe[1]:CURRent:RANGe:AUTO <b>` Applies to battery channel (#1)
`SENSe2:CURRent:RANGe:AUTO <b>` Applies to charger channel (#2)

This command is coupled to the `:RANGe <n>` command. When auto range is enabled, the response for `:RANGe?` query returns the selected range value, which can be 5.0000 A, 0.5000 A, 0.0500 A, or 0.0050 A on the battery channel. Charger channel returns are 5.0000 A or 0.0050 A. If you then disable auto range, the instrument will remain at the last selected range.

NOTE If the limit setting is greater than 1A while on the 5A current range, the following message will be briefly displayed when ranging down:

CURRENT LIMIT ON
mA RANGE <= 1A

`[SOURce1]:VOLTage <n>` Applies to battery channel (#1)
`SOURce2:VOLTage <n>` Applies to charger channel (#2)

This command sets voltage amplitude in volts: 0 to 15 (1mV resolution).

`[SOURce1]:CURRent <n>` Applies to battery channel (#1)
`SOURce2:CURRent <n>` Applies to charger channel (#2)

With a milliamp measurement range selected, the maximum current limit is 1A. For the battery channel, these ranges are 5 mA, 50 mA, or 500 mA. The charger channel range is 5 mA.

NOTE Sending a value that exceeds 1 A will generate a parameter out of range error message (-222).

`[SOURce[1]]:CURRent:STATe?` Applies to battery channel (#1)
`SOURce2:CURRent:STATe?` Applies to charger channel (#2)

1. With the LIMit type selected, this command returns a "1" if the power supply is operating as a constant-current source (current limit reached). With the TRIP type selected, a "1" is returned if the output has turned off (tripped) due to current limit being reached. It will clear to "0" when the output is turned back on.
2. The operation event register can be read to determine if the power supply is in current limit and if the output has tripped (turned off) as a result of the current limit condition. See *Section 7* for details.

`OUTput[1]:IMPedance <NRf>` Applies to battery channel (#1)

This battery channel only command may be set from 0–1 Ω in 0.01 Ω steps. The command can be used with the output ON or OFF.

`OUTput[1]:BANDwidth <name>` Applies to battery channel (#1)
`OUTput2:BANDwidth <name>` Applies to charger channel (#2)

This command specifies HIGH or LOW bandwidth. You can program the bandwidth at any time.

NOTE The bandwidth query will return user-specified settings, not necessarily the present instrument value. Refer to *Table 2-2* for how output state settings affect the actual bandwidth configuration.

`BOTHOUTON` Turns both channels ON
`BOTHOUTOFF` Turns both channels OFF

When sending either command, make note that the command is applied to battery channel (#1) first and then to charger channel (#2). This allows both channels' output state to be controlled with a single bus command while preventing the outputs from being turned ON or OFF simultaneously. No short form exists for this command.

Reading back V and I

V and I display modes (Single or Dual)

Measured output voltages and currents are displayed with either SINGLE or DUAL V AND I display modes. Dual displays both channels simultaneously; single only shows the readings for the active channel.

NOTE	To display measured readings if the instrument is in the settings mode, press the **SET** key until the blinking stops (the measured readings can then be displayed). To determine if the instrument is in the settings mode, check for a blinking cursor in a digit of the voltage or current field (if present, the instrument is in the setting mode).

These display modes are selected as follows:

1. Press the **DISPLAY** key.
2. Press the ▲ or ▼ keys to scroll to **SINGLE V AND I** or **DUAL V AND I**.
3. For **SINGLE V AND I**, press the ◄ or ► keys to select Channel **#1** or **#2**.
4. Press **ENTER** to select and return to display of readings.

NOTE	Voltage readings are located on the top line of the display, and current readings are located on the bottom line when in single display mode. For dual display mode the top line has the voltage and current readings for battery channel, and the bottom line has the readings for charger channel. For details about display modes, see *Display modes*.

Measurement configuration

CURRENT RANGE #1/#2, INTEGRATION RATE #1/#2, and the AVER READINGS #1/#2 can be checked or changed from the menu (which is accessed by pressing the **MENU** key). The #1 (battery channel active) or #2 (charger channel active) will appear on the top line of the display (use ◄ or ► keys to toggle the active channel).

NOTE	See *Table 1-3* for an illustration of the menu structure. Rules to navigate the menu follow the table.

Current range

Current range is linked with current limit. Therefore, as a general rule, the user selects the current range before setting the current limit. The current range can be changed at any time, but selecting the lower range may change the current limit setting (see *Outputting voltage and current* for details on current range and current limit).

NPLC rate

The integration (reading) rate of the instrument is specified as a parameter based on the number of power-line cycles (NPLC), where 1 PLC for 60Hz line frequency is 16.67msec (1/60). In general, the fastest integration time (0.002 PLC) results in increased reading noise. The slowest integration

time (10 PLC) provides the best common-mode and normal-mode rejection. In-between settings are a compromise between speed and noise.

The NPLC RATE #2 menu item is also used to set the reading rate for DVM measurements. Note that NPLC RATE #1/#2 is not used to set the integration rate for pulse current and long integration measurements. These measurements are described in *Section 3* and *Section 4*, respectively.

Average readings

The average reading count (1 to 10) specifies the number of measurement conversions to average for each reading. For example, with a reading count of 5, each displayed reading will be the average of five measurement conversions.

The AVER READINGS #2 menu items are also used to set the average reading count for DVM measurements. Note that AVER READINGS #1/#2 is not used to set the average reading count for pulse current (see *Section 3*) or long integration measurements (see *Section 4*).

SCPI programming — measure V and I, and DVM input

The commands to measure output voltage and current, and the DVM input are summarized in *Table 2-4* (a listing following the table contains specific command notes). The "Programming examples" at the end of this section demonstrates how to use these commands.

Table 2-4
SCPI commands: Measure V and I, and DVM input

Commands	Description	Default
SENSe[1]	SENSe[1] subsystem for battery channel (#1):	
:FUNCtion <name>	Select readback function: "VOLTage", "CURRent".	VOLT
:NPLCycles <n>	Set integration rate (in line cycles) for voltage, current, measurements: 0.002 to 10.	1.0
:AVERage <NRf>	Specify the average count for voltage and current measurements: 1 to 10.	1
SENSe2	SENSe2 subsystem for charger channel (#2):	
:FUNCtion <name>	Select readback function: "VOLTage", "CURRent", or "DVMeter".	VOLT
:NPLCycles <n>	Set integration rate (in line cycles) for voltage, current, and DVM measurements: 0.002 to 10.	1.0
:AVERage <NRf>	Specify the average count for voltage, current, and DVM measurements: 1 to 10.	1
READ[1]?	Trigger and return one reading for battery channel (#1)*.	
READ[1]:ARRay?	Trigger an array of readings and return them for battery channel (#1)*.	
READ2?	Trigger and return one reading for charger channel (#2)*.	
READ2:ARRay?	Trigger an array of readings and return them for charger channel (#2)*.	
BOTHFUNC <name>	Sets the battery channel (#1), then the charger channel (#2) to the function specified by <name>. Valid strings for <name> are "VOLTage", "CURRent", "PCURrent", or "LINTegration". Since "DVMeter" is a charger-only function, sending this command with the name "DVMeter" will generate a string data error (-150) message.	

*This command applies to the currently selected function.

Command notes (measure V and I, and DVM input)

`SENSe[1]:FUNCtion <name>` Applies to battery channel (#1)
`SENSe2:FUNCtion <name>` Applies to charger channel (#2)

The parameter name can instead be enclosed in single quotes (for example: 'CURRent').

With "DVMeter" selected, the instrument measures the voltage applied to the input of the digital voltmeter (DVM) on the charger channel (#2) only.

The "**PCURrent**" and "**LINTegration**" parameters for `:FUNCtion` (which are not listed in *Table 2-4*) select the pulse current and long integration measurement modes. These measurement modes are covered in *Section 3* and *Section 4*, respectively.

`SENSe[1]:AVERage <NRf>` Applies to battery channel (#1)
`SENSe2:AVERage <NRf>` Applies to charger channel (#2)

- When requesting a single reading (`FETch?`, `READ?`, or `MEASure?`), average count specifies the number of measurement conversions to average for the reading. For example, with the average count set to 10, `READ?` will trigger 10 measurement conversions and return (and display) the average of those 10 conversions for the battery channel. When requesting an array of readings (`FETCh:ARRay?`, `READ:ARRay?` or `MEASure:ARRay?`), average count specifies the number of measurements to place in an array. For example, with the average count set to 10, `READ:ARRay?` will trigger and return 10 battery channel readings (charger channel command similar).
- Signal-oriented measurement commands (for example: `READ?`) are covered in *Section 9*.

Independent voltage measurements (DVM)

The power supply has an independent digital voltmeter (DVM) on the charger channel (# 2) only that can measure up to +30VDC and down to -5VDC. Connections for the DVM are shown in *Figure 2-1*.

DVM input display mode

The DVM input display mode must be selected in order to measure voltage applied to DVM input of the power supply.

NOTE	To display measured readings if the instrument is in the settings mode, press the **SET** key until the blinking stops (the measured readings can then be displayed). To determine if the instrument is in the settings mode, check for a blinking cursor in a digit of the voltage or current field (if present, the instrument is in the setting mode).

This display mode is selected as follows:

1. Press the **DISPLAY** key to access the display menu.
2. Press the ◄ or ► keys to scroll to **DISPLAY TYPE #2** (DVM is a Channel 2 only feature).
3. Press the ▲ or ▼ keys to scroll to **DVM INPUT**.
4. Press **ENTER** to select.

NOTE	For details about display modes, see *Display modes*.

Measurement configuration

The NPLC RATE #2 and AVER READINGS #2 for DVM measurements can be checked or changed from the menu (which is accessed by pressing the **MENU** key). Select Channel #2 by pressing the ◄ or ► keys.

NOTE	*Table 1-3* shows the menu structure. Rules to navigate the menu follow the tables.

These two measurement configuration menu items are the same ones used for SINGLE V AND I measurements (see *Measurement configuration* for details on NPLC rate and average readings).

SCPI programming - DVM

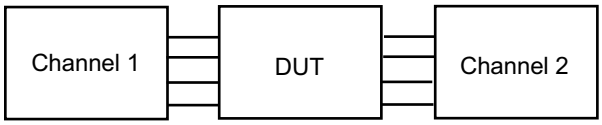
The commands to perform V AND I measurements on the charger channel (#2) are also used to perform DVM measurements. These commands are documented in *Table 2-3*.

The "DVM measurements" programming example at the end of this section demonstrates how to use these commands to measure the DVM input.

Sink operation

Either channel can sink current if its load is at a higher voltage then the channel's output. This enables a channel to simulate a discharged battery, and the second channel to simulate a charger so that a device's charger-control circuitry can be tested.

Figure 2-5
Charger Control Circuit Testing



Program V_{chan2} > V_{Chan1} to force Channel 1 to sink current

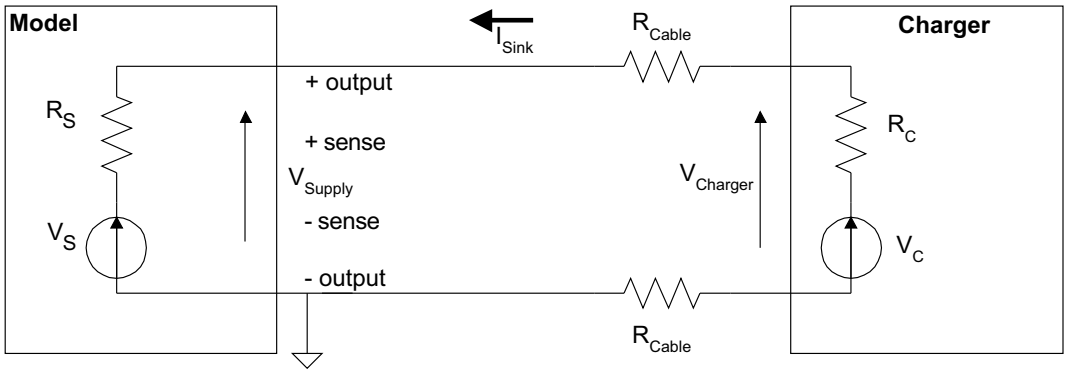
NOTE	For Channel 1 to simulate a discharged battery (by sinking current), and for Channel 2 to simulate a charger, program the Channel 2 voltage to be greater than the Channel 1 voltage.

Sink operation allows the power supply to be used as a constant current load. To function as a constant current load, the power supply must be in compliance (current limit). When operating as a sink, the power supply is dissipating power rather than sourcing it. *Figure 2-6* shows an example of how the power supply can be made to operate as a sink. An external source, such as a battery charger circuit, whose voltage is higher than the programmed power supply voltage, is connected as shown. If the supply is operated in remote sense and

$V_{Charger} > V_{Supply} + I_{sink}R_{cable}$, is satisfied, current I_{sink} flows into the positive (+) terminal of the power supply. Current readback is negative.

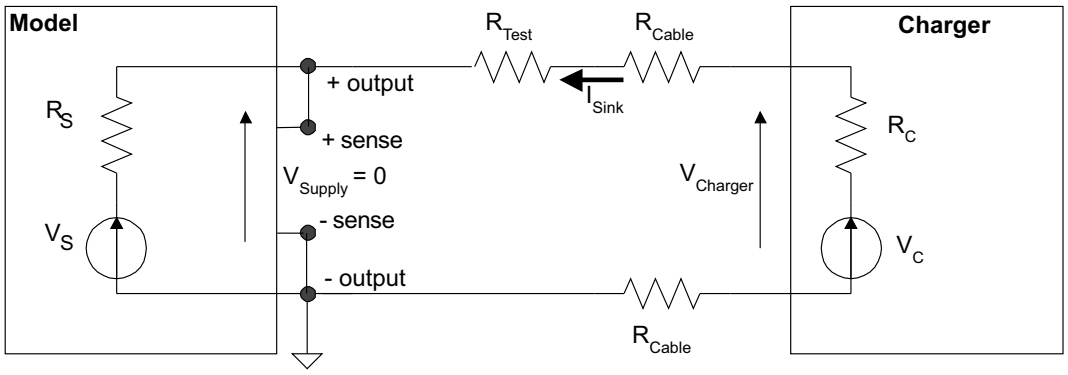
CAUTION	Exceeding current sink capacity (0–5 V: 3A max. 5 V–15 V: Derate 0.2 A per volt above 5 V) could cause damage to the power supply that is not covered by the warranty.

Figure 2-6
Sink operation



However, in this configuration current compliance may not be reached and current measurements may be unstable if $I_{sink}R_{cable}$ is large. *Figure 2-7* shows a preferred method for measuring the current output of the charger circuit at a rated output voltage with the power supply operating in local sense mode. Set the supply output voltage to 0.00 V and the enter the desired test (compliance) current, I_{test}. Select R_{test} so that $V_{charger}$, the desired test voltage, is the product of I_{test} and R_{test}.

Figure 2-7
Preferred method



NOTE	Figure 2-7 shows the preferred method for measuring current output of the charger circuit at a rated output voltage with the power supply operating in local sense mode.

Unless high speed transient performance is absolutely required when operating as a sink, the LOW bandwidth output mode provides superior results with a constant current or voltage load such as a battery charger.

Programming examples

Outputting and reading back V and I

The following command sequences demonstrate how to output voltage and current, and read back (measure) the actual voltage and current:

Battery channel (#1)

```
DISP:CHAN 1                    ' Select battery channel as active one.
VOLT 5                         ' Set output voltage to 5V.
SENS:CURR:RANG:AUTO ON         ' Enable auto range for current.
CURR 750e-3                    ' Set current limit to 750mA.
CURR:TYPE TRIP                 ' Select trip mode for current limit.
SENS:FUNC 'VOLT'               ' Select the voltage measurement function.
SENS:NPLC 2                    ' Set integration rate to 2 PLC.
SENS:AVER 5                    ' Set average reading count to 5.
OUTP ON                        ' Turn on the power supply output.
READ?                          ' Trigger 5 voltage measurement conversions
                                 and return the average of those 5 conversions.
                                 The average reading is displayed on the front panel.
SENS:FUNC 'CURR'               ' Select current measurement function.
READ?                          ' Trigger 5 current measurement conversions and
                                 return the average of those 5 conversions.
                                 The average of the 5 readings is displayed on
                                 the front panel.
```

Charger channel (#2)

```
DISP:CHAN 2                    ' Select charger channel as active one.
SOUR2:VOLT 5                   ' Set output voltage to 5V.
SENS2:CURR:RANG:AUTO ON        ' Enable auto range for current.
SOUR2:CURR 750e-3              ' Set current limit to 750mA.
SOUR2:CURR:TYPE LIM            ' Select LIM mode for current limit.
SENS2:FUNC 'VOLT'              ' Select the voltage measurement function.
SENS2:NPLC 4                   ' Set integration rate to 4 PLC.
SENS2:AVER 4                   ' Set average reading count to 4.
OUTP2 ON                       ' Turn on the power supply output.
READ2?                         ' Trigger 4 voltage measurement conversions
                                 and return the average of those 4 conversions.
SENS2:FUNC 'CURR'              ' Select current measurement function.
READ2:ARR?                     ' Trigger 4 current measurement conversions and
                               ' return all 4 conversions. The average of the
                               ' 4 readings is displayed on the front panel.
```

DVM measurements

The following command sequence demonstrates how to measure voltage applied to the DVM input of the power supply:

Charger channel (#2)

```
DISP:CHAN 2                    ' Set active channel - charger.
SENS2:FUNC 'DVM'               ' Select the DVM Input function.
SENS2:NPLC 3                   ' Set integration rate to 3 PLC.
SENS2:AVER 8                   ' Set average reading count to 8.
READ2:ARR?                     ' Trigger and return 8 readings. The average
                               ' of the 8 readings is displayed on the front
                               ' panel.
```

Analog output

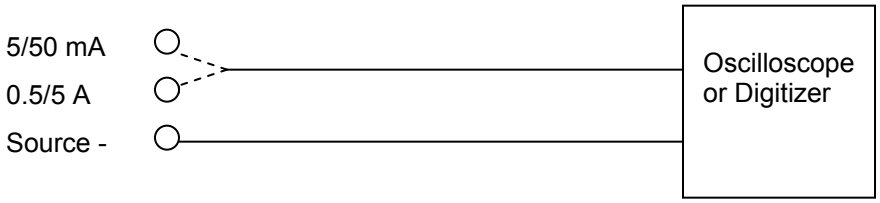
There are two analog output terminals: a 0.5/5 A output terminal for use when the battery channel is programmed for either the 5 A or the 500 mA range and a 5/50 mA output terminal for use when the battery channel is programmed for either the 50 mA or the 5 mA range. Connect to the appropriate analog output terminal and the Source - terminal.

The analog outputs provide a voltage output based on the measured current as follows:

- 0.5/5 A Output referenced to Source - : 1 A/V (each volt out represents 1 A)
- 5/50 mA Output referenced to Source - : 10 mA/V (each volt out represents 10 mA)

Each terminal's output impedance is nominally 1000 Ohms.

Figure 2-8
Analog output Connections



Section 3

Pulse Current Measurements

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Overview

The power supply can perform current measurements for dynamic loads on either battery channel (#1) or charger channel (#2). The built-in measurements include:

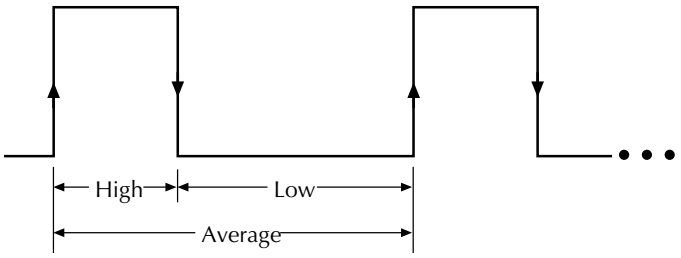
- Peak measured current - measures the peak (high) current of the pulse train.
- Idle measured current - measures the idle (low) current of the pulse train.
- Average transmit current - measures the average current of the pulse train.

The high, low, and average measurements of a pulse are illustrated in *Figure 3-1*. The high measurement is triggered on the rising edge of the pulse, and an integration is performed for the time specified for the high measurement. The falling edge of the pulse triggers the low measurement, and an integration is performed for the time specified for the low measurement. An average measurement is triggered on the rising edge, and the integration is specified by the average measurement time setting. Each pulse current measurement reading will trigger on the respective edge.

NOTE Two other measurements of pulse currents are available over the bus. *Pulse current digitization* and *Pulse current STEP method (battery channel only)* for details.

Available current measurement range(s) are 5 A, 500 mA, 50 mA, and 5 mA on the battery channel and 5 A on the charger channel.

Figure 3-1
Pulse current measurement



▲ High and average measurements triggered on leading edge of pulse

▼ Low measurement triggered on falling edge of pulse

Trigger level

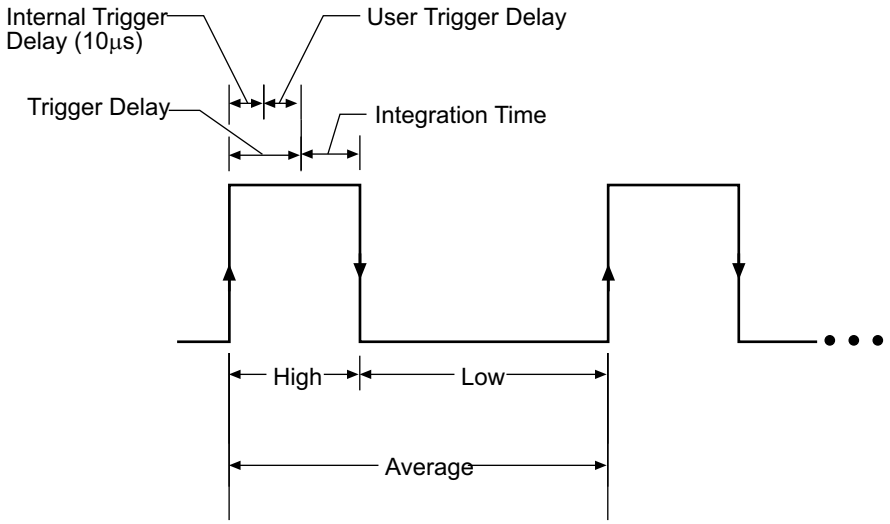
For the various current ranges on Model 2308, to avoid false pulse detection, you can use a trigger level of up to 5A. All pulses, noise, or other transients that are less than the set trigger level will be ignored. The charger channel has only one trigger level range setting from 0 to 5 A. The battery channel (#1) has four trigger level settings that are applicable when the corresponding current range is selected: 5 A, 500 mA, 50 mA, and 5 mA. For 5 A trigger level setting, the level may be set from 0 to 5 A. Likewise, the level may be set from 0 to 500 mA for the 500 mA trigger level setting, 0 to 50 mA for the 50 mA trigger level setting and 0 to 5 mA for the 5 mA trigger level setting. These settings affect the trigger level setting when the corresponding current range is

selected on the battery channel. For the charger channel, pulse current is only available on the 5 A current range.

Trigger delay

The high, low, or average integration times can either be manually or automatically set. When a pulse is detected, there is a 10 μsec code execution delay (internal trigger delay - see *Figure 3-2*) before the integration time begins. An additional user trigger delay can be set to allow the leading edge pulse overshoot to settle. Regardless of the user trigger delay setting, the internal trigger delay is always present.

Figure 3-2
Trigger delay for high pulse current measurement



High = integration time specified for high measurement time + *Trigger Delay*
Low = integration time specified for low measurement time + *Trigger Delay*
Average = integration time specified for average measurement time + *Trigger Delay*

Trigger Delay = Internal trigger delay (10μs) + User trigger delay

The integration time will not start until the trigger delay period expires after detecting the pulse. For accurate readings, make sure that the trigger delay (user and internal) plus the integration time does not exceed the time for the overall pulse measurement. Refer to *Figure 3-2* for an illustration containing the trigger delay relationships for a high pulse current measurement.

Integration times

The three integration time periods for pulse measurements can be set automatically or manually by the user. When the pulse auto time operation is performed, the instrument measures the high and low periods of the detected pulse and sets appropriate integration times. The pulse average time is set to the sum of the measured high and low times. The three integration times apply for all subsequent pulse measurements until another pulse auto time is performed or the times are changed manually. The pulse auto time feature can detect pulses in the 80 μsec to 833 msec range. Auto time (when used) accounts for the internal trigger delay (10 μsec).

You can manually set the pulse high time, pulse low time, and pulse average time. However, you must make sure the integration time covers the portion of the pulse of interest. For example, if the pulse is high for 600 μsec, the high integration time must be ≤600 μsec. If not, you will integrate a low portion of the pulse, and the high pulse measurement will be compromised. Be sure to factor in

the trigger delay (both internal plus user) when determining integration times (see *Figure 3-2*). When manually set using the front-panel keys, the values are changed in increments of 33.3333 μsec. This ensures that an integral value of 33.3333 μsec will be selected.

NOTE	Auto time does not account for user trigger delay - if using auto time, make sure the user trigger delay is appropriately set for the desired overall measurement time.

After auto time acquires a time value (auto time), the auto time is adjusted for the internal trigger delay of 10 μsec (auto internal time). The auto internal time is then adjusted to be an integral time value of 33.3333 μsec (auto integral time). For example:

auto time value= 28.053 msec

auto internal time= 28.053 ms - 0.010 msec = 28.043 ms

auto integral time= 28.033 ms (response returned when time setting is queried)

When a pulse time is set via the bus, the time is assumed to be an auto internal time (i.e., the value is assumed to be adjusted for the internal delay value). This value is then adjusted to the applicable integral value. For example:

manual time value= 5.040 msec

integral time= 5.033 ms (response returned when time setting is queried)

Average readings count

NOTE	The menu item AVER READINGS #1/#2 applies to average readings for DVM, I and V where AVERAGE READINGS under PULSE CURRENT #1/#2 menu item applies to pulse current measurements. Note that DVM is supported by charger channel (#2) only.

The average readings count specifies how many measurements (integrations) are performed and averaged for each displayed reading. For example, assume that the pulse average readings count is 10 and you are measuring PULSE HIGH. Each displayed reading will reflect the average of 10 peak pulse measurements.

Measurement configuration

NOTE	Current range is selected from the CURRENT RANGE #1/#2 item of the menu. Integration times, average readings count, trigger delay and trigger level are set from the PULSE CURRENT item of the menu. Details on integration rate, average readings count, trigger delay and trigger level are provided in the *Overview*.

See *Table 1-3* for an illustration of the menu structure. Rules to navigate the menu follow the table.

The menu item AVER READINGS #1/#2 applies to average readings for DVM, I, and V, where the AVERAGE READINGS under PULSE CURRENT #1/#2 applies to pulse current measurement.

Current range

The instrument will not auto range with the pulse current measurement function selected. Changes to the auto range setting are not used during pulse current measurements but are retained for when pulse current measurements are no longer taken. Pulse current measurements may be performed on any of the current ranges for the battery channel (#1). Pulse current measurements are always performed on the 5 A range for charger channel (#2). Therefore, selecting pulse current with the 5 mA range active on the charger channel (#2) will cause the supply to first switch to the 5 A range regardless of the current range setting (5 mA or AUTO).

Current range is linked to current limit. Therefore, as a general rule, the user selects the current range before setting the current limit (see *Outputting voltage and current*). Current range is selected from CURRENT RANGE #1/#2 item of the menu (CURRENT RANGE #1 refers to the battery channel while CURRENT RANGE #2 refers to the charger channel).

NOTE	To get better trigger level resolution, make sure the current range (battery channel only) is set appropriately for the expected measurement.

Integration times

Use the following items of the PULSE CURRENT #1/#2 menu item to set integration times:

NOTE	Set PULSE CURRENT integration times in the range of 33.3 μsec to 833 ms (833333 μsec) in 33.3333 μsec steps.

- **HIGH TIME** - Use to set the integration period (in μsec) for high pulse-current measurements. Make sure to account for the internal (10 μsec) and user trigger delay.
- **LOW TIME** - Use to set the integration period (in μsec) for low pulse-current measurements. Make sure to account for the internal (10 μsec) and user trigger delay.
- **AVERAGE TIME** - Use to set the integration period (in μsec) for average pulse-current measurements. Make sure to account for the internal (10 μsec) and user trigger delay.
- **AUTO TIME** - Use to automatically set the integration times for high, low, and average pulse-current measurements. These times are based on detecting the pulse and remain until another auto time is performed or the times are manually changed. Auto time accounts for the internal (10 μsec) delay but not the user trigger delay.
- **PULSE TIMEOUT** - Use to set the variable pulse current time-out feature for pulse current measurements. The default value is 1.000 second (incremented in 1ms steps). See *Using FAST, SEARch, and DETect* for detailed usage information on properly setting this TimeOUT variable.

Average readings count

Use the AVERAGE READINGS item of the PULSE CURRENT #1/#2 menu item to set the average readings count. This count specifies the number of measurements (integrations) to average for each reading. For example, with measurement count set to 10, each displayed

reading will reflect the average of 10 pulse current measurements. Each measurement needs to start after detecting the respective edge for triggering.

NOTE	Set AVERAGE READINGS count in the range of 1 to 100.

Trigger delay and trigger level

Use the following items of the PULSE CURRENT menu item to set trigger delay and trigger level:

- **TRIGGER DELAY** - Use to specify additional user trigger delay (0 to 100 msec in 10 µsec steps). See *Trigger delay* previously discussed in this section for details. This user trigger delay is in addition to the internal trigger delay of 10 µsec.
- **TRIGGER LEVEL** - Use to specify the trigger level for the 5 A, 500 mA, 50 mA, or 5 mA current ranges (battery channel (#1) only). Note that pulse current only works on the 5 A current range for the charger channel. Pulses less than the specified level are not detected.

  Battery channel (#1): The following table shows the trigger levels for each current range along with trigger hysteresis and trigger level step size:

Table 3-1
Current range and trigger level settings

Current range	Trigger level setting	Trigger hysteresis	Setting step size
5 A	0-5 A	10 mA	5 mA
500 mA	0-500 mA	1 mA	0.5 mA or 500 µA
50 mA	0-50 mA	0.1 mA	0.05 mA or 50 µA
5 mA	0-5 mA	0.01 mA	0.005 mA or 5µA

Trigger hysteresis is built into the hardware. If a pulse does not exceed the appropriate hysteresis level, trigger detection will not occur. The trigger level ranges for the battery channel (#1) are displayed as follows:

5 A range:	PCUR TRIG LEV #1 A(5.0) 0.000 A
500 mA range:	PCUR TRIG LEV #1 A(500) 0.0000 A
50 mA range:	PCUR TRIG LEV #1 mA (50) 0.00000A
5 mA range:	PCUR TRIG LEV #1 mA (5) 0.000000A

Charger channel (#2) - Set the trigger level from 0 to 5 A in 5 mA steps. However, there is approximately 10 mA of trigger hysteresis built into the hardware. Therefore, if a pulse does not exceed this level, trigger detection will not occur.

To change the trigger level setting for a current range (from within pulse current TLEV menu screen):

NOTE	For charger channel (#2), skip to step 3 (there is only one trigger level setting - 5 A).

Step 1: Place the blinking cursor on the "A" at the far right end of line two of the display.

Step 2: Press the ▲ or ▼ keys to display the desired current range trigger level setting option.

Step 3: Press the ▲, ▼, ◄, or ► keys to scroll to the desired trigger level setting (in amps).

Step 4: Press **ENTER** to update the trigger level setting for the displayed current range.

Pulse current display mode

Pulse current measurements are displayed with the pulse current display mode selected.

To display the pulse current:

NOTE	If the instrument is in the settings mode, press the **SET** key until the blinking stops (the measured readings can then be displayed). To determine if the instrument is in the settings mode, check for a blinking cursor in a digit of the voltage or current field (if present, the instrument is in the setting mode).

1. Press the **DISPLAY** key to access the display menu.
2. If the desired active channel is not selected, use the ◄ or ► keys to scroll to **DISPLAY TYPE #1** or **DISPLAY TYPE #2**.
3. Press the ▲ or ▼ keys until **PULSE CURRENT** is displayed.
4. Press **ENTER** to select.
5. Use the ▲ or ▼ keys to display the desired pulse measurement; **PULSE HI**, **PULSE LO**, or **PULSE AVG**.

NOTE	For details on display modes, see *Display modes*.

Pulse current measurement procedure

The following steps summarize the procedure to perform pulse measurements:

1. Follow the instructions in *Editing output voltage and current limit values* to set the output voltage and current limit.
2. Select the desired current range (see *Selecting proper current range*) for the battery channel (5 A, 500 mA, 50 mA, or 5 mA). Only the 5 A range is supported for the charger channel. Changes to the auto range setting are not used during pulse current measurements but are retained for when pulse current measurements are no longer take.
3. Press the **MENU** key to access the menu.
4. Press the ▲ or ▼ keys to scroll to **PULSE CURRENT**.
5. Press the ◄ or ► keys to select Channel **#1** or **#2**.
6. Press **ENTER** to select.
7. Press the ▲ or ▼ keys to scroll to **TRIGGER LEVEL**.

8. Press **ENTER** to select.
9. For the battery channel only, press the ▲ or ▼ keys to scroll to the desired current range trigger level (5 A, 500 mA, 50 mA, or 5 mA).
10. Use the ▲, ▼, ◄, or ► keys to scroll to the desired trigger level setting.
11. Press **ENTER** to select.

NOTE	Pulse measurements for the battery channel are performed on the current range selected (5 A, 500 mA, 50 mA, or 5 mA); pulse measurements on the charger channel are automatically performed on the 5 A current range. On the battery channel, the trigger level setting will automatically update to the trigger level associated with the selected current range.

12. From the **PULSE CURRENT #1/#2** item of the menu, set the **TRIGGER DELAY** (optional), **INTEGRATION TIMES**, and **AVERAGE READINGS COUNT** (optional).
13. Press **MENU** to exit the menu structure then press **OPERATE**.
14. Follow the instructions to select the pulse current display type in *Pulse current display mode*.

NOTE	Setting the trigger level with the output off will cause the pulse time-out message to appear. However, the trigger level will be set.

No pulses detected

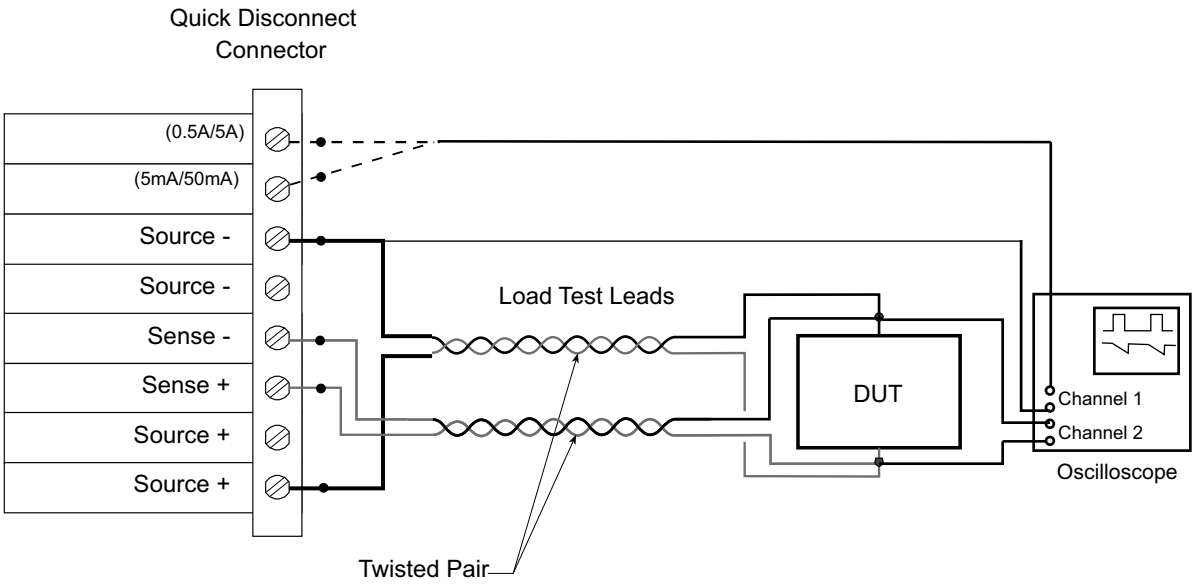
If no pulses are detected, current will not be measured (i.e. -----A) and the "NO PULSE" message will be displayed. The "NO PULSE" message is displayed with dashes or the last valid pulse reading. Dashes are shown if the pulse-current measurement settings are not appropriate for detecting pulses. The last valid pulse is shown if the pulse disappears while taking readings and no change in pulse settings was made.

Pulses are not detected with the output OFF. With the output ON, pulses will not be detected if the trigger level is too low or too high. Perform the following procedure to find an appropriate trigger level. Make sure the voltage and current settings are appropriate for detecting pulses.

Determining correct trigger level (pulse current)

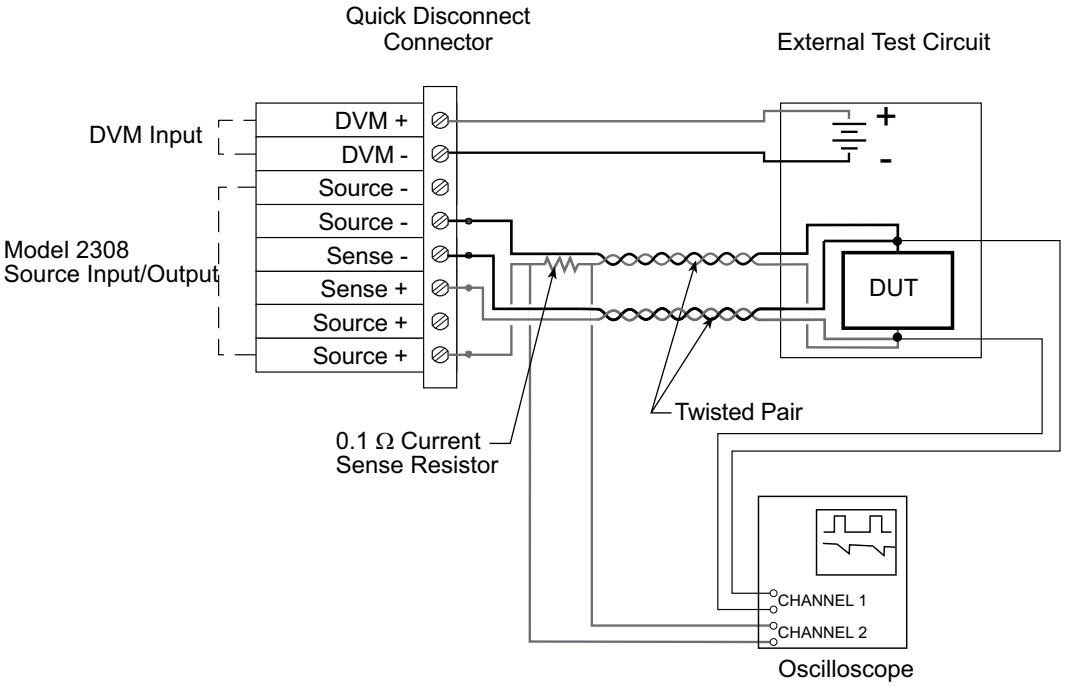
NOTE If possible, always use an oscilloscope to determine the timing and transient characteristics of a DUT. The waveform information is very useful in setting up the Model 2308, reducing setup time and achieving maximum performance and productivity. The voltage and current characteristics of the DUT can be determined with a 2-channel Oscilloscope as shown in *Figure 3-3*. Differential oscilloscope inputs are required to prevent grounding the supply output leads.

Figure 3-3
Determining voltage and current characteristics for battery channel



NOTE *Figure 3-3* contains a simple circuit for determining the dynamic voltage and current characteristics of the DUT.

Figure 3-4
Determining voltage and current characteristics for charger channel



To find a suitable trigger level:

1. Follow the instructions in *Editing output voltage and current limit values* to set the output voltage and current limit.
2. Select the desired current range (see *Selecting proper current range*) for the battery channel (5 A, 500 mA, 50 mA, or 5 mA). Only the 5 A range is supported for the charger channel. Note changes to the auto range setting are not used during pulse current measurements but are retained for when pulse current measurements are no longer take.
3. Press **OPERATE**.
4. Follow the instructions to select the pulse current display type in *Pulse current display mode*.

NOTE	If the trigger level is too low or too high, the "NO PULSE" message will be displayed.

5. Press the **MENU** key.
6. Press the ▲ or ▼ keys to scroll to **PULSE CURRENT**.
7. Press the ◄ or ► keys to select Channel **#1** or **#2**.
8. Press **ENTER** to select.
9. Press the ▲ or ▼ keys to scroll to **TRIGGER LEVEL**.
10. Press **ENTER** to select.
11. For the battery channel only, press the ▲ or ▼ keys to scroll to the desired current range trigger level (5 A, 500 mA, 50 mA, or 5 mA).
12. Press the ▲, ▼, ◄, or ► keys to scroll to the desired trigger level.

13. Press **ENTER** to save your settings and return to the main menu.

NOTE If the trigger level is still too low or too high, the TRIG NOT DETECTED message will be displayed briefly. Note that it may take a few seconds for the message to appear (see *TRIG NOT DETECTED message* for more information).

14. If the message appeared, repeat Step *9* until a valid trigger level is found.
15. Press **MENU** to exit the menu structure and display pulse current measurements.

TRIG NOT DETECTED message

The TRIG NOT DETECTED message is displayed when specific TLEV settings, coupled with corresponding current range, have been set and a trigger has not been detected. Refer to *Table 3-2* for the message preconditions.

Table 3-2
TRIG NOT DETECTED message

TLEV setting	Current range	TRIG NOT DETECTED Message displayed?
90 mA for 500 mA current range	5 A	No (not checked because TLEV setting does not match current range)
90 mA for 500 mA current range	50 mA	No (not checked because TLEV setting does not match current range)
0.75 A for 5 A current range	5 A	May appear*
0.1 A for 500 mA current range	500 mA	May appear*
3.0 A for 5A current range	5 A	May appear*
0.03 A for 50 mA current range	50 mA	May appear*
0.003 A for 5 mA current range	5 mA	May appear*
1.1 A for 5 A current range	5 mA	No (not checked because TLEV setting does not match current range)
1.1 A for 5 A current range	500 mA	No (not checked because TLEV setting does not match current range)

*Depends upon the OUTPUT:
If OFF, the message will appear.
If ON, display of the message will depend on the trigger level setting. If trigger level setting greater than the expected low measurement and less than the expected high measurement, the message will not appear.
For example, if the expected pulse high value is 2.2 A and the expected pulse low value is 0.5 A, the output is on, and the current range is 5 A, notice the following results:
Setting 0.3 A TRIG NOT DETECTED is displayed (setting too low).
Setting 3.0 A TRIG NOT DETECTED is displayed (setting too high).
Setting 1.1 A The message will not display (setting correct).

See *To change the trigger level setting for a current range* for information on setting the trigger level setting for a current range. For the charger channel (#2), the trigger level setting is only available on the 5 A range.

NOTE	Setting the trigger level and/or the current range may cause the PULSE CURR TRIG NOT DETECTED message to appear.

SCPI programming - pulse current measurements

The commands for pulse current measurements are summarized in *Table 3-3* (a listing following the table contains specific command notes). *Programming examples* demonstrate how to use these commands.

Table 3-3
SCPI commands - pulse current measurements

Command	Description	Default
SENSe[1]	SENSe subsystem for battery channel (#1):	
:FUNCtion "PCURrent"	Select pulse current measurement function.	VOLT
:PCURrent	Pulse current configuration:	
:AVERage <NRf>	Specify average count: 1–100 (pulse current measurements) or 1–5000 (pulse current digitization).	1
:MODE <name>	Select measurement mode; HIGH, LOW or AVERage.	HIGH
:TIME	Set integration times:	
:AUTO	Integration times set automatically.	
:HIGH <NRf>	Specify integration time (in sec) for high pulse measurements; 33.33e-6 to 0.8333.	3.333e-5
:LOW <NRf>	Specify integration time (in sec) for low pulse measurements; 33.33e-6 to 0.8333.	3.333e-5
:AVERage <NRf>	Specify integration time (in sec) for average pulse measurements; 33.33e-6 to 0.8333.	3.333e-5
:DIGitize <NRf>	Specify integration time (in sec) for digitizing or burst measurements; 33.33e-6 to 0.8333.	3.333e-5
:SYNChronize	Pulse detection triggering:	
[:STATe]	Send ON to select pulse current measurements or OFF to select pulse current digitization.	ON
:TLEVel	Trigger level:	
[:AMP] <NRf>	Set the trigger level in amps for use when on the 5 A current range: 0.0 A-5.0 A in 5 mA steps.	0.0
:HUNDred <NRf>	Set the trigger level in amps for use when on the 500mA current range: 0.0 mA-500 mA in 0.5 mA or 500 μA steps.	0.0
:FIFTy <NRf>	Set the trigger level in amps for use when on the 50 mA current range: 0.0 mA-50 mA in 0.05 mA or 50 μA steps.	0.0
:FIVE <NRf>	Set the trigger level in amps for use when on the 5 mA current range: 0.0-5 mA in 0.005 mA or 5 μA steps.	0.0

Table 3-3
SCPI commands - pulse current measurements (cont.)

Command	Description	Default
:DELay <NRf>	Specify trigger delay in seconds: 0.0–0.1 (pulse current measurements) or 0.0–5.0 (pulse current digitization).	0.0
:STEP <b>	Performs a series of measurements (*Pulse current step method*)	OFF
:UP <NRf>	<0-20> (max is for both up and down combined)	1
:DOWN <NRf>	<0-20> (max is for both up and down combined)	1
:TIME <NRf>	33.3µsec–100msec	200 µsec
:TimeOUT <NRf>	TimeOUT (other than the first): 2msec–200msec	2 ms
:INITial <NRf>	First TimeOUT step: 10msec–60secs	2 sec
:DELay <NRf>	0msec–100msec (in 10msec steps)	0
:SEQuence <NRf, NRf>	Define up to 19 delay sequence values using the index and the time value (e.g. "1,1e-3" sets the first delay to 1ms). Ranges: 1-19 (parameter 1) and 0 to 100e-3 (parameter 2).	0
:LENgth <NRf>	Define the delay sequence length (0 to 19). Specify zero to always use the PCUR:STEP:DELay value.	0
:SKIP <b>	Specify whether (1) or not (0) to skip sequential triggers. 1=Only requires 1 trigger 0 = Requires multiple triggers	0
:TLEVx <NRf>	Set trigger level for each TLEV step where x equals 1–20 (the maximum settings are based on the selected current range. Therefore, the current range must be selected before setting the step trigger level values)	0.0
:FAST	Enable or disable pulse current fast readings.	OFF
:SEARch	Enable or disable pulse current search.	ON
:DETect	Enable or disable pulse current detection mode.	OFF
:TimeOUT	Specify length of timeout: 5ms - 32s incrementing in 1ms.	1 (sec)
SENSe2	SENSe subsystem for charger channel (#2):	
:FUNCtion "PCURrent"	Select pulse current measurement function.	VOLT
:PCURrent	Pulse current configuration:	
:AVERage <NRf>	Specify average count: 1 to 100 (pulse current measurements), or 1 to 5000 (pulse current digitization).	1
:MODE <name>	Select measurement mode; HIGH, LOW or AVERage.	HIGH
:TIME	Set integration times:	
:AUTO	Integration times set automatically.	
:HIGH <NRf>	Specify integration time (in sec) for high pulse measurements; 33.33e-6 to 0.8333.	3.333e-5

Table 3-3
SCPI commands - pulse current measurements (cont.)

Command	Description	Default
:LOW <NRf>	Specify integration time (in sec) for low pulse measurements; 33.33e-6 to 0.8333.	3.333e-5
:AVERage <NRf>	Specify integration time (in sec) for average pulse measurements; 33.33e-6 to 0.8333.	3.333e-5
:DIGitize <NRf>	Specify integration time (in sec) for digitizing or burst measurements 33.33e-6 to 0.8333.	3.333e-5
:SYNChronize	Pulse detection triggering:	
[:STATe]	Send ON to select pulse current measurements or OFF to select pulse current digitization.	ON
:TLEVel <NRf>	Set trigger level in amps: 0.0–5.0	0.0
:DELay <NRf>	Specify trigger delay in seconds: 0.0–0.1 (pulse current measurements) or 0.0–5.0 (pulse current digitization).	0.0
:FAST	Enable or disable pulse current fast readings.	OFF
:SEARch	Enable or disable pulse current search.	ON
:DETect	Enable or disable pulse current detection mode.	OFF
:TimeOUT	Specify length of timeout: 5ms - 32s incrementing in 1ms.	1 (sec)
READ[1]?	Trigger and return one reading for battery channel (#1).	
READ[1]:ARRay?	Trigger an array of readings and return them for battery channel (#1).	
READ2?	Trigger and return one reading for charger channel (#2).	
READ2:ARRay?	Trigger an array of readings and return them for charger channel (#2).	

Command notes (pulse current measurements)

`SENSe[1]:FUNCtion 'PCURrent'` Applies to battery channel (#1)
`SENSe2:FUNCtion 'PCURrent'` Applies to charger channel (#2)

This parameter name can also be enclosed in single quotes (as shown above).

`SENSe[1]:PCURrent:AVERage <NRf>` Applies to battery channel (#1)
`SENSe2:PCURrent:AVERage <NRf>` Applies to charger channel (#2)

1. When requesting a single reading (`FETCh?`, `READ?`, or `MEASure?`), average count specifies the number of pulse current measurement conversions to average for the reading. For example, with the average count set to 10, `READ?` will trigger 10 pulse current measurement conversions and return (and display) the average of those 10 battery channel conversions (charger channel command similar).
2. When requesting an array of readings (`FETCh:ARRay?`, `READ:ARRay?` or MEASure:ARRay?), average count specifies the number of pulse current measurements to place in an array. For example, with the average count set to 10, `READ:ARRay?` will trigger and return 10 battery channel readings (charger channel command similar).
3. For pulse current digitization, use an array reading command (such as `READ:ARRay?`) to return the digitized readings.
4. Signal-oriented measurement commands (such as `READ?`) are covered in *Section 9*.

`SENSe[1]:PCURrent:TIME` Applies to battery channel (#1)
`SENSe2:PCURrent:TIME` Applies to charger channel (#2)

When manually setting the pulse HIGH, LOW, AND AVERage time:

1. The integration time should only cover the portion of the pulse to be measured.
2. Factor in trigger delays (both internal and user) when determining integration times. Before the integration process begins (after pulse detection) the internal trigger delay of 10 µs (for code execution), in addition to any user-specified trigger delay, must elapse.

NOTE	AUTO time will account for the internal trigger delay (10 µsec) but not for any user trigger delay (user trigger delay is set using the DELay command).

`SENSe[1]:PCURrent:TIME:DIGitize <NRf>` Applies to battery channel (#1)
`SENSe2:PCURrent:TIME:DIGitize <NRf>` Applies to charger channel (#2)

This command allows you to specify the integration time that occurs when Model 2308 is digitizing or in burst mode (`SENS:PCUR:SYNC:STAT` is OFF for the particular channel). This feature allows you to sample a pulse load for a longer time by increasing the integration time from 33.3 µs.

NOTE	Pulse current digitization is also known as pulse current burst mode.

`SENSe[1]:PCURrent:SYNChronize <b>` Applies to battery channel (#1)
`SENSe2:PCURrent:SYNChronize <b>` Applies to charger channel (#2)

Boolean parameters:

- ON or 1 - Enables trigger synchronization for pulse current measurements. A pulse current reading will not trigger until the specified trigger level is detected and the specified trigger delay (both the internal plus the user delay) period expires.
- OFF or 0 - Disables trigger synchronization and selects pulse current digitization. See *Pulse current digitization* for details on digitizing a current pulse or waveform.

:TLEVel Commands

A valid trigger level for detecting the pulse is needed whether trigger synchronization is ON or OFF (see `:SYNChronize` commands above).

`SENSe[1]:PCURrent:SYNChronize:DELay <NRf>` Applies to battery channel (#1)
`SENSe2:PCURrent:SYNChronize:DELay <NRf>` Applies to charger channel (#2)

1. The smallest step size for trigger delay is 10 µsec. If you specify a smaller step size, it is adjusted up to the next 10 µsec step value (e.g., 43 µsec is adjusted up to 50 µsec).
2. After pulse detection but before the integration process begins, the internal trigger delay of 10 µsec (for code execution) in addition to any user specified trigger delay must elapse. This command is used to set the user trigger delay.
3. Make sure this setting works with the `:TIME` settings to produce an accurate reading. Although AUTO accounts for internal trigger delay, HIGH, LOW, and AVERage do not. Note that none of the TIME commands account for the user trigger delay.

`SENSe[1]: PulseCURrent:FAST <b>` Applies to battery channel (#1)
`SENSe2: PulseCURrent:FAST <b>` Applies to charger channel (#2)

See *Using FAST, SEARch, and DETect* for detailed usage information.

`SENSe[1]:PulseCURrent:SEARch <b>`	Applies to battery channel (#1)
`SENSe2: PulseCURrent:SEARch <b>`	Applies to charger channel (#2)

See *Using FAST, SEARch, and DETect* for detailed usage information.

`SENSe[1]: PulseCURrent:DETect <b>`	Applies to battery channel (#1)
`SENSe2: PulseCURrent:DETect <b>`	Applies to charger channel (#2)

See *Using FAST, SEARch, and DETect* for detailed usage information.

`SENSe[1]:PulseCURrent:TimeOUT <NRf>`	Applies to battery channel (#1)
`SENSe2: PulseCURrent: TimeOUT <NRf>`	Applies to charger channel (#2)

See *Using FAST, SEARch, and DETect* for detailed usage information on properly setting the TimeOUT variable.

Using FAST, SEARch, and DETect

Use the `FAST` command to have the quickest response for pulse current measurements triggered by the measurement commands (for example, `MEASure`, `READ` or `*TRG`). Note that when you use the `FAST` command, there is no indication that the instrument is correctly configured for detecting pulses until a measurement command is sent. When the trigger level is set, use the `SEARch` command to retain quick responses to measurement commands and to ensure that the instrument is configured correctly for detecting pulses. Use the `DETect` command to ensure that the unit is configured correctly and can read the pulse before sending a measurement command.

Use FAST, SEARch, and DETect to control how background readings are taken. A background reading is a measurement taken by the power supply between user triggered readings. The selected function dictates how background readings are taken between user triggered readings.

For pulse current, a background reading involves looking for the pulse and optionally generating a reading for the user. The various settings of `SEARch`, `FAST`, and `DETect` allow the user to fine tune the function. This enables the function to perform the desired background readings (if any) between user triggered readings. The default settings (`FAST:OFF`, `SEARch:ON`, and `DETect:OFF`) allow the pulse current background readings to be taken. If no pulse is present, the setting of TimeOUT affects how responsive the supply is to bus commands. If a pulse is present, the search time affects how responsive the supply is to bus commands (refer to *Figure 3-5*). *Table 3-4* contains the available settings for `FAST`, `SEARch`, and `DETect` commands and a description of the resulting action.

In order to efficiently use `FAST`, `SEARch`, and `DETect` for pulse current measurements, the user must know the approximate period of the expected pulse. TOUT (TimeOUT) specifies the timeout length for searching for the pulse (default setting is 1 second). When the TOUT value is reached, "NO PULSE" is displayed (top line of the front-panel display) if default settings for FAST, SEARch, and DETect are used. See *Table 3-4* for what is shown on the front-panel display if the default settings are not used. Set the value for TOUT as follows:

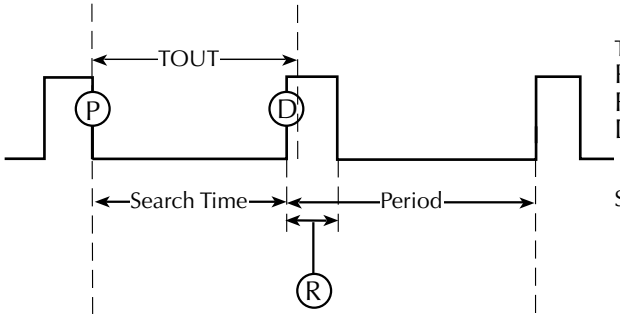
TOUT = search Time + Period

Search Time = time allowed for detection of a pulse edge

Period = time between consecutive pulse edges

In other words, the timeout value should be set to allow sufficient time for detection of the pulse if the edge is just missed. In *Figure 3-5*, (P) is the point to start looking for the pulse. Since the rising edge was just missed, (D) will be the first detectable rising edge. If the timeout is less than search time, a pulse trigger time out (due to TOUT) may occur. Therefore, if the period = 0.4 seconds, a good TOUT value would be 0.5 seconds. A similar method for selecting a TOUT value would be to use a value equal to 105% of the expected pulse period.

Figure 3-5
PCURrent and SEARch time for pulse high measurement



TOUT setting must account for Search Time and Period.
P = Search for Pulse High edge started
R = Reading time taken
D = Detected pulse edge (Rising for pulse high and average measurements)

Search Time:
Measured from when unit starts looking for the pulse until the first detectable desired edge. This is a rising edge for HIGH and AVG measurements, and falling edge for LOW measurements.

Period: Time between consecutive pulse edges.

NOTE If a pulse is not present, timeout needs to elapse (TOUT). This (TOUT elapsing) paces the unit for processing bus commands.

- If DETECT ON (only), search time needs to elapse before responding to a bus command.
- If SEARCH OFF or FAST ON, search time and TOUT are not incurred while processing non-user triggered commands (refer to *Section 9* of the User's Manual for examples of user triggered).
- Search time or TimeOUT needs to elapse when checking TLEV command for valid setting, if enabled.

Table 3-4
PCURrent FAST, SEARch, and DETect commands

FAST	SEARCH	DETECT	DESCRIPTION
ON ON ON ON	ON ON OFF OFF	ON OFF ON OFF	The unit is most responsive to bus commands in this mode. The supply does not wait for TOUT or search time for background pulse current readings and TLEV command checks. front panel displays FAST HI / LO / AVG (in remote mode) instead of PCUR HI / LO / AVG (if in local mode). The bottom line may show a previous reading or dashes based on what commands were sent previously when in remote mode. With FAST set to ON, no pulse detection between user-triggered readings occurs, no checking for the parameter of PCUR TLEV commands to detect a pulse occurs, no setting of the pulse trigger timeout bits in the status model between user-triggered readings occurs. front panel has no indication that pulse is not detected. Over the bus, an overflow reading indicates no pulse detected when asked for a user triggered reading. For triggered readings, the PTT (Pulse Trigger Timeout) bit is latched until read so the bit may still be set in the status model from a previous timeout (see *Section 7* on the status model for more information-Model 2308 User's Manual). For triggered readings, the PTT (Pulse Trigger Timeout) bit will be set if the reading times out and the pulse is not detected.
OFF OFF	OFF OFF	ON OFF	The unit is more responsive to bus commands in this mode since the supply does not need to wait for TOUT or search time for pulse current background readings. However, the supply does need to wait for TOUT or search time when checking the parameter setting for TLEV commands. Refer to *Figure 3-5*. front panel displays NO SEARCH instead of PULSE HI / LO / AVG. The bottom line may show a previous reading or dashes based on what commands were sent previously when in remote mode. The setting of the pulse trigger timeout bits in the status model will only occur between user-triggered readings if TLEV commands are sent. For triggered readings, the PTT (Pulse Trigger Timeout) bit will be set if the reading times out and the pulse is not detected. Also, since the PTT bit is latched until read, the bit may still be set in the status model from a previous timeout (see *Section 7* on the status model for more information-Model 2308 User's Manual).

Shaded cells designate command with precedence in each mode.

Table 3-4
PCURrent FAST, SEARch, and DETect commands (cont.)

FAST	SEARCH	DETECT	DESCRIPTION
OFF	ON	ON	This mode allows the user to know whether the pulse disappeared before a user-triggered reading is requested. The responsiveness of bus commands is governed by TOUT (if no pulses are detected), or by search time (if pulses are detected). Therefore, the longest response time to bus commands is approximately the greater of either TOUT or search time values. Refer to *Figure 3-5*. If the pulse is detected, the front panel will display DETECT HI / LO / AV on the top line of the display. If no pulses are detected, the front panel will display NO DETECT as well as the PTT (Pulse Trigger Timeout) bit being set in the status model. Since the PTT bit is latched until read, a query for the PTT bit may indicate that pulse trigger timeout occurred although the display is showing DETECT (see *Section 7* on the status model for more information-Model 2308 User's Manual). The bottom line may show a previous reading or dashes based on what commands were sent previously when in remote mode. Checking for the parameter of PCUR TLEV command may set the PTT bit of the status model. For triggered readings, the PTT (Pulse Trigger Timeout) bit will be set if the reading times out and the pulse is not detected.
OFF	ON	OFF	With DETect OFF, background pulse current measurements will occur between user-triggered readings as well as pulse detection. If the pulse is detected, the front panel will display PULSE HI / LO / AVG on the top line of the display along with the reading on the bottom line. If no pulses are detected, the front panel will display "NO PULSE" as well as the PTT (Pulse Trigger Timeout) bit being set in the status model. Since the PTT bit is latched, a query for the PTT bit may indicate that pulse trigger timeout occurred although the display is displaying PULSE HI / LO / AVG and a reading (see *Section 7* on the status model for more information-Model 2308 User's Manual). Checking for the parameter of PCUR TLEV commands to detect a pulse may set the PTT bit. If detecting pulses, the supply's responsiveness to bus commands is affected by search time. If not detecting pulses, the supply's responsiveness to bus commands is affected by TOUT. Therefore, the longest response time to bus commands is approximately the greater of either TOUT or search time (refer to *Figure 3-5*). In this mode, the front panel will show PULSE HI / LO / AVG on the top line with a reading on the bottom. Checking the parameter of PCUR TLEV commands to detect a pulse may set the PTT bit of the status model if TLEV setting causes no pulse detection. For triggered readings, the PTT (Pulse Trigger Timeout) bit will be set if the reading times out and the pulse is not detected.

Shaded cells designate command with precedence in each mode.

Pulse current digitization

The following discussion explains how to digitize a current waveform. A programming example at the end of this section demonstrates proper command sequence for pulse current digitization.

Overall steps for digitization:

1. Sync up to desired edge for measurement.
2. After detecting edge, wait for the internal and also any user trigger delay.

3. Take specified number of readings. The supply synchronizes to only the first reading. After taking the first reading, the supply no longer synchronizes to the selected edge nor does it wait for a trigger delay (internal or user trigger delay).

In the pulse current digitization mode with a integration time (SENS:TIME:DIG) of 33 μs, readings are generated approximately every 244 μs for battery channel (313 μs for charger channel) and placed in the instrument measurement output buffer. The 244 μs or 313 μs time interval is the sum of the integration period, 33μsec, and the period required to convert this information into a measurement, approximately 211 μsec for battery channel (280 μs for charger channel). These conversions time will be needed as the integration time for digitization is increased. However, the approximate time for a reading stored in the buffer will be the integration time + conversion time. The instrument initiates the storage and conversion process for the desired number of iterations, as specified with the AVERAGE command, when the :TLEVel threshold is exceeded. The message DIGITIZE is displayed instead of readings. The NO PULSE message will be displayed if the pulse is not detected. Pulse current digitization is selected by disabling trigger synchronization:

`SENS[1]:PCUR:SYNC <b>`	battery channel (#1)
`SENS2:PCUR:SYNC <b>`	charger channel (#2)

<b>	=	OFF	Select pulse current digitization (trigger synchronization disabled).
	=	ON	Select pulse current measurements (trigger synchronization enabled).

The commands to set the trigger level and trigger delay for pulse current measurements also apply for pulse current digitization. However the trigger delay can be set up to five seconds.

`SENS[1]:PCUR:SYNC:DEL <NRf>`	battery channel (#1)
`SENS2:PCUR:SYNC:DEL <NRf>`	charger channel (#2)
`<NRf> = 0 to 5`	User trigger digitization delay in seconds (10 μsec steps). For digitization, the internal trigger delay is 10 μsec.

To detect the pulse, the digitization process synchronizes to the edge specified by the following command:

`SENS[1]:PCUR:MODE <name>`			battery channel (#1)
`SENS2:PCUR:MODE <name>`			charger channel (#2)
<name>	=	HIGH or AVER	Sync up to rising edge of pulse for 1st reading of digitization.
	=	LOW	Sync up to falling edge of pulse for 1st reading of digitization.

After any specified delay period expires, the instrument takes the number of readings specified by the average count command:

`SENS[1]:PCUR:AVER <NRf>`	battery channel (#1)
`SENS2:PCUR:AVER <NRf>`	charger channel (#2)
`<NRf> = 1 to 5000`	Digitize 1 to 5000 readings.

NOTE *Pulse current digitization* for a programming example.

Pulse current step method

Use the pulse current step method to perform a series of different trigger level measurements on the same current range. This method is available on the battery channel through GPIB operation only - `SENS:PCUR:STEP` commands (see *Table 3-3*). Use this method to decrease the time required to take a sequence of measurements. To use this method, properly set trigger level steps, integration time, time-out setting, and current range for the entire sequence of measurements. Out of these settings, only trigger level may be set to a unique value for each step - settings for

integration time and current range apply to all steps in the measurement sequence. Timeout has two settings - one for the first step and one for the remaining steps in the sequence. Use an array command to trigger this method since an array of values are returned (e.g., `:READ[1]:ARRay?`).

TLEV steps

TLEV (trigger level) steps are used to define the pulse sequence. A maximum of 20 steps may be defined. These steps can be all UP steps, all DOWN steps, or a combination with the summation of UP and DOWN steps to measure not exceeding 20 (see *Table 3-5*). UP steps are always measured before DOWN steps. To use the step method on pulse forms with DOWN steps first, special programming considerations can be taken. Refer to *Pulse sequences - down steps first*.

NOTE Do not change the current range after the trigger level ranges are selected. Erroneous readings may result. Erroneous readings will occur if the existing trigger level settings are out of range for the new current range, or if the trigger level settings are unable to detect the pulse on the new current range.

When using the pulse current step method, select the current range first, then set the trigger level step values. Select the most accurate current range suitable for the highest trigger level step value. Current range needs to be specified before step values because the step values max setting is based on selected current range. Also, only one current range is used during the step operation. You may change current ranges; the step values will be verified against the new current range (see *Changing ranges* for more detail).

Table 3-5
Setting UP and DOWN commands

Command	Description
`:SENS:PCUR:STEP:UP 1`	**1 (UP) + 1 (DOWN default) ≤20** ∴ this command is ok.
`:SENS:PCUR:STEP:UP 20`	**20 (UP) + 1 (DOWN) > 20** ∴this command generates an error message (-222, parameter out of range). Both the up and down settings stay at 1.
`:SENS:PCUR:STEP:DOWN 3`	**3 (DOWN) + 1 (UP) ≤20** ∴ this command is ok.
`:SENS:PCUR:STEP:UP 12`	**12 (UP) + 3 (DOWN) ≤20** ∴this command is ok.
`:SENS:PCUR:STEP:DOWN 10`	**12 (UP) + 10 (DOWN) > 20** ∴ this command generates an error message (-222, parameter out of range). The down setting stays at 3.

Active steps refer to valid UP steps plus valid DOWN steps. If pulse current step method is selected when a trigger command is received, the number of measurements taken equals the number of active steps. Therefore, to receive all measurements at once, use array commands. If array commands are not used, then a single reading is returned. This single reading represents the average of the active step measurements.

NOTE If there are zero (0) active steps when a trigger command for step is received (number of steps UP + the number of steps DOWN = 0), one reading will be returned (an overflow).

The step method can be used on a variety of pulse forms. See *Figure 3-6* for pulse forms that can be measured either as one-shot pulse or as a continuous pulse train. For other pulse forms that can be measured as one-shot only pulses, see *Figure 3-7*. For pulse trains that have steps that rise and fall between steps, use the one-shot method to measure the step values (see *Pulse sequences - rising and falling*). If the continuous method is used on these pulse trains, the first step may trigger on any step that would be appropriate for that trigger level. For example, a first step trigger level of 200 milliamps may trigger on any step with an expected value greater that 200 milliamps. *Figure 3-9* shows that with a first step TLEV of 200 milliamps that any one of the six steps may actually trigger as a first step reading. Hence, the array of step readings may have overflow readings and/or expected step values out of sequence. In addition, this would vary between triggered step measurements.

Figure 3-6
Sample pulse forms for step method

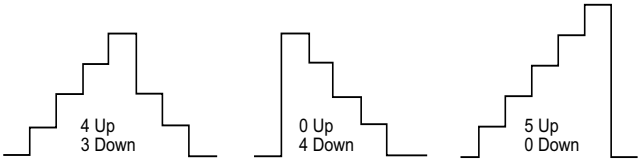


Figure 3-7
Sample one-shot only pulses for step method

Trigger level settings

The trigger level may be set to a unique value for each active step. Use the TLEV*x* command to set appropriate trigger levels for each active step in the waveform. Make sure that the maximum setting for the selected current range is not exceeded (see *Range with pulse current step*).

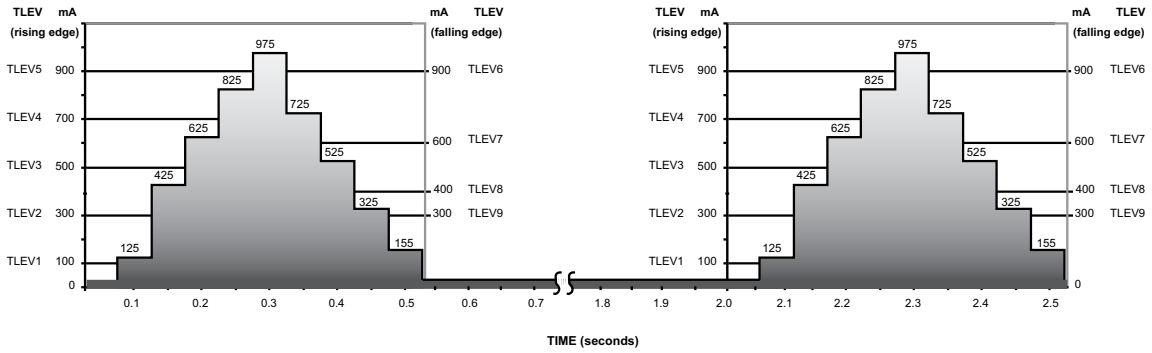
Figure 3-8 has 5 rising edge steps and 4 falling edge steps. Set the trigger levels for each step measurement according to the expected pulses. Based on the wave form, the nine trigger levels could be set as follows:

Table 3-6
Trigger Level Setting for *Figure 3-8*

Rising		Falling	
TLEV1	100 mA	TLEV6	900 mA
TLEV2	300 mA	TLEV7	600 mA
TLEV3	500 mA	TLEV8	400 mA
TLEV4	700 mA	TLEV9	300 mA
TLEV5	900 mA		

For a programming example of this sample, see *Sample step method*.

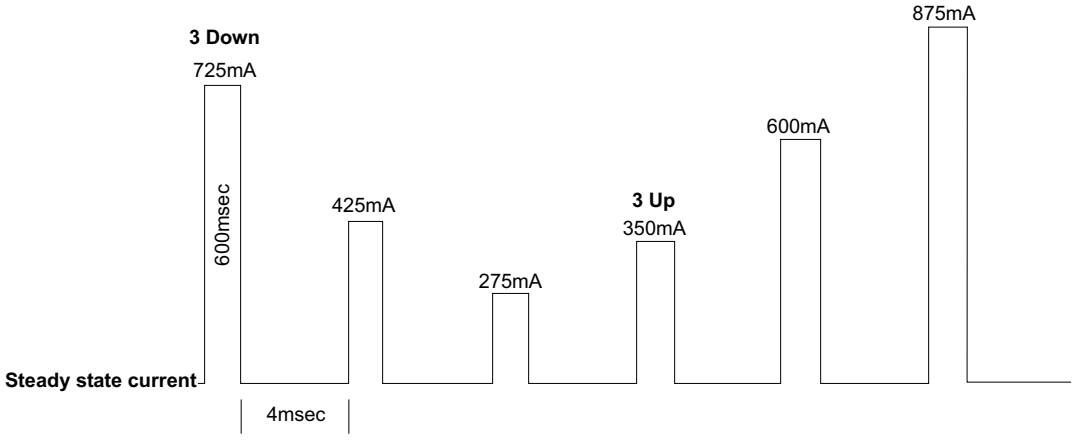
Figure 3-8
Sample :STEP Pulse measurement



Pulse sequences - rising and falling

Consider the pulse form in *Figure 3-9*. This pulse form has three falling (DOWN) level steps followed by three rising (UP) level steps. Since these steps rise and fall to the same steady state current, active steps need to be designated as 6 UP and 0 DOWN to measure the step level current. If DOWN steps are specified then, the step level current measured will be the steady state current.

Figure 3-9
Pulse form with rise and fall steps



For the active steps, the trigger level may be set to a value appropriate for each rising or falling step, or set to the same value for all active steps. If using the same values for all TLEV*x* steps, make sure the TLEV value set is appropriate for the smallest step (in *Figure 3-9*, the TLEV value could not be greater than 275mA). See *Table 3-7* for sample trigger level values.

Table 3-7
Sample TLEV values for *Figure 3-9*

TLEV*x*	**Unique TLEV*x* value**	**Same TLEV*x* value**
TLEV1	550 mA	200 mA
TLEV2	325 mA	200 mA
TLEV3	200 mA	200 mA
TLEV4	300 mA	200 mA
TLEV5	500 mA	200 mA

Table 3-7
Sample TLEV values for *Figure 3-9*

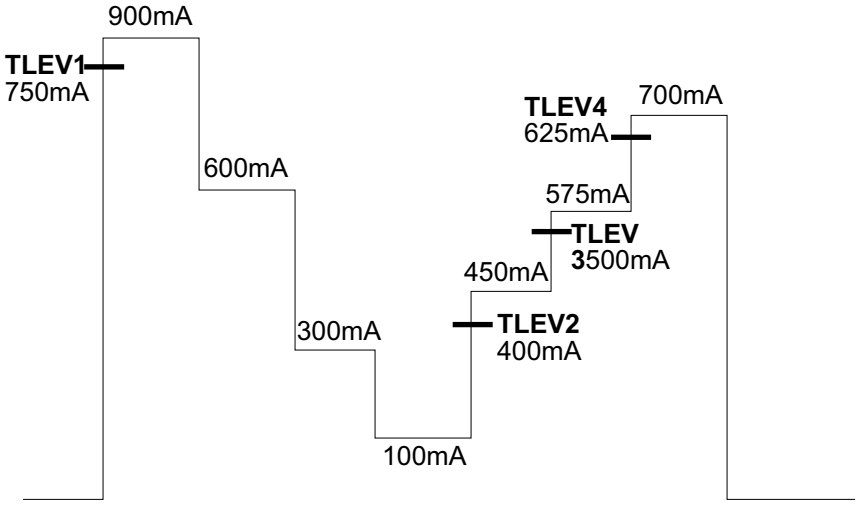
TLEV*x*	**Unique TLEV*x* value**	**Same TLEV*x* value**
TLEV6	800 mA	200 mA

Use the one-shot method for measuring the pulses since this pulse sequence rises and falls between steps. To accomplish this, configure the Model 2308 for measuring the pulse sequence then generate the pulse sequence (See the programming example *One-shot pulse*).

Pulse sequences - down steps first

Consider the pulse form in *Figure 3-10*. This pulse form has three DOWN steps followed by three UP steps but does not rise or fall between the steps.

Figure 3-10
Pulse form with down steps first (600µsec step duration)



To measure the up step values in this pulse sequence, set the value for UP steps to equal the sum of actual UP steps plus one while setting the DOWN step value to zero. In *Figure 3-10*, the UP steps are set to 4 and DOWN steps to 0 (If UP steps are set to a non-zero value, the Model 2308 measures them first). Also set TLEV1 for the initial step. This value needs to be appropriate for detecting the first DOWN step as an UP step measurement (in *Figure 3-10*, this value is set at 750mA). For the UP steps, set the trigger level to a value appropriate for each rising step. The key to detecting this pulse sequence is setting the step timeout to a value high enough to bypass the remaining down steps after measuring the first step.

For *Figure 3-10*, the following expected measurement values and TLEV values were used:

Expected measurements:

UP 450 mA, 575 mA, and 700 mA (4th-6th pulses)

DOWN 900 mA, 600 mA, 300 mA (1st-3rd pulses)

TLEV values (all rising)

TLEV1	750 mA (1st pulse)	TLEV3	500 mA (5th pulse)
TLEV2	400 mA (4th pulse)	TLEV4	625 mA (6th pulse)

This pulse sequence can be measured using the continuous pulse method (see the programming example *Continuous pulse train*). Similarly, this pulse train could be measured using the one-shot method. For the one-shot method, the first step trigger level value could be any value for detecting the 900 milliamp step.

Timeout setting

TOUT (TimeOUT - timeout setting) specifies the timeout length for detecting a given pulse step. When the TOUT value is reached, an overflow value for that step reading is returned. Although all step measurements after the first TOUT step are returned as overflow readings, all step measurements performed before TOUT was exceeded will have correct readings.

Two timeout settings are used: one for the initial step and another for the rest of the active steps. The setting for the initial timeout should be set slightly longer than the period of the pulse for continuous pulse trains. The other timeout setting should cover the longest step duration. Also, make sure to account for trigger delays when determining timeout settings. There are two possible trigger delays: the internal trigger delay (10 μsec necessary for code execution), and any user specified trigger delay (optional). The trigger delays occur before the integration process begins but after pulse detection.

To use the pulse current step method to measure a one-shot pulse train, set the initial timeout to the maximum setting of 60 seconds. This allows the Model 2308 to be triggered for step measurements, then a few seconds of delay before generating the one-shot pulse train. The few seconds of delay are required to ensure the Model 2308 is setup and ready to detect the first step when it happens along with the rest of the steps.

Integration time

For the pulse current step method, the integration time is required to be at least 400μsec less than the step duration. This 400μsec allows for the Model 2308 to complete the previous measurement conversion and become ready for the next pulse edge. With this in mind, *Table 3-8* lists appropriate integration times. Integration time applies to all active steps when step measurements are requested — each step has the same integration time.

Table 3-8
Sample integration times

Pulse step duration	Step integration times
3.8 ms	≤ 3.4 ms
1.25 ms	≤ 0.85 ms
800 μsec	≤ 400 μsec
500 μsec	≤ 100 μsec

Range with pulse current step

Select an appropriate current range for the desired measurements. Four current ranges are available: 5 A, 500 mA, 50 mA, and 5 mA. Make sure all TLEV values are valid in the selected current range. There is only one current range for all active steps - each step does not have a unique current range.

Changing ranges

When changing ranges, the currently active TLEV (trigger level) step values are checked. This check verifies that the new range maximum setting does not exceed the range (i.e., 5 A for the 5 A range, 500 mA for the 500 mA range, 50 mA for the 50 mA range, or 5 mA for the 5 mA range). If just one of the active step TLEV values exceeds the maximum setting for the new current range, then all step TLEV values are set to 0A.

For example: When changing from the 5 amp current range to the 500 mA range, a TLEV value greater than 500 mA resets all active trigger level values. Alternatively, if you change from the 5 A current range to the 500 mA range and no trigger level settings exceed 500 mA, the previous settings will be used for the 500 mA range.

NOTE Change TLEV settings for each step using the `:STEP:TLEVx` command.

Programming examples

Pulse current measurements

The following command sequence will return the average of 10 peak pulse current measurements:

Battery channel (#1)

```
DISP:CHAN 1                    ' Sets active channel - battery.
SENS:CURR:RANG 0.5             ' Select 500 mA range.
VOLT 15                        ' Set output voltage to 15V.
CURR 0.75                      ' Set current limit to 750mA.
OUTP ON                        ' Turn output on.
SENS:PCUR:SYNC ON              ' Enable trigger synchronization.
SENS:PCUR:AVER 10              ' Set average count to 10.
SENS:PCUR:SYNC:TLEV:HUND 0.1   ' Set trigger level to 100mA for 500 mA trigger level setting.
SENS:PCUR:TIME:AUTO            ' Set integration times automatically.
SENS:PCUR:MODE HIGH            ' Configure to measure peak pulse.
SENS:FUNC "PCUR"               ' Select pulse current function.
READ?                          ' Trigger 10 measurement conversions and
                               ' return the average of those 10 conver-
                               ' sions. The average of the 10 conversions
                               ' is displayed on the front panel. Each of
                               ' the ten conversion syncs to the rising
                               ' edge.
```

Charger channel (#2)

```
DISP:CHAN 2                    ' Sets active channel - charger.
SENS2:CURR:RANG 5              ' Select 5 A range.
SOUR2:VOLT 15                  ' Set output voltage to 15V.
SOUR2:CURR 0.75                ' Set current limit to 750 mA.
OUTP2 ON                       ' Turn output on.
SENS2:PCUR:SYNC ON             ' Enable trigger synchronization.
SENS2:PCUR:AVER 10             ' Set average count to 10.
SENS2:PCUR:SYNC:TLEV 0.1       ' Set trigger level to 100 mA.
SENS2:PCUR:TIME:HIGH 600e-3    ' Set integration high time to 600ms.
```

```
SENS2:PCUR:SYNC:DEL 50e-3      ' Set trigger delay to 50 msec.
SENS2:PCUR:MODE HIGH           ' Configure to measure peak pulse (trigger
                               ' on rising edge).
SENS2:FUNC "PCUR"              ' Select pulse current function.
READ2?                         ' Trigger 10 measurement conversions and
                               ' return the average of those 10 conver-
                               ' sions. The average of the 10 conversions
                               ' is displayed on the front panel. Each of
                               ' the ten conversion syncs to the rising
                               ' edge.
```

Pulse current digitization

The following command sequence returns 3600 digitized readings.

Battery channel (#1)

```
DISP:CHAN 1                    ' Sets active channel - battery.
SENS:CURR:RANG 0.5             ' Select 500 mA range.
VOLT 15                        ' Set output voltage to 15V.
CURR 0.75                      ' Set current limit to 750 mA.
OUTP ON                        ' Turn output on.
SENS:PCUR:SYNC OFF             ' Disable trigger synchronization.
SENS:PCUR:AVER 3600            ' Set average count to 3600.
SENS:PCUR:SYNC:TLEV:HUND 0.1   ' Set trigger level to 100 mA for 500 mA range.
SENS:PCUR:SYNC:DEL 500e-3      ' Set trigger delay to 500 msec.
SENS:PCUR:MODE LOW             ' Configure to measure low pulse (trigger on
                               ' falling edge).
SENS:PCUR:TIME:DIG 1e-4        ' Set digitize integration time to 100us
SENS:FUNC "PCUR"               ' Select pulse current function.
READ:ARR?                      ' Trigger and return 3600 readings after sync-
                               ' ing to the falling edge for the 1st reading only.
```

Charger channel (#2)

```
DISP:CHAN 2                    ' Sets active channel - charger.
SENS2:CURR:RANG 5              ' Select 5 A range.
SOUR2:VOLT 15                  ' Set output voltage to 15 V.
SOUR2:CURR 0.75                ' Set current limit to 750 mA.
OUTP2 ON                       ' Turn output on.
SENS2:PCUR:SYNC OFF            ' Disable trigger synchronization.
SENS2:PCUR:AVER 3600           ' Set average count to 3600.
SENS2:PCUR:SYNC:TLEV 0.1       ' Set trigger level to 100 mA.
SENS2:PCUR:SYNC:DEL 50e-3      ' Set trigger delay to 50 msec.
SENS:PCUR:MODE LOW             ' Configure to measure low pulse (trigger on falling edge).
SENS:PCUR:TIME:DIG 1e-4        ' Set digitize integration time to 100 us
SENS2:FUNC "PCUR"              ' Select pulse current function.
READ2:ARR?                     ' Trigger and return 3600 readings after syncing to the
                               ' falling edge for the 1st reading only.
```

Pulse current STEP method (battery channel only)

NOTE	To function correctly, the current range must be selected before setting the trigger level step settings.

Sample step method

The following command sequence measures pulses similar to the one shown in *Figure 3-8*. The step duration is 50ms with a pulse period of 2 seconds.

```
DISP:CHAN 1                    ' Set active channel - battery.
```

```
SENS:CURR:RANG 3              ' Select 5A current range.
SENS:PCUR:STEP ON             ' Enable step.
SENS:FUNC 'PCUR'              ' Select PCUR function.
SENS:PCUR:STEP:UP 5           ' Specify 5 up steps.
SENS:PCUR:STEP:DOWN 4         ' Specify 4 down steps
                              ' active steps = 9 (5 up + 4 down).
SENS:PCUR:STEP:TIME 20e-3     ' Specify 20 milliseconds integration time
                              ' for all active steps must be within 400 µsec
                              ' of step duration.
SENS:PCUR:STEP:TOUT:INIT 3    ' Specify 3 seconds for first step timeout
                              ' (this has to be longer than pulse period).
SENS:PCUR:STEP:DEL 10e-3      ' Specify 10 milliseconds for user step delay.
                              ' With 50 milliseconds of step duration, we
                              ' use 50 milliseconds (step duration) -
                              ' 30 milliseconds = 20 milliseconds spare time.
                              ' Recall 400 microseconds needed for complet-
                              ' ing previous step measurement and being
                              ' ready for next.
SENS:PCUR:STEP:TLEV1 100e-3   ' Step 1 tlev value.
SENS:PCUR:STEP:TLEV2 300e-3   ' Step 2 tlev value.
SENS:PCUR:STEP:TLEV3 500e-3   ' Step 3 tlev value.
SENS:PCUR:STEP:TLEV4 700e-3   ' Step 4 tlev value.
SENS:PCUR:STEP:TLEV5 900e-3   ' Step 5 tlev value.
SENS:PCUR:STEP:TLEV6 900e-3   ' Step 6 tlev value.
SENS:PCUR:STEP:TLEV7 600e-3   ' Step 7 tlev value.
SENS:PCUR:STEP:TLEV8 400e-3   ' Step 8 tlev value.
SENS:PCUR:STEP:TLEV9 300e-3   ' Step 9 tlev value.
READ:ARR?                     ' Trigger and return the 9 step measurements.
```

NOTE Since this sample program is for a continuous pulse train, the pulse it measures could also be measured using the single shot method (see *One-shot pulse*).

One-shot pulse

NOTE To function correctly, the current range must be selected before setting the trigger level step settings.

The following command sequence measures pulses similar to the one shown in *Figure 3-9* with a one-shot pulse measurement. The step duration is 600 µsec with 4 msec between steps.

```
DISP:CHAN 1                   ' Set active channel - battery.
SENS:PCUR:STEP ON             ' Enable step.
SENS:FUNC 'PCUR'              ' Select PCUR function.
SENS:PCUR:STEP:UP 6           ' Specify 6 up steps.
SENS:PCUR:STEP:DOWN 0         ' Specify 0 down steps (remember the default
                              ' is 1). Pulse sequences - rising and falling for more information.
SENS:CURR:RANG 3              ' Select 5 A current range.
SENS:PCUR:STEP:TIME 100e-6    ' Specify 100 microseconds for step integra-
                              ' tion time.
SENS:PCUR:STEP:DEL 50e-6      ' Specify 50 microseconds for step delay.
                              ' Recall 400 microseconds needed for complet-
                              ' ing previous step measurement and being
                              ' ready for next. With 600 microseconds of
                              ' step duration, we have 50 microseconds to
                              ' spare:
                              ' 600 (step duration) - 400 (step processing
                              ' time) - 100 (step integration time) -
                              ' 50(step delay) = 50 (spare time).
SENS:PCUR:STEP:TOUT 8e-3      ' Specify 8 milliseconds for step timeout ex-
```

```
                                ' cept first one.
SENS:PCUR:STEP:TOUT:INIT 60     ' Specify 60 seconds for first step timeout.
                                ' Recall for one shot pulse measurement, need
                                ' to have a long initial step timeout since
                                ' want to trigger the 2308 for pulse step mea-
                                ' surement and wait between 3 to 5 seconds be
                                ' fore generating the one shot pulse to guar-
                                ' antee the Model 2308 is waiting for
                                ' detection of first step.
```

Using the same step trigger level for all steps is contained in the following sample. *Table 3-7* contains a sample with the one trigger level (as shown) and also with unique trigger levels for each step.

```
SENS:PCUR:STEP:TLEV1 200e-3     ' Step 1 TLEV value.
SENS:PCUR:STEP:TLEV2 200e-3     ' Step 2 TLEV value.
SENS:PCUR:STEP:TLEV3 200e-3     ' Step 3 TLEV value.
SENS:PCUR:STEP:TLEV4 200e-3     ' Step 4 TLEV value.
SENS:PCUR:STEP:TLEV5 200e-3     ' Step 5 TLEV value.
SENS:PCUR:STEP:TLEV6 200e-3     ' Step 6 TLEV value.
READ:ARR?                       ' Trigger and return the 6 step measurements
```

After sending this command, wait a few seconds before generating a one shot pulse sequence.

Continuous pulse train

NOTE	To function correctly, the current range must be selected before setting the trigger level step setting.

The following command sequence measures pulses similar to the one shown in *Figure 3-10* in a continuous pulse train. The step duration is 600 µsec with a step period of 2 seconds.

```
DISP:CHAN 1                     ' Set active channel - battery.
SENS:CURR:RANG 5                ' Select 5 A current range.
SENS:PCUR:STEP ON               ' Enable step.
SENS:FUNC 'PCUR'                ' Select PCUR function.
SENS:PCUR:STEP:UP 4             ' Specify 4 up steps.
SENS:PCUR:STEP:DOWN 0           ' Specify 0 down steps.
SENS:PCUR:STEP:TIME 100e-6      ' Specify 100 microseconds for step
                                ' integration time.
SENS:PCUR:STEP:DEL 50e-6        ' Specific 50 microseconds for step delay.
                                ' Recall 400 microseconds needed for complet-
                                ' ing previous step measurement and being
                                ' ready for next. With 600 microseconds of
                                ' step duration, we have 50 microseconds to
                                ' spare:
                                ' 600 (step duration) - 400 (step processing
                                ' time) - 100 (step integration time) -
                                ' 50(step delay) = 50 (spare time).
SENS:PCUR:STEP:TOUT 3e-3        ' Specify 3 milliseconds for step
                                ' timeout except for first step. Recall
                                ' timeout needs to be long enough to bypass
                                ' the 600 mA, 300 mA, and 100 mA steps, but not
                                ' so short it misses the 450 mA step (600µsec x
                                ' 3 = 1.8 msec). Using 3 µsec accounts for the
                                ' first step spare time as well.
SENS:PCUR:STEP:TOUT:INIT 3      ' Specify 3 seconds for first step timeout.
                                ' Recall for continuous pulse measurement,
                                ' need to have an initial step timeout long
                                ' enough to bypass the pulse period.
SENS:PCUR:STEP:TLEV1 750e-3     ' Step 1 tlev value.
SENS:PCUR:STEP:TLEV2 400e-3     ' Step 2 tlev value.
SENS:PCUR:STEP:TLEV3 500e-3     ' Step 3 tlev value.
```

```
SENS:PCUR:STEP:TLEV4 625e-3    ' Step 4 tlev value.
READ:ARR?                      ' Trigger and return the 4 step measurements.
```

Section 4

Long Integration Measurements

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Overview

Long integration is an average current measurement of one or more pulses that can be performed on either the battery channel (#1) or the charger channel (#2). The integration time can be as long as 60 seconds. Since long integration is an average measurement, the integration time should be a complete pulse period or an integral number of pulse periods.

Long integration measurements are accomplished by taking an integral number of integration cycles during the total measurement time. An integration cycle is the line cycle period (16.67 ms for 60 Hz) plus a small processing time. The system calculates the number of integration cycles required based on the total time and rounds down to the nearest integer. Therefore, the actual measurement time can be slightly less than the requested measurement time by up to one line cycle time (one cycle is 16.67 ms for 60 Hz and 20 ms for a 50 Hz line frequency. A long integration reading, R_1, is the average of a series of current measurements, m_i, defined by:

$$R_1 = \frac{\sum_{k=1}^{n} m_i}{n}$$

where *n* is an integer given by:

$$n = \text{int}\left\{\frac{I_t}{1\,PLC}\right\}$$

where:

1*PLC* = one power line cycle

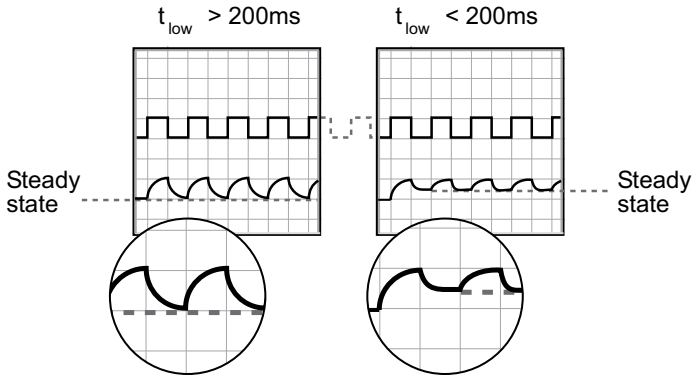
I_t = integration time

Here the integration time specified by the user and denominator represents the integration time of 1 PLC (16.67 msec for 60 Hz or 20 ms for 50 Hz) and processing overhead. The function int rounds the argument down to next lowest integer.

Long integration is a technique to extend the capabilities of the power supply A/D circuit beyond its maximum integration time period. The A/D can measure pulses up to 833 ms. To extend this time period for longer pulses, the long integration technique uses a filtered and sampled measurement of the waveform. This gives the power supply the ability to measure signals with periods up to 60 seconds.

The filtering of the waveform adds some restrictions to the types of pulses being measured. If a pulse train has a high duty cycle, where the off time is less than 200 ms, the first period of the measured waveform will not have settled to steady state, therefore it will be an inaccurate measurement. In all cases where the off or low time is less than 200 ms, the filtered pulse will have reached steady state in the second cycle of the waveform and, therefore, can be accurately measured (*Figure 4-1*). In other words, to measure a periodic waveform with low times less than 200 ms (high duty cycle), start measurements after the first period occurs. This is not a problem for one-shot pulses or for pulses with off times greater than 200 ms.

Figure 4-1
Steady state for waveforms based on low pulse times



Integration time

The integration time period can be set automatically or manually by the user. The integration time can be as long as 60 seconds. For 60 Hz power line frequency, the minimum integration time setting is 850 msec. For 50 Hz power line frequency, the minimum integration setting is 840 msec.

Use AUTO TIME when you want to perform a long integration measurement of each pulse. When the AUTO TIME operation is performed, the instrument measures the time between two rising pulse edges and sets an appropriate integration time that will encompass the high and low periods of the pulse. This integration time applies for all subsequent long integration measurements until another AUTO TIME is performed or the time is changed manually.

If you want the integration period to encompass two or more pulses, you will have to set the integration time manually. However, you must make sure that the integration time covers only the portion of the pulse you want to measure. For example, if you want a long integration of two pulses, you must make sure that the set integration time does not extend into the third pulse.

Trigger edge

A pulse edge can be used to trigger the start of the measurement. Either a rising or a falling pulse edge can start the measurement. A pulse has to be detected before a rising or falling pulse edge can trigger a long integration measurement. All pulses that are less than the specified trigger level are ignored (*Trigger level*). Pulse edges are ignored while a long integration is in process.

A third option is available if you do not want measurements controlled by pulse edges. With NEITHER selected, measurements start as soon as the long integration function is selected. This option does not need a valid trigger level to generate a reading. It will perform a measurement and produce a reading of the current even if a pulse is not present. Therefore, with NEITHER selected, the NO PULSE message will not appear on the display.

Trigger level

Before a rising or falling pulse edge can trigger the start of a long integration, the pulse must first be detected. Trigger level specifies the minimum pulse level that will cause detection. For example, if the trigger level is set for 2 A, pulses that are ≥2 A will be detected. Current pulses <2 A are ignored.

The charger channel has only one trigger level setting for the 5 A current range: 0 A to 5 A. The battery channel (#1) has four trigger level settings (one for each one of the current ranges: 5 A, 500 mA, 50 mA, or 5 mA). For the 5 A current range, the trigger level may be set from 0 A to 5 A. For the 500 mA current range, the trigger level may be set from 0 mA to 500 mA. Similarly, the level setting may be set from 0 mA to 50 mA for the 50 mA current range and from 0 to 5 mA for the 5 mA current range. These settings affect trigger level resolution and are only used when the corresponding current range is selected. The trigger level setting option on the battery channel allows you to set a trigger level with greater resolution.

Pulse timeout

TOUT (timeout) specifies the timeout length for the pulse. When the TOUT value is reached, "NO PULSE" is displayed (top line of the front-panel display). Set the value for TOUT as follows:

TOUT = LINT TIME + x

where x makes TOUT > LINT TIME

TOUT = timeout (time allowed for detection of a pulse)

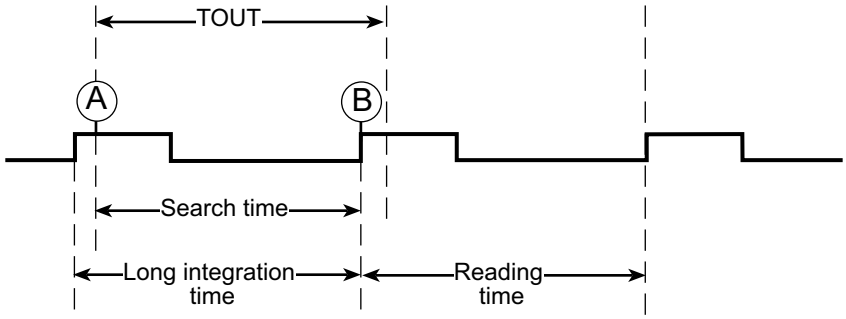
LINT TIME = long integration time (time allowed for reading after pulse occurs)

For example, if the trigger edge is set to rising, the timeout value should be set to allow sufficient time for detection of the pulse if the rising edge is just missed. In *Figure 4-2*, point (A) is the point where we start looking for the pulse. Since the rising edge was just missed, point (B) will be the first detectable rising edge. If the timeout is less than long integration time, a pulse trigger time out (due to TOUT) may occur. Therefore, if long integration time = 1.8 seconds, a good TOUT value would be 2 seconds. A similar method for selecting a TOUT value would be to use a value equal to 105% of the expected pulse period.

Summarizing *Figure 4-2*:

1. Reading begins searching for high pulse at point (A).
2. Earliest pulse detected at point (B).
3. Reading time equals Long integration time.

Figure 4-2
Long integration, search, and reading time comparison



NOTE If a pulse is not present, timeout needs to elapse (TOUT) before "NO PULSE" appears on the display. Search Time needs to elapse when checking TLEV command for valid setting.

PULSE TIMEOUT applies only to long integration measurements that are configured to be triggered by rising or falling pulse edges. After the long integration function is selected, the instrument searches for a pulse. If a pulse is not detected within the specified time (PULSE TIMEOUT), the "NO PULSE" message will be displayed. While the "NO PULSE" message is displayed, the instrument continues to search for a pulse. With a long timeout setting, the instrument may appear locked up while it is searching for the pulse to start the long integration. PULSE TIMEOUT can be set from 1.000 to 63.000 seconds.

With neither trigger edge selected, pulse timeout is not used and a pulse search is not conducted. Therefore, the "NO PULSE" message is never displayed. Measurements start as soon as the long integration function is selected, even if no pulse is present. It is the responsibility of the user to determine if a pulse was present when the measurement was made.

NOTE For GPIB operation:

1. Use `:SEARch` to disable the search for pulses (see the `:SEARch` command in *Table 4-2*).
2. `:FAST` (enables a fast readings mode) can be used with long integration functionality (see the `:FAST command` in *Table 4-2*).
3. `:DETect` may be enabled to only detect pulses between user triggered readings (see the `:DETect` command in *Table 4-2*).
4. See *Using FAST, SEARch, and DETect*.

Measurement configuration

NOTE Current range is selected from the CURRENT RANGE #1/#2 item of the menu. Integration time, trigger edge, trigger level, and pulse timeout are set from the LONG INTEGRAT #1/#2 item of the menu. Details on integration time, trigger edge, trigger level, and pulse timeout are provided in the *Overview*.

Table 1-3 shows the menu structure. Rules to navigate the menu follow the table.

Current range

The instrument will not auto range with the long integration measurement function selected. Changes to the auto range setting are not used during long integration measurements but are retained for when long integration measurements are no longer taken. Long integration measurements may be performed on any of the four ranges for battery channel (#1). Long integration measurements are always performed on the 5 A range for the charger channel (#2). Therefore, selecting long integration with the 5 mA range active will cause the supply to first switch to the 5 A range on the charger channel.

NOTE To get better trigger level resolution, make sure the current range is set appropriately for the expected measurement on the battery channel (#1).

Current range is linked to current limit. Therefore, as a general rule, the user selects the current range before setting the current limit. See *Outputting voltage and current* for details on current range and current limit. Current range is selected from CURRENT RANGE #1/#2 item of the menu (CURRENT RANGE #1 refers to the battery channel (#1) while CURRENT RANGE #2 refers to the charger channel).

Integration time

Use the following items of the LONG INTEGRAT #1/#2 menu item to set the integration time. (LONG INTEGRAT #1 refers to the battery channel (#1) while LONG INTEGRAT #2 refers to the charger channel).

INTEGRATION TIME

Manually set the long integration time. For 60Hz power line frequency, integration time can be set from 850 msec to 60 sec (1 ms step value). For 50Hz power line frequency, integration time can be set from 840 msec to 60 sec (1 ms step value).

AUTO TIME

Use to automatically set the integration time. When the AUTO TIME operation is performed, the instrument measures the time between two rising pulse edges and sets an appropriate integration time that will encompass the high and low periods of a single pulse.

AUTO TIME searches for two consecutive RISING edges (the setting of trigger edge does not affect AUTO TIME). Therefore, with NEITHER edge set, the PTT (Pulse Trigger Timeout) bits in the status model may get set (see *Section 7* on the status model for more information). Although

Auto Time does not use the user setting for trigger edge, the user setting for edge will be used for trigger commands (For example, *READ?* and *MEASure?*).

Pulse timeout

Use the PULSE TIMEOUT item of the LONG INTEGRAT #1/#2 menu item to set pulse timeout (LONG INTEGRAT #1 refers to the battery channel (#1) while LONG INTEGRAT #2 refers to the charger channel (#2)).

Set pulse timeout (from 1 to 63 seconds) for long integration measurements that are configured to be triggered by RISING or FALLING pulse edges. If a pulse is not detected within the specified time (PULSE TIMEOUT), the "NO PULSE" message will be displayed. While the "NO PULSE" message is displayed, the instrument continues to search for a pulse. With NEITHER edge selected, the PULSE TIMEOUT setting is inactive.

Trigger edge and trigger level

Use the following items of the LONG INTEGRAT#1/#2 menu item to set trigger edge, and trigger level (LONG INTEGRAT #1 refers to the battery channel (#1) while LONG INTEGRAT #2 refers to the charger channel (#2)).

Trigger edge

A pulse edge can be used to trigger the start of the measurement (TRIGGER EDGE). Select RISING to use a rising pulse edge to start the measurement. Select FALLING to use a falling pulse edge to start the measurement. A third option is available if you do not want measurements controlled by pulse edges. With NEITHER selected, measurements will start as soon as the long integration function is selected. A pulse has to be detected before a RISING or FALLING pulse edge can trigger a long integration measurement (see *Trigger level*).

Trigger level

Before a RISING or FALLING pulse edge can trigger the start of a long integration, the pulse must first be detected. TRIGGER LEVEL specifies the minimum pulse level that will cause detection on the selected current range. For the battery channel (#1), any current range is acceptable and the trigger level setting corresponding to the selected current range will be used to detect the pulse. For the charger channel only, the 5 A range is used.

For battery channel (#1) - The trigger level can be set for either the 5 A, 500 mA, 50 mA, or 5 mA current range. For the 5 A current range, the trigger level can be set from 0 to 5A in 5 mA steps. For the current 500 mA range, the trigger level can be set from 0 to 500 mA in 0.5 mA steps. For the current 50 mA range, the trigger level can be set from 0 to 50 mA in 0.05 mA steps. For the 5 mA current range, the trigger level can be set from 0 mA to 5 mA in 0.005 mA steps.

The four trigger level ranges are displayed as follows using the TRIGGER LEVEL menu option:

5 A range:	PCUR TRIG LEV #1
	A(5.0) 0.000 A
500 mA range:	PCUR TRIG LEV #1
	A(500) 0.0000 A
50 mA range:	PCUR TRIG LEV #1
	mA (50) 0.00000A
5 mA range:	PCUR TRIG LEV #1
	mA (5) 0.000000A

To toggle the current range for the trigger level setting, place the blinking cursor on the "A" at the far right end of line two of the display, and press the ▲ and ▼ keys. After keying in the trigger level (in amps), press **ENTER** to update the displayed range for that trigger level setting only.

Charger channel (#2) - Set the trigger level from 0 to 5 A in 5 mA steps.

Long integration display mode

Long integration measurements are displayed with the long integration display mode selected.

To display Long Integration mode:

NOTE	If the instrument is in the settings mode, press the **SET** key until the blinking stops (the measured readings can then be displayed). To determine if the instrument is in the settings mode, check for a blinking cursor in a digit of the voltage or current field (if present, the instrument is in the setting mode).

1. Press the **DISPLAY** key to access the display menu.
2. Press the ◄ or ► keys to select channel **#1** or **#2**.
3. Press the ▲ or ▼ keys to scroll to **LONG INTEGRATION**.
4. Press **ENTER** to select.

NOTE	For details on display modes, see *Display modes* .

Long integration measurement procedure

The following steps summarize the procedure to perform long integration current measurements:

1. Follow the instructions in *Editing output voltage and current limit values* to set the output voltage and current limit.
2. When using the battery channel (#1), select the desired current level range (5 A, 500 mA, 50 mA, or 5 mA) from the CURRENT RANGE #1 menu. For battery channel (#1), long integration measurements may be performed on any of the four current ranges. As the current range changes, the trigger level setting will update automatically with the corresponding trigger level setting to detect pulses. For the charger channel, long integration measurements are automatically performed on the 5 A current range.
3. Press **OPERATE**.

NOTE	Setting the trigger level with the output off will also cause the pulse timeout message to appear. However, the trigger level will be set.

4. From the LONG INTEGRAT #1/#2 item of the menu, set **INTEGRATION TIME**, **PULSE TIMEOUT**, **TRIGGER EDGE** and **TRIGGER LEVEL** as appropriate (LONG INTEGRAT #1 refers to the battery channel (#1) while LONG INTEGRAT #2 refers to the charger channel

(#2)). If using the battery channel (#1), make sure to set the trigger level for the current range selected in step 2.

NOTE	If you select AUTO TIME to set the integration time, the pulse timeout message LONG INT TRIG NOT DETECTED will occur if the output is OFF. This message indicates that the integration time has not been updated. To update the integration time, you will have to again select AUTO TIME after the output is turned ON.

5. Press the **DISPLAY** key.
6. Press the ▲ or ▼ keys to scroll to **LONG INTEGRATION**.
7. Press **ENTER** to select.
8. Observe the long integration readings on the display.

General notes

Long integration readings will not be taken if the active channel is not the same as the selected channel. For example, if the battery channel (#1) is set to LINT and the active channel is the charger channel (#2) then, long integration readings will not be taken on the battery channel (#1). Therefore, while the charger channel (#2) is active with the LINT function selected on the battery channel (#1), you will not incur the LINT integration time or LINT timeout from the battery channel (#1) while waiting for responses from the charger channel (#2). Since no long integration readings are being taken, you will not get any information on whether the pulse is present or not on the battery channel (#1).

- Make sure the voltage and current settings are appropriate for DUT.
- If a pulse timeout occurs (no pulses detected), current will not be measured (i.e. ----A) and the NO PULSE message will be displayed. Pulses are not detected with the output OFF. With the output ON, pulses will not be detected if the trigger level is too low or too high. Perform the *Determining correct trigger level (long integration)* procedure to find an appropriate trigger level.
- While the NO PULSE message is displayed, the instrument continues to search for a pulse. The search can be terminated by pressing any front-panel key. The NOT TRIG message replaces the NO PULSE message. To restart the search, press ▲ or ▼ keys while displaying long integration readings. The timeout or pulse detection will need to elapse before the display changes.
- To stop taking long integration readings, press any front-panel key. As long as the instrument remains in the long integration display state, the measurement process can be resumed by pressing ▲ or ▼ keys. While readings are not being taken, the bottom line displays the last valid long integration reading, or dashes if no pulse detected before being stopped.

Determining correct trigger level (long integration)

1. After selecting the appropriate voltage and current values, turn on the output.
2. Follow instructions in *Long integration display mode* to select the long integration display type.

NOTE	If the trigger level is too low or too high, the "NO PULSE" message will be displayed. If long integration measurements are instead being displayed, the trigger level is valid. You can skip the rest of this procedure.

3. Go into the main menu (press the **MENU** key twice - the first press will stop the readings while the second press accesses the menu). Select **LONG INTEGRAT #1/#2** (select **LONG INTEGRAT #1** for the battery channel (#1) and **LONG INTEGRAT #2** for the charger channel (#2)).
4. Select and adjust the **TRIGGER LEVEL** and press **ENTER**. The unit starts looking for the rising edge of the pulse (this is regardless of the trigger edge setting). If the trigger level is still too low or too high, the LONG INT TRIG NOT DETECTED message will be displayed briefly. Note that it may take as long as the timeout value for the message to appear (see *LONG INT TRIG NOT DETECTED message* for more information).
5. If the message appeared, repeat step 4 until a valid trigger level is found.
6. Press the **MENU** key to exit the menu structure and display long integration current measurements.

NOTE For the battery channel (#1), make sure the current range setting agrees with the trigger level setting set in Step 4.

LONG INT TRIG NOT DETECTED message

The TRIG NOT DETECTED message is possibly displayed when specific TLEV settings coupled with specific current ranges have been set and a trigger has not been detected. Refer to *Table 4-1* for message preconditions.

See *Long integration measurement procedure* for information on setting the current range.

Table 4-1
TRIG NOT DETECTED message

TLEV setting	Current range	TRIG NOT DETECTED Message displayed?
90 mA for 500 mA current range	5 mA	No (not checked because TLEV setting does not match current range)
90 mA for 500 mA current range	50 mA	No (not checked because TLEV setting does not match current range)
0.75 A for 5 A current range	5 A	May appear*
0.1 A for 500 mA current range	500 mA	May appear*
3.0 A for 5 A current range	5 A	May appear*
0.03 A for 50 mA current range	50 mA	May appear*
0.003 A for 5 mA current range	5 mA	May appear*
1.1 A for 5 A current range	5 mA	No (not checked because TLEV setting does not match current range)
1.1 A for 5 A current range	500 mA	No (not checked because TLEV setting does not match current range)

*Depends upon the OUTPUT:
If OFF, the message will appear.
If ON, display of the message will depend on the trigger level setting. If trigger level setting greater than the expected low measurement and less than the expected high measurement, the message will not appear.
For example, if the expected pulse high value is 2.2 A and the expected pulse low value is 0.5 A, the output is on, and the current range is 5 A, notice the following results:
Setting 0.3 A TRIG NOT DETECTED is displayed (setting too low).
Setting 3.0 A TRIG NOT DETECTED is displayed (setting too high).
Setting 1.1 A The message will not display (setting correct).

NOTE Setting the trigger level and/or the current range may cause LONG INT TRIG NOT DETECTED to appear.

SCPI programming

The commands for long integration measurements are summarized in *Table 4-2* (a listing following the table contains specific command notes). *Programming examples* demonstrate how to use these commands.

Table 4-2
SCPI commands - long integration measurements

Command	Description	Default
:SENSe[1]	SENSe subsystem for battery channel (#1):	
:FUNCtion "LINTegration"	Select long integration measurement function.	VOLT
:LINTegration	Long integration configuration:	
:TIME <NRf>	Set integration time (in sec): X to 60 (where X is 0.850 for 60Hz, or 0.840 for 50Hz).	1
:AUTO	Integration time set automatically.	
:TLEVel <NRf>	Path to set trigger level feature:	
[:AMP] <NRf>	Set the trigger level in amps for use when on the 5A current range: 0.0 A-5.0 A in 5 mA steps	0.0
:HUNDred <NRf>	Set the trigger level in amps for use when on the 500mA current range: 0.0 mA-500 mA in 0.5 mA or 500 μA steps.	0.0
:FIFTy <NRf>	Set the trigger level in amps for use when on the 50mA current range: 0.0 mA-50 mA in 0.05 mA or 50μA steps.	0.0
:FIVE <NRf>	Set the trigger level in amps for use when on the 5 mA current range: 0.0 mA-5 mA in 0.005 mA or 5 μA steps.	0.0
:TEDGe <name>	Select trigger edge to initiate the measurement: RISING, FALLING, or NEITHER.	RISING
:TimeOUT <NRf>	Specify length of timeout: 1–63 (sec).	16
:SEARch <b>	Enable or disable pulse search.	ON
:FAST <b>	Enable or disable long integrations fast readings.	OFF
:DETect <b>	Enable or disable pulse detection mode.	OFF
:SENSe2	SENSe subsystem for the charger channel (#2):	
:FUNCtion "LINTegration"	Select long integration measurement function.	VOLT
:LINTegration	Long integration configuration:	
:TIME <NRf>	Set integration time (in sec): X to 60 (where X is 0.850 for 60Hz, or 0.840 for 50Hz).	1
:AUTO	Integration time set automatically.	
:TLEVel <NRf>	Set trigger level in amps: 0–5 (5mA resolution).	0.0

Table 4-2
SCPI commands - long integration measurements

Command	Description	Default
:TEDGe <name>	Select trigger edge to initiate the measurement: RISING, FALLING, or NEITHER.	RISING
:TimeOUT <NRf>	Specify length of timeout: 1–63 (sec).	16
:SEARch <b>	Enable or disable pulse search.	ON
:FAST <b>	Enable or disable long integrations fast readings.	OFF
:DETect <b>	Enable or disable pulse detection mode.	OFF
READ[1]?	Trigger and return one reading for battery channel (#1).	
READ2?	Trigger and return one reading for charger channel (#2).	

Command notes (long integration measurements)

```
SENSe[1]:FUNCtion 'LINTegration'        Applies to battery channel (#1)
SENSe2:FUNCtion 'LINTegration'          Applies to charger channel (#2 )
```

The parameter name can be enclosed in single or double quotes (single - shown above, double - shown in *Table 4-2*).

```
SENSe[1]:LINTegration:SEARch <b>        Applies to battery channel (#1)
SENSe2:LINTegration:SEARch <b>          Applies to charger channel (#2 )
```

Refer to *Using FAST, SEARch, and DETect* for detailed usage information.

```
SENSe[1]:LINTegration:FAST <b>          Applies to battery channel (#1)
SENSe2:LINTegration:FAST <b>            Applies to charger channel (#2 )
```

Refer to *Using FAST, SEARch, and DETect* for detailed usage information.

```
SENSe[1]:LINTegration:DETect <b>        Applies to battery channel (#1)
SENSe2:LINTegration:DETect <b>          Applies to charger channel (#2 )
```

Refer to *Using FAST, SEARch, and DETect* for detailed usage information.

```
READ[1]?                                Applies to battery channel (#1)
READ2?                                  Applies to charger channel (#2 )
```

After sending a trigger reading command to perform long integration measurements, do not address the power supply to talk until all readings are completed. Details on `READ?` and the other signal-oriented measurement commands are provided in *Section 9*.

Using FAST, SEARch, and DETect

Use the `FAST` command to have the quickest response for pulse current measurements triggered by the measurement commands (for example, `MEASure`, `READ`, or `*TRG`). Note that when you use the `FAST` command, there is no indication that the instrument is correctly configured for detecting pulses until a measurement command is sent. When the trigger level is set, use the `SEARch` command to retain quick responses to measurement commands and to ensure that the instrument is configured correctly for detecting pulses. Use the `DETect` command to ensure that the unit is configured correctly and can read the pulse before sending a measurement command.

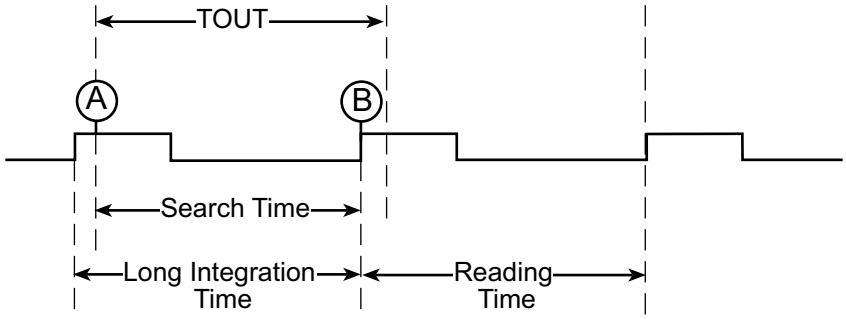
Use FAST, SEARch, and DETect to control how background readings are taken. A background reading is a measurement taken by the power supply between user triggered readings. The selected function dictates how background readings are taken between user triggered readings.

For long integration, a background reading involves looking for the pulse and optionally generating a reading for the user. The various settings of SEARch, FAST, and DETect allow the user to fine tune the function. This enables the function to perform the desired background readings (if any) between user triggered readings. The default settings (FAST:OFF, SEARch:ON, and DETect:OFF) allow the long integration background readings to be taken. If no pulse is present, the setting of TimeOUT affects how responsive the supply is to bus commands. If a pulse is present, the search time plus reading time (TIME setting) affects how responsive the supply is to bus commands (refer to *Figure 4-3*). *Table 4-3* contains the available settings for FAST, SEARch, and DETect commands and a description of the resulting action. For more information on search time, reading time, and TimeOUT, see *Pulse timeout* .

NOTE

- If a pulse is not present, timeout needs to elapse (TOUT).
- If DETECT ON (only), search time needs to elapse before responding to a bus command (reading time not incurred).
- If SEARCH OFF or FAST ON, search time and reading time not incurred.

Figure 4-3
TOUT and search time



NOTE Search time needs to elapse when checking TLEV command for valid setting.

Table 4-3
FAST, SEARch, and DETect command reference

FAST	SEARch	DETect	Description
ON ON ON ON	ON ON OFF OFF	ON OFF ON OFF	The unit is most responsive to bus commands in this mode. The supply does not wait for TOUT or search time plus reading time for background readings and TLEV command checks. Refer to *Figure 4-3*. front panel displays "FAST LINT" instead of "LONG INT". With FAST set to ON, no background long integration measurements occur, no pulse detection between user-triggered readings occur, no checking for the parameter of LINT TLEV commands to detect a pulse occur, no setting of the pulse trigger timeout bits in the status model between user-triggered readings occur. For triggered readings to set the PTT (Pulse Trigger Timeout) bits in the status model, set TEDGe to be RISING or FALLING. If TEDGe is set to NEITHER, the PTT will not be set after the initial setting of FAST to ON and TEDGe to NEITHER. The setting of NEITHER specifies no pulse edge for synchronization or detection. The bit is latched until read so the bit may still be set in the status model from a previous timeout (see *Section 7* on the status model for more information).
OFF OFF	OFF OFF	ON OFF	The unit is more responsive to bus commands in this mode since the supply does not need to wait for TOUT or search time plus reading time for background readings. However, the supply does need to wait for TOUT or search time when checking the parameter setting for TLEV commands. Refer to *Figure 4-3*. front panel displays "NO SEARCH" instead of "LONG INT". Although no background long integration measurements or pulse detection between user-triggered readings will occur, the checking for the parameter of LINT TLEV commands to detect a pulse will occur. The setting of the pulse trigger timeout bits in the status model will only occur between user-triggered readings if TLEV commands sent. This is regardless of the TEDGe setting since the RISING edge is used for this feature. For triggered readings to set the PTT (Pulse Trigger Timeout) bits in the status model, the TEDGe setting needs to be RISING or FALLING. If TEDGe is set to NEITHER, the PTT will not be set after the initial setting of SEARch to OFF and TEDGe to NEITHER. The setting of NEITHER specifies no pulse edge for synchronization or detection. The bit is latched until read so the bit may still be set in the status model from a previous timeout (see *Section 7* on the Status model for more information).

Shaded cells designate command with precedence in each mode.

Table 4-3
FAST, SEARch, and DETect command reference

FAST	SEARch	DETect	Description
OFF	ON	ON	This mode allows the user to know whether the pulse disappeared before a user-triggered reading is requested. The responsiveness of bus commands is governed by LINT TOUT (if no pulses are detected), or by search time (if pulses are detected). Reading time does not have to elapse after detecting the pulse in this mode. Therefore, the longest response time to bus commands is approximately the greater of either TOUT or search time values. Refer to *Figure 4-3*. With DETect ON, no background long integration measurements will occur between user-triggered readings but pulse detection occurs. If the pulse is detected, the front panel will display DETECT on top line of display instead of LONG INT. If no pulses are detected, the front panel will display NO DETECT as well as the PTT (Pulse Trigger Timeout) bit being set in the status model. Since the PTT bit is latched (see *Section 7* on Status Model), a query for the PTT bit may indicate that pulse trigger timeout occurred although the display is showing DETECT. The checking for the parameter of LINT TLEV commands will occur which may set the PTT bit since looking for a rising edge. This functionality occurs if TEDGe is set to RISING or FALLING. If TEDGe is set to NEITHER, pulse detection will fail since synchronization to an edge for triggering does not occur (there is nothing for the unit to detect). In this mode, the DETECT/NO DETECT on the front panel is not reliable and the setting of the PTT bit of the status model will not happen. Since checking for the parameter of LINT TLEV commands to detect a pulse looks for the RISING edge, this will occur and may set the PTT bit of the status model.
OFF	ON	OFF	With DETect OFF, background long integration measurements will occur between user-triggered readings as well as pulse detection. If the pulse is detected, the front panel will display LONG INT on top line of display along with the reading on the bottom line. If no pulses are detected, the front panel will display NO PULSE as well as the PTT (Pulse Trigger Timeout) bit being set in the status model. Since the PTT bit is latched (see *Section 7* on Status Model), a query for the PTT bit may indicate that pulse trigger timeout occurred although the display is displaying LONG INT and a reading. Checking for the parameter of LINT TLEV commands to detect a pulse occurs by looking for a rising edge. This may set the PTT bit. If detecting pulses, the supply's responsiveness to bus commands is affected by search time plus reading time. If not detecting pulses, the supply's responsiveness to bus commands is affected by TOUT. Therefore the longest response time to bus commands is approximately the greater of either TOUT or search time plus reading time (refer *Figure 4-3*). This functionality occurs if TEDGe is set to RISING or FALLING. If TEDGe is set to NEITHER, pulse detection will fail since synchronization to an edge for triggering does not occur (there is nothing for the unit to detect). In this mode, the front panel will show LONG INT on the top line with a reading on the bottom. The user will have to determine if the pulse was present for the reading or not. In this mode, the PTT bit of the status model will not be set as well and therefore, not useful. Since checking the parameter of LINT TLEV commands to detect a pulse looks for the RISING edge, this may set the PTT bit of the status model if TLEV setting causes no rising edge pulse detection.

Shaded cells designate command with precedence in each mode.

Programming examples

Battery channel (#1)

```
DISP:CHAN 1                    ' Sets display to battery channel.
SENS:CURR:RANG 300e-3          ' Select 500 mA range.
VOLT 15                        ' Set output voltage to 15 V.
CURR 0.75                      ' Set current limit to 750 mA.
OUTP ON                        ' Turn output on.
SENS:LINT:TLEV:HUND 0.1        ' Set trigger level to 100 mA for 500 mA trigger level range.
SENS:LINT:TEDG RISING          ' Select rising trigger edge to initiate measurement.
SENS:LINT:TIME:AUTO            ' Set integration time automatically for single pulse.
SENS:FUNC "LINT"               ' Select long integration function.
READ?                          ' Trigger and return one reading and reading shown on display.
```

Charger channel (#2)

```
DISP:CHAN 2                    ' Sets display to charger channel.
SENS2:CURR:RANG 5              ' Select 5 A range.
SOUR2:VOLT 15                  ' Set output voltage to 15 V.
SOUR2:CURR 0.75                ' Set current limit to 750 mA.
OUTP2 ON                       ' Turn output on.
SENS2:LINT:TEDge RISING        ' Select rising trigger edge to initiate
                               ' measurement.
SENS2:LINT:TLEV 0.1            ' Set trigger level to 100 mA.
SENS2:LINT:TIME:AUTO           ' Set integration time automatically for single pulse.
SENS2:FUNC "LINT"              ' Select long integration function.
READ2?                         ' Trigger and return one reading and reading shown on display
```

Section 5

Relay Control

In this section:

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Controlling relays	5-4
SCPI programming	5-5

Overview

Model 2308 can be used to control up to four external relays. The control circuit is made up of four peripheral drivers: A +5VDC source (250 mADC maximum), a coil diode suppression connection, and a chassis ground return. The drive for the relay may be provided by the supplied +5VDC source or an external DC voltage source.

Figure 5-1 shows the simplified power supply control circuit and a typical configuration to control an external relay driven by an external power source. As shown in the illustration, voltage applied to the power supply must not exceed 24VDC and current for the relay circuit must not exceed 100mADC per channel.

Figure 5-2 shows the simplified power supply control circuit and a typical configuration to control an external relay driven by the internal power source. If the supplied +5VDC source is used to drive the external relay, the relay circuit must not exceed 250mADC total (100 mADC per channel).

Note that the coil protection diodes are built in to the power supply driver (the user is not required to add external protection diodes to protect the relay coils).

CAUTION To prevent damage to the power supply that is not covered by the warranty, always make sure to:

Connect suppression diodes (pin 7) to the appropriate voltage source (the appropriate voltage source will either be an external power source or pin 8 if using the internal source).

Never exceed the voltage and current limits of the power supply's relay control port:

External Source: 24VDC, 100 mA per channel

Internal source:

1. 5 VDC, 250 mA maximum total current from all channels combined.
2. 100 mA per channel maximum (not to exceed the 250 mA maximum total current).

Connect and disconnect relay drive circuits with the power supply power OFF.

Figure 5-1
External source relay control

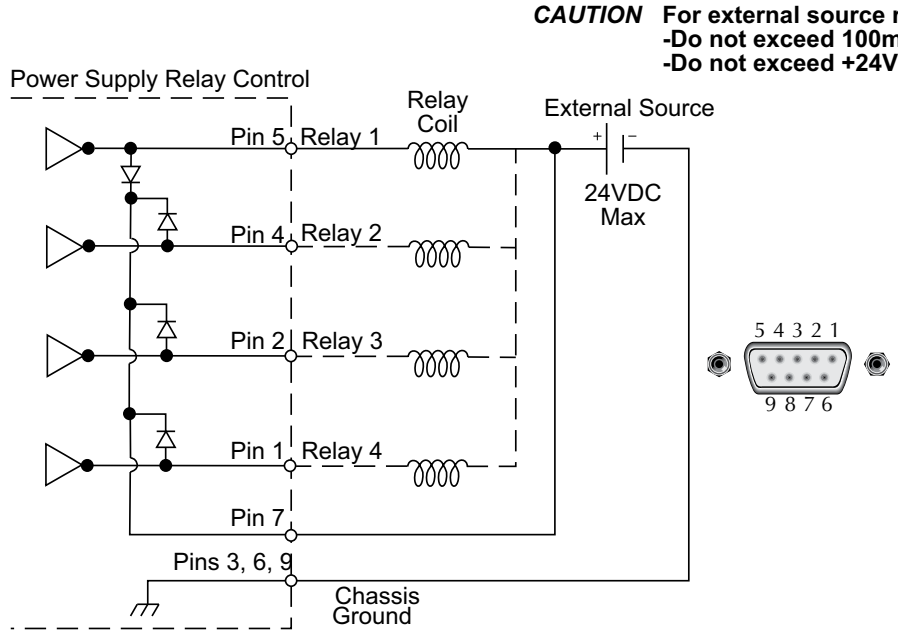
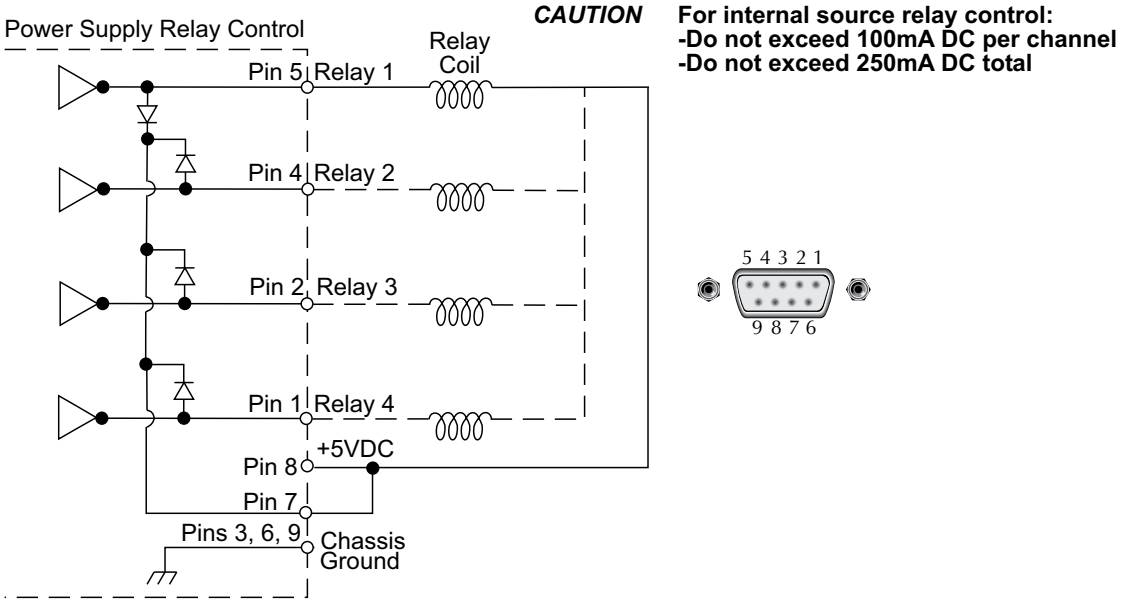


Figure 5-2
Internal source relay control



Connections

An external relay circuit is connected to the power supply via the 9-pin D-SUB connector located on the rear panel. *Table 5-1* contains pinouts and connections for this connector. The illustration provides terminal identification for the conductors of the plug.

Figure 5-3
Relay connector (9-pin D-sub)

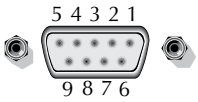


Table 5-1
Relay pinouts (for *Figure 5-3*)

Pin	Connection
1	Relay 4
2	Relay 3
3	Ground
4	Relay 2
5	Relay 1
6	Ground
7	Suppression diodes
8	+5 VDC
9	Ground

Controlling relays

The external relays (whether powered by the external or internal source) are controlled from the main menus OUTPUT RELAYS menu item (the main menu is accessed by pressing the **MENU** key). Each of the four output relays can be controlled from this menu.

NOTE *Table 1-3* shows the menu structure. Rules to navigate the menu follow the table.

Pressing the **ENTER** key accepts the current configuration; pressing the **MENU** key cancels the changes and recalls the previous settings.

Setting a relay (1–4) to a 1 closes the relay control circuit (energizes the relay). A 0 opens the circuit (de-energizes the relay).

1. Press the **MENU** key.
2. Press ▲ or ▼ keys to scroll to **OUTPUT RELAYS**.
3. Press **ENTER** to select.
4. Use the ◄ or ► keys to move the blinking cursor through the available relays (1: 2: 3: & 4:). Immediately following the relay number and colon is the relay control option. Set the relay control options for each relay to a 1 or 0. Selecting a 1 closes the relay control circuit to energize the relay; selecting a 0 opens the circuit to de-energize the relay.
5. Use the ▲ and ▼ arrow key to toggle the blinking cursor's value between 1 (close) or zero (open).

6. Repeat steps 2 and 3 to set the relays as desired.
7. Save the changes for all four relays (press the **ENTER** key located on the front panel).

NOTE	To cancel changes made, press the **MENU** key (this sets the instrument back to the last saved changes). Changes must be canceled before pressing **ENTER**.

All relays open (sample)

```
  OUTPUT RELAYS
1:0 2:0 3:0 4:0
```

Relays 1 and 2 closed and 3 and 4 open (sample).

```
  OUTPUT RELAYS
1:1 2:1 3:0 4:0
```

SCPI programming

Table 5-2 summarizes output relay command controls.

Table 5-2
SCPI command - output relay control

Command	Description	Default
OUTPut[1]	OUTPut subsystem from battery channel (#1):	
:RELay1 <name>	Close (1) or open (0) relay control circuit for relay 1.	ZERO
:RELay2 <name>	Close (1) or open (0) relay control circuit for relay 2.	ZERO
:RELay3 <name>	Close (1) or open (0) relay control circuit for relay 3.	ZERO
:RELay4 <name>	Close (1) or open (0) relay control circuit for relay 4.	ZERO

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Section 6

GPIB Operation

In this section:

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Introduction

The GPIB bus is the IEEE-488 instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975. Model 2308 conforms to these standards:

- IEEE-488-1987.1
- IEEE-488-1987.2

These standards define a syntax for sending data to and from instruments, how the instrument interprets this data, what registers should exist to record the state of the instrument, and a group of common commands.

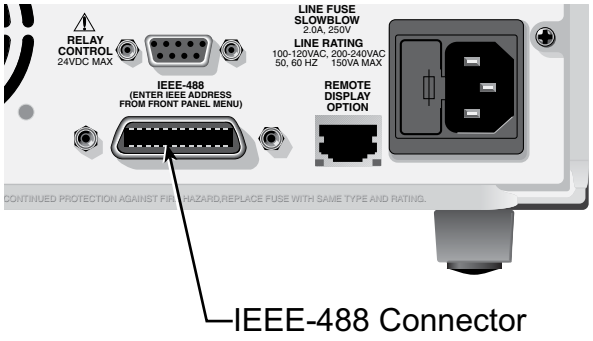
- SCPI 1995.0 (Standard Commands for Programmable Instruments)

This standard defines a command language protocol. It goes one step further than IEEE-488-1987.2 and defines a standard set of commands to control every programmable aspect of the instrument.

GPIB bus connections

To connect the power supply to the GPIB bus, use a cable equipped with standard IEEE-488 connectors. The IEEE connector on the power supply is shown in *Figure 6-1*.

Figure 6-1
IEEE-488 connector



NOTE	To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. Available shielded cables from Keithley Instruments are Models 7007-1 and 7007-2.

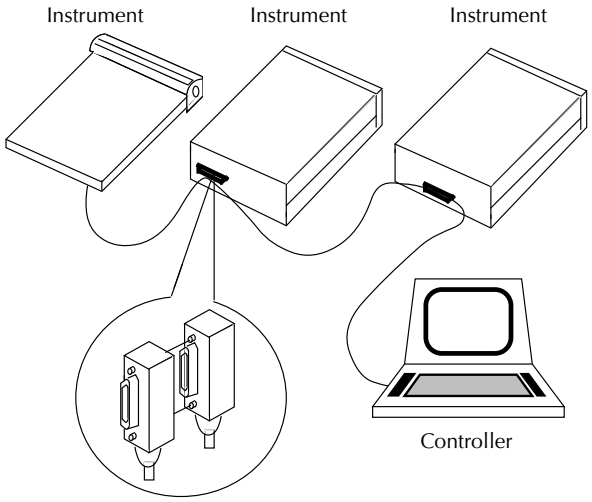
For a multi-unit test system, you can daisy-chain the instruments to the controller by connecting an IEEE cable from one unit to another. *Figure 6-2* shows a typical multi-unit connecting scheme daisy chaining. Although any number of connectors could be stacked on one instrument's GPIB port, avoid possible mechanical damage by not stacking more than three.

Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. See the controller's instruction manual if it is not equipped with an IEEE-488 style connector.

CAUTION The IEEE-488 connector on the interface accepts metric screws. Do not use early versions of IEEE-488 cables that do not use metric screws to secure connections. On the GPIB cable connectors, metric screws are dark colored while non-metric screws are silver colored.

NOTE Daisy chaining (*Figure 6-2*) is recommended when installing multi-unit connecting schemes.

Figure 6-2
Daisy chaining



NOTE Observe the following limits concerning the IEEE-488 bus:

- There can be a maximum separation of 4 meters between any two instruments on the bus.
- Make sure the maximum cable length used is the lesser of 20 meters, or 2 meters multiplied by the number of devices.
- Limit the number of instruments on the bus to 15 (maximum) with no two instruments having the same address.

Primary address

Model 2308 ships from the factory with a GPIB address of 16. You can set the address to a value of 0 to 30. Do not assign the same address to another device or to a controller that is on the same GPIB bus.

The GPIB address is checked and/or changed from the menu (which is accessed by pressing the **MENU** key).

NOTE	See *Table 1-3* for an illustration of the menu structure. Rules to navigate the menu follow the table.

Once in the menu, select **GPIB ADDRESS**. After setting the address value, make sure you press **ENTER** to select it.

NOTE	The present address is displayed on power-up on the top line of the display.

Setting the GPIB timeout for responses

When using GPIB to control the power supply, make sure to set the GPIB timeout for responses. The appropriate setting is dependent on the power supply configuration. The GPIB timeout for responses is the duration the computer waits before timing out after sending a request.

Example

Command	Description
`READ?`	Requests power supply to trigger a reading for the selected function on the battery channel (#1).
Programming language specific	Request power supply talk.

Once the request for the response is made, the "GPIB timeout for responses" activates. "GPIB timeout for responses" is set in milliseconds (1/1000sec).

Long integration readings

When taking long integration readings, make sure to set the timeout value longer than the integration time. For example, if the integration period is 15 seconds, set the "GPIB timeout for responses" to a value greater than 15000. Setting the "GPIB timeout for responses" greater than the integration time ensures that a GPIB timeout does not occur while the Model 2308 is integrating the reading. The GPIB timeout may need to be set to a value greater than twice the long integration time for cases where the triggered edge was just missed (refer to *Figure 4-2*).

Pulse current readings

When taking a pulse current low readings with a low time of 500ms and a pulse average of 50, the integration will take 25 seconds. Because the integration period is 25 seconds, set the "GPIB timeout for responses" to a value greater than 25000. Setting timeout when taking pulse current high and pulse current average readings is similar.

MAV (Message Available Bit)

The MAV is an alternative to setting the GPIB timeout for responses. The MAV is the message available bit of the status register. Enabling the MAV bit causes an SRQ to occur when the instrument has a message to send to the computer.

When using the MAV, two additional commands are required `*SRE 16` and the command that waits for SRQ (specific to programming language).

Example

Command	Description
`*SRE 16`	Sets the MAV bit to enable. This command is required before the sending `READ?` command.
`READ?`	Requests power supply to trigger a reading for the selected function on the battery channel (#1).
Programming language specific	Wait for SRQ.
Programming language specific	Request power supply to talk.

General bus commands

General bus commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. *Table 6-1* lists applicable general bus commands.

Table 6-1
General bus commands

Command	Effect on power supply
`REN`	Goes into remote when next addressed to listen.
`IFC`	Reset interface; all devices go into talker and listener idle states.
`LLO`	Local key locked out.
`GTL`	Cancel remote; restore front-panel operation for the power supply.
`DCL`	Return all devices to known conditions.
`SDC`	Returns power supply to known conditions.
`GET`	Initiates a trigger.
`SPE, SPD`	Serial polls the power supply.

REN (remote enable)

The remote enable command is sent to the power supply by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true does not actually place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote.

Note that the instrument does not have to be in remote to be a talker.

Also, note that all front-panel controls except for LOCAL and POWER are inoperative while the instrument is in remote. You can restore normal front-panel operation by pressing the **LOCAL** key.

IFC (interface clear)

The IFC command is sent by the controller to place all instruments on the bus in the local, talker, listener idle states. The power supply responds to the IFC command by canceling TALK or LSTN mode, if the instrument was previously placed in one of those states. Note that this command does not affect the status of the instrument; settings, data, and event registers are not changed.

To send the IFC command, the controller must set the IFC line true for a minimum of 100µs.

LLO (local lockout)

Use the LLO command to prevent local operation of the instrument. After the unit receives LLO, all its front-panel controls except POWER are inoperative. In this state, pressing the **LOCAL** key will not restore control to the front panel. The GTL command restores control to the front panel.

GTL (go to local)

Use the GTL command to put a remote mode instrument into local mode. The GTL command also restores front-panel key operation.

DCL (device clear)

Use the DCL command to clear the GPIB interface and return it to a known state. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously.

When the power supply receives a DCL command, it clears the input buffer and output queue, cancels deferred commands, and clears any command that prevents the processing of any other device command. A DCL does not affect instrument settings and stored data.

SDC (selective device clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL.

GET (group execute trigger)

GET is a GPIB trigger that is used as an event to control operation. The power supply reacts to this trigger if it is the programmed control source.

SPE, SPD (serial polling)

Use the serial polling sequence to obtain the power supply serial poll byte. The serial poll byte contains important information about internal functions. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the power supply.

Front panel aspects of GPIB operation

The following paragraphs describe aspects of the front panel and remote panel that are part of GPIB operation, including the remote operation indicator, **LOCAL** key, and messages.

Remote indicator and LOCAL key

When the power supply is in the remote state, the "R" character is displayed in the bottom right corner of the display. It blinks as a solid block character. "R" does not necessarily indicate the state of the REM line, as the instrument must be addressed to listen with REM true before the "R" indicator turns on.

When the instrument is in the remote state, all front-panel keys, except for the LOCAL key, are locked out. The LOCAL key cancels the remote state and restores local operation of the instrument. Pressing the LOCAL key also turns off the "R" indicator and returns the display to normal if a user-defined message was displayed.

If the LLO (local lockout) command is in effect, the LOCAL key is also inoperative.

Error and status messages

See *Appendix A* for a list of error and status messages associated with IEEE-488 programming. The instrument can be programmed to generate an SRQ, and command queries can be performed to check for specific error conditions.

Programming syntax

The information in the following paragraphs covers syntax for both common commands and SCPI commands. For information not covered here, refer to *Section 8* for common commands or to *Section 11* for SCPI commands. Also refer the IEEE-488.2 and SCPI standards.

Command words

Program messages are made up of one or more command words and parameters.

Commands and command parameters

Common commands and SCPI commands may or may not use a parameter. The following are some examples:

*SAV <NRf>	Parameter (NRf) required
*RST	No parameter used
:DISPlay:TEXT:STATe <b>	Parameter <b> required
:STATus:PRESet	No parameter used.

Put at least one space between the command word and the parameter.

Brackets [ ] - Some command words are enclosed in brackets ([ ]). These brackets are used to denote an optional command word that does not need to be included in the program message. For example:

```
:FORMat[:DATA]?
```

These brackets indicate that `:DATA` is implied (optional) and does not have to be used. Thus, the above command can be sent as `:FORMat?` or `:FORMat:DATA?`.

Notice that the optional command is used without the brackets. When using optional command words in your program, do not include the brackets.

Parameter types - The following are some of the more common parameter types:

- <b> Boolean - Used to enable or disable an instrument operation. 0 or OFF disables the operation, and 1 or ON enables the operation.
  Example:

`:DISPlay:TEXT:STATe` ON Enable text message mode of display.

• <name> Name parameter - Select a parameter name from a listed group.

Example:

<name>= LIMit

=TRIP

`:CURRent:LIMit:TYPE TRIP` - Turn output off when current limit reached on battery channel (#1).

• <NRf> Numeric representation format - This parameter is a number that can be expressed as an integer (e.g., 8), a real number (e.g., 23.6), or an exponent (2.3E6).

Example:

`SENSe[1]:AVERage 5`	Set average count value to 5 for battery channel (#1)

• <n> Numeric value - A numeric value parameter can consist of an NRf number or one of the following name parameters: DEFault, MINimum, MAXimum. When the DEFault parameter is used, the instrument is programmed to the *RST default value. When the MINimum parameter is used, the instrument is programmed to the lowest allowable value. When the MAXimum parameter is used, the instrument is programmed to the largest allowable value.

Examples:

`:SENSe[1]:NPLCycles 2`	Set integration period to 2 PLC
`:SENSe[1]:NPLCycles DEFault`	Set integration period to 1 PLC
`:SENSe[1]:NPLCycles MINimum`	Set integration period to 0.002 PLC
`:SENSe[1]:NPLCycles MAXimum`	Set integration period to 10 PLC

• <numlist> Numlist - Specify one or more numbers for a list. Example:

:STATus:QUEue:ENABle (-110:-222)	Enable errors -110 thru -222

Angle Brackets **< >** - Angle brackets (< >) are used to denote a parameter type. Do not include the brackets in the program message. For example:

:OUTPut[1] <b>

The <b> indicates that a Boolean-type parameter is required. Therefore, to turn on the output for the battery channel (#1), the command with the ON or 1 parameter must be sent as follows:

:OUTPut[1] ON
:OUTPut[1] 1

Query commands

This type of command requests (queries) the presently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form.
Example:

`:SENSe[1]:CURRent:RANGe?`	Queries the present current range for the battery channel (#1).

Most commands that require a numeric parameter (<n>) can also use the DEFault, MINimum, and MAXimum parameters for the query form. These query forms are used to determine the *RST default value and the upper and lower limits for the fundamental command. Examples:

`:SENSe[1]:CURRent:RANGe? DEFault`	Queries the *RST default value.
`:SENSe[1]:CURRent:RANGe? MINimum`	Queries the lowest allowable value.
`:SENSe[1]:CURRent:RANGe? MAXimum`	Queries the largest allowable value.

Case sensitivity

Common commands and SCPI commands are not case sensitive. You can use upper or lower case and any case combination.
Examples:

`*RST`	= `*rst`
`:DATA?`	= `:data?`
`:STATus:PRESet`	= `:status:preset`

Long-form and short-form versions

A SCPI command word can be sent in its long-form or short-form version. The command subsystem tables in *Section 11* provide the long-form version. However, the short-form version is indicated by upper case characters.
Examples:

`:STATus:PRESet`	long-form
`:STAT:PRES`	short-form
`:STATus:PRES`	long-form and short-form combination

Note that each command word must be in either long-form or short-form. For example,

`:STATu:PRESe` is illegal and will generate an error. The command will not be executed.

Short-form rules

Use the following rules to determine the short-form version of any SCPI command or parameter:

- If the length of the word is four letters or less, no short form version exists. Example:
  `:auto = :auto`

These rules apply to words that exceed four letters:

- If the fourth letter of the word is a vowel, delete it and all the letters after it. Example:
  `:dvmeter = :dvm`
- If the fourth letter of the command word is a consonant, retain it but drop all the letters after it. Example:
  `:format = :form`
- If the command contains a question mark (?; query) or a non-optional number included in the command word, you must include it in the short-form version. Example:
  :function? = :func?
  `:SOURce2 = :SOUR2`
- Command words or characters that are enclosed in brackets ([ ]) are optional and need not be included in the program message.

Program messages

A program message is made up of one or more command words sent by the computer to the instrument. Each common command is a three letter acronym preceded by an asterisk (*). SCPI commands are categorized in the subsystem. For example, `:STATus` subsystem will be used to help explain how command words are structured to formulate program messages.

:STATus	Path (Root)
:OPERation	Path
:ENABle <NRf>	Command and parameter
:ENABle?	Query command
:PRESet	Command

Single command messages

The previous command structure has three levels. The first level is made up of the root command (:STATus) and serves as a path. The second level is made up of another path (:OPERation) and a command (:PRESet). The third path is made up of one command for the :OPERation path. The three commands in this structure can be executed by sending three separate program messages as follows:

```
:stat:oper:enab <NRf>
:stat:oper:enab?
:stat:pres
```

In each of the above program messages, the path pointer starts at the root command (:stat) and moves down the command levels until the command is executed.

Multiple command messages

You can send multiple command messages in the same program message as long as they are separated by semicolons (;). Here is an example showing two commands in one program message:

:stat:pres; :stat:oper:enab <NRf>

When this command is sent, the first command word is recognized as the root command (:stat). When the next colon is detected, the path pointer moves down to the next command level and executes the command. When the path pointer sees the colon after the semicolon (;), it resets back to the root level and starts over.

Commands that are on the same command level can be executed without having to retype the entire command path. Example:

:stat:oper:enab <NRf>; enab?

After the first command (:enab) is executed, the path pointer is at the third command level in the structure. Since :enab? is also on the third level, it can be typed in without repeating the entire path name. Notice that the leading colon for :enab? is not included in the program message. If a colon were included, the path pointer would reset to the root level and expect a root command. Since :enab? is not a root command, an error would occur.

Command path rules

- Each new program message must begin with the root command, unless it is optional (e.g., [:SOURce1]). If the root is optional, treat a command word on the next level as the root.
- The colon (:) at the beginning of a program message is optional and need not be used. Example:
  :stat:pres = stat:pres
- When the path pointer detects a colon (:), it moves down to the next command level. An exception is when the path pointer detects a semicolon (;), which is used to separate commands within the program message (see next rule).
- When the path pointer detects a colon (:) that immediately follows a semicolon (;), it resets back to the root level.

- The path pointer can only move down; it cannot be moved up a level. Executing a command at a higher level requires that you start over at the root command.

Using common and SCPI commands in the same message

Both common commands and SCPI commands can be used in the same message as long as they are separated by semicolons (;). A common command can be executed at any command level and will not affect the path pointer.
Example:

```
:stat:oper:enab <NRf>; *ESE <NRf>
```

Program message terminator (PMT)

Each program message must be terminated with an LF (line feed), EOI (end or identify), or an LF+EOI. The bus will hang if your computer does not provide this termination. The following example shows how a program message must be terminated:

```
:outp on <PMT>
```

Command execution rules

- Commands execute in the order that they are presented in the program message.
- An invalid command generates an error and is not executed.
- Valid commands that precede an invalid command in a multiple command program message are executed.
- Valid commands that follow an invalid command in a multiple command program message are ignored.

Response messages

A response message is the message sent by the instrument to the computer in response to a query command program message.

Sending a response message

After sending a query command, the response message is placed in the output queue. When the power supply is then addressed to talk, the response message is sent from the output queue to the computer.

Multiple response messages

If you send more than one query command in the same program message (see *Multiple command messages*), the multiple response messages for all the queries are sent to the computer when the power supply is addressed to talk. The responses are sent in the order the query commands were sent and are separated by semicolons (;). Items within the same query are separated by commas (,). The following example shows the response message for a program message that contains four single item query commands:

```
0; 1; 1; 0
```

Response message terminator (RMT)

Each response is terminated with an LF (line feed) and EOI (end or identify). The following example shows how a multiple response message is terminated:

```
0; 1; 1; 0; <RMT>
```

Message exchange protocol

Two rules summarize the message exchange protocol:

Rule 1: You must always tell the power supply what to send to the computer.

Rule 2: The complete response message must be received by the computer before another program message can be sent to the power supply.

The following two steps must always be performed to send information from the instrument to the computer:

1. Send the appropriate query command(s) in a program message.
2. Address the power supply to talk.

Section 7

Status Structure

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Overview

Model 2308 provides a series of status registers and queues allowing the operator to monitor and manipulate the various instrument events. The status structure is shown in *Figure 7-1*. The heart of the status structure is the status byte register. This register can be read by the user's test program to determine if a service request (SRQ) has occurred, and what event caused it.

Status byte and SRQ

The status byte register receives the summary bits of four status register sets and two queues. The register sets and queues monitor the various instrument events. When an enabled event occurs, it sets a summary bit in the status byte register. When a summary bit of the status byte is set and its corresponding enable bit is set (as programmed by the user), the RQS/MSS bit will set to indicate that an SRQ has occurred.

Status register sets

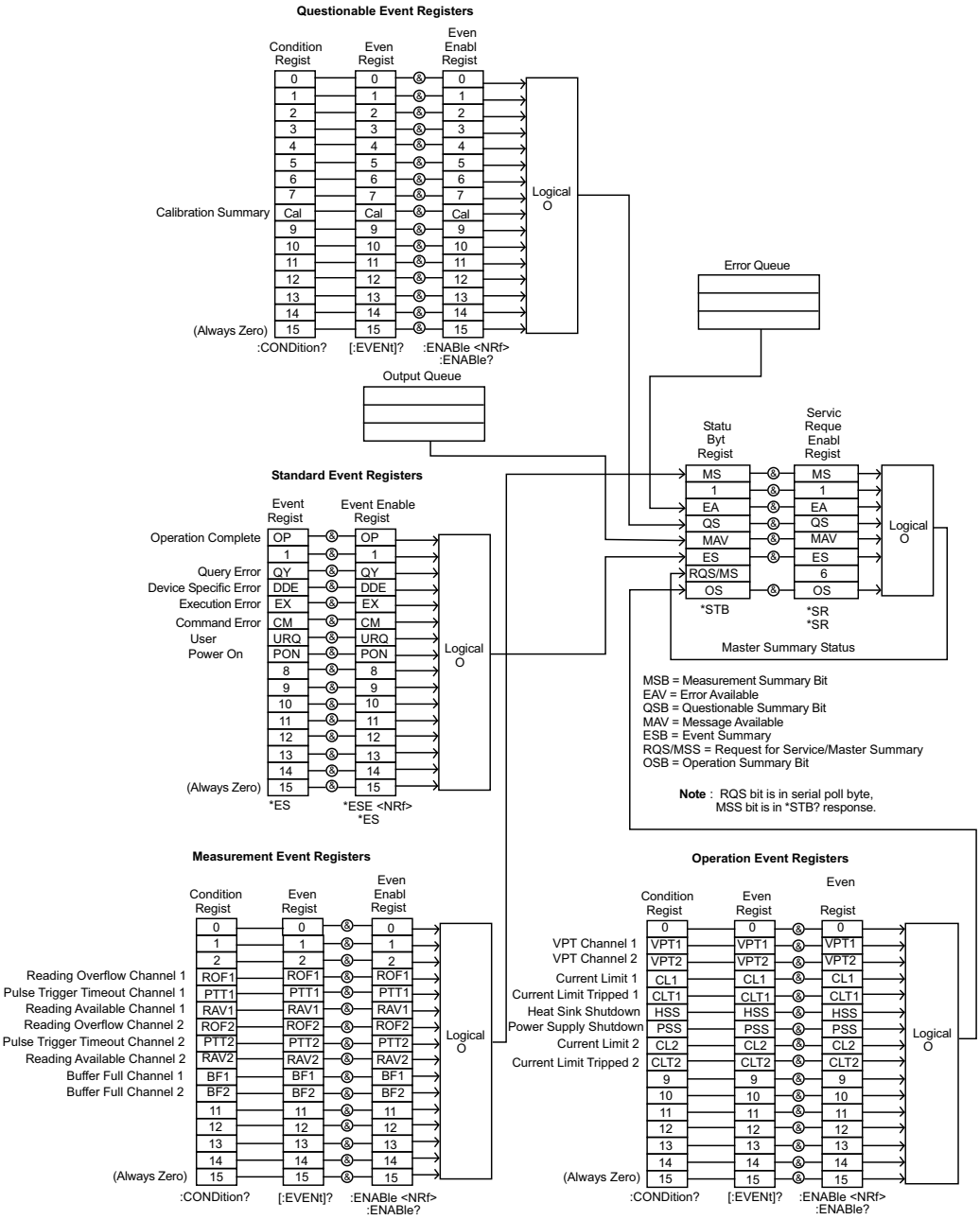
A typical status register set is made up of a condition register, an event register and an event enable register. A condition register is a read-only register that constantly updates to reflect the present operating conditions of the instrument.

When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. When an event register bit is set and its corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the status byte register.

Queues

Model 2308 uses an output queue and an error queue. The response messages to query commands are placed in the output queue. As various programming errors and status messages occur, they are placed in the error queue. When a queue contains data, it sets the appropriate summary bit of the status byte register.

Figure 7-1
Status model structure



Clearing registers and queues

When the power supply is turned on, the bits of all registers in the status structure are clear (reset to 0) and the two queues are empty. Commands to reset the event and event enable registers, and the error queue are listed in *Table 7-1*. In addition to these commands, any enable register can be reset by sending the 0 parameter value with the individual command to program the register.

NOTE `*RST` has no effect on status structure registers and queues. See *Queues* for details on the error queue.

Table 7-1
Common and SCPI commands - reset registers and clear queues

Commands	Description	Ref
To reset registers: *CLS	Reset all bits of the following event registers to 0: Standard event register Operation event register Measurement event register Questionable event register	
STATus :PRESet	STATus subsystem: Reset all bits of the following enable registers to 0: Operation event enable register Measurement event enable register Questionable event enable register	Note 1
To clear error queue: *CLS	Clear all messages from error queue	Note 2
STATus :QUEue {:NEXT}? :CLEar	STATus subsystem: Error queue: Read and clear the oldest error/status message. Clear all messages from error queue.	Note 3
SYSTem :ERRor? :CLEar	SYSTem subsystem: Read and clear the oldest error/status message. Clear all messages from error queue.	Note 3

Notes:
1. The standard event enable register is not reset by STATus:PRESet or *CLS. Send the 0 parameter value with *ESE to reset all bits of that enable register to 0 (see *Status byte and service request commands* for service request enable register).
2. STATus:PRESet has no effect on the error queue.
3. Use either of the two :CLEar commands to clear the error queue.

Programming and reading registers

Programming enable registers

The enable registers can be programmed by the user. All other registers in the status structure are read-only registers. The following explains how to ascertain the parameter value for the various commands used to program enable registers. The actual commands are covered later in this section (refer to *Table 7-1* and *Table 7-6*).

A command to program an event enable register is sent with a decimal parameter value that determines the desired state (0 or 1) of each bit in the appropriate register. The bit positions of the register (*Table 7-2*) indicate the parameter value in binary format. For example, if you wish to sets bits B4, B3 and B1, the binary value would be 11010 (where B4=1, B3=1, B2=0, B1=1, B0=0 and all other bits are 0). The decimal equivalent of binary 11010 is 26. Therefore, the parameter value for the enable command is 26.

Another way to determine the decimal value is to add up the decimal weights for the bits that you wish to set. Note that includes the decimal weight for each register bit. To set bits B4, B3 and B1, the parameter value would be the sum of the decimal weights for those bits (16+8+2 = 26).

Table 7-2
16-bit status register

A) Bits 0 through 7

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)

B) Bits 8 through 15

Bit Position	B15	B14	B13	B12	B11	B10	B9	B8
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	32768 (2^{15})	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	1024 (2^{10})	512 (2^9)	256 (2^8)

Reading registers

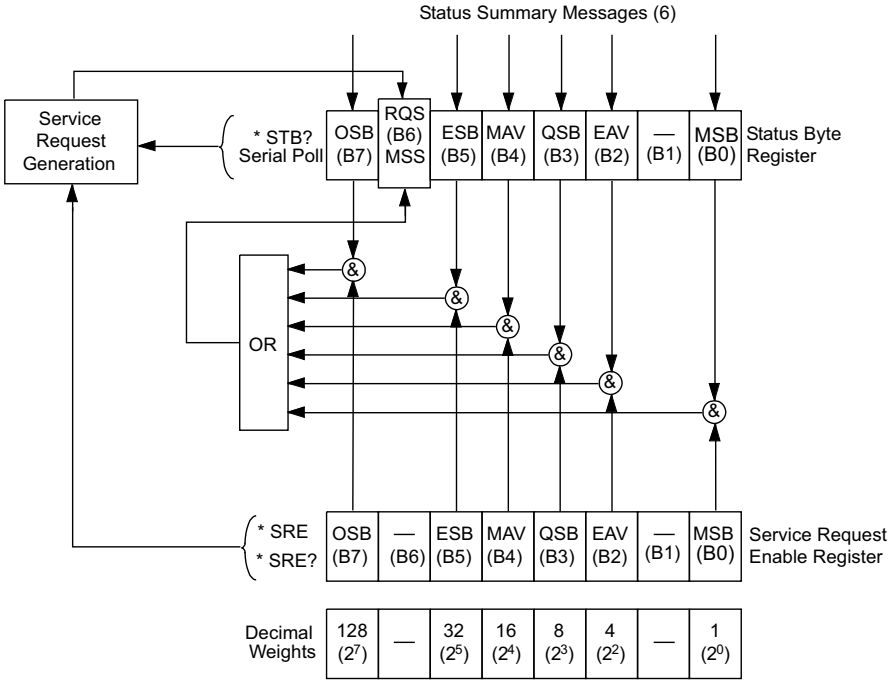
Any register in the status structure can be read by using the appropriate query (?) command. The specific query commands are covered later in this section (refer to *Table 7-3* through *Table 7-6*).

The response message to the query command is a decimal value. To determine which bits in the register are set, convert that decimal value to its binary equivalent. For example, the binary equivalent of decimal 41 is 101001. This binary value indicates that bits B5, B3 and B0 are set.

Status byte and service request (SRQ)

Service request is controlled by two 8-bit registers; the status byte register and the service request enable register. *Figure 7-2* shows the structure of these registers.

Figure 7-2
Status byte and service request



OSB = Operation Summary Bit
MSS = Master Summary Status
RQS = Request for Service
ESB = Event Summary Bit
MAV = Message Available
QSB = Questionable Summary Bit
EAV = Error Available
MSB = Measurement Summary Bit
& = Logical AND
OR = Logical OR

Status byte register

The summary messages from the status registers and queues are used to set or clear the appropriate bits (B0, B2, B3, B4, B5, and B7) of the status byte register. These summary bits do not latch, and their states (0 or 1) are solely dependent on the summary messages (0 or 1). For example, if the standard event register is read, its register will clear. As a result, its summary message will reset to 0, which in turn will reset the ESB bit in the status byte register.

The bits of the status byte register are described as follows:

- **Bit B0, measurement status (MSB)** - Set summary bit indicates that an enabled measurement event has occurred.
- **Bit B1** - Not used.
- **Bit B2, error available (EAV)** - Set summary bit indicates that an error or status message is present in the error queue.
- **Bit B3, questionable summary bit (QSB)** - Set summary bit indicates that an enabled questionable event has occurred.
- **Bit B4, message available (MAV)** - Set summary bit indicates that a response message is present in the output queue.
- **Bit B5, event summary bit (ESB)** - Set summary bit indicates that an enabled standard event has occurred.

- **Bit B6, request service (RQS)/master summary status (MSS)** - Set bit indicates that an enabled summary bit of the status byte register is set.
- **Bit B7, operation summary (OSB)** - Set summary bit indicates that an enabled operation event has occurred.

Depending on how it is used, bit B6 of the status byte register is either the request for service (RQS) bit or the master summary status (MSS) bit:

- When using the serial poll sequence of the power supply to obtain the status byte (a.k.a. serial poll byte), B6 is the RQS bit (see *Serial polling and SRQ*).
- When using the `*STB?` command (see *Status byte and service request commands*) to read the status byte, B6 is the MSS bit.

Service request enable register

The generation of a service request is controlled by the service request enable register. This register is programmed by the user and is used to enable or disable the setting of bit B6 (RQS/MSS) by the status summary message bits (B0, B2, B3, B4, B5, and B7) of the status byte register. As shown in *Figure 7-2*, the summary bits are logically ANDed (&) with the corresponding enable bits of the service request enable register. When a set (1) summary bit is ANDed with an enabled (1) bit of the enable register, the logic "1" output is applied to the input of the OR gate and, therefore, sets the MSS/RQS bit (B6) in the status byte register.

The individual bits of the service request enable register can be set or cleared by using the `*SRE` common command. To read the service request enable register, use the `*SRE?` query command. The service request enable register clears when power is cycled or a parameter value of 0 is sent with the `*SRE` command (i.e. `*SRE 0`). The commands to program and read the SRQ enable register are listed in *Table 7-3*.

Serial polling and SRQ

Any enabled event summary bit that goes from 0 to 1 will set bit B6 and generate an SRQ (service request). In your test program, you can periodically read the status byte to check if an SRQ has occurred and what caused it. If an SRQ occurs, the program can, for example, branch to an appropriate subroutine that will service the request.

Typically, SRQs are managed by the serial poll sequence of the power supply. If an SRQ does not occur, bit B6 (RQS) of the status byte register will remain cleared, and the program will simply proceed normally after the serial poll is performed. If an SRQ does occur, bit B6 of the status byte register will set, and the program can branch to a service subroutine when the SRQ is detected by the serial poll.

The serial poll automatically resets RQS of the status byte register. This allows subsequent serial polls to monitor bit B6 for an SRQ occurrence generated by other event types. After a serial poll, the same event can cause another SRQ, even if the event register that caused the first SRQ has not been cleared.

The serial poll does not clear MSS. The MSS bit stays set until all status byte summary bits are reset.

SPE, SPD (serial polling)

The `SPE`, `SPD` general bus command is used to serial poll the power supply. Serial polling obtains the serial poll byte (status byte). Typically, serial polling is used by the controller to determine which of several instruments has requested service with the SRQ line.

Status byte and service request commands

The commands to program and read the status byte register and service request enable register are listed in *Table 7-3*. For details on programming and reading registers, see *Programming enable registers* and *Reading registers*.

NOTE	To reset the bits of the service request enable register to 0, use 0 as the parameter value for the *SRE command (i.e. *SRE 0).

Table 7-3
Common and SCPI Commands - status byte and service request enable registers

Command	Description	Default
*STB? *SRE <NRf> *SRE?	Read status byte register Program the service request enable register: 0 to 255 Read the service request enable register	(Note)

Note: *CLS and STATus:PRESet have no effect on the service request enable register.

Programming example — read status byte

The following command sequence enables EAV (error available), sends an invalid command, and then reads the status byte register:

```
*CLS                        ' Clear Status Byte Register.
*SRE 4                      ' Enable EAV.
BAD:COMMand                 ' Send an invalid command to generate an error.
*STB?                       ' Read status byte. The value 68 will be returned to indicate
                              that bits B2 (EAV) and B6 (MSS) of the Status Byte Register
                              are set.
```

Status register sets

As shown in *Figure 7-1*, there are four status register sets in the status structure of the power supply: standard event status, operation event status, measurement event status and questionable event status.

Register bit descriptions

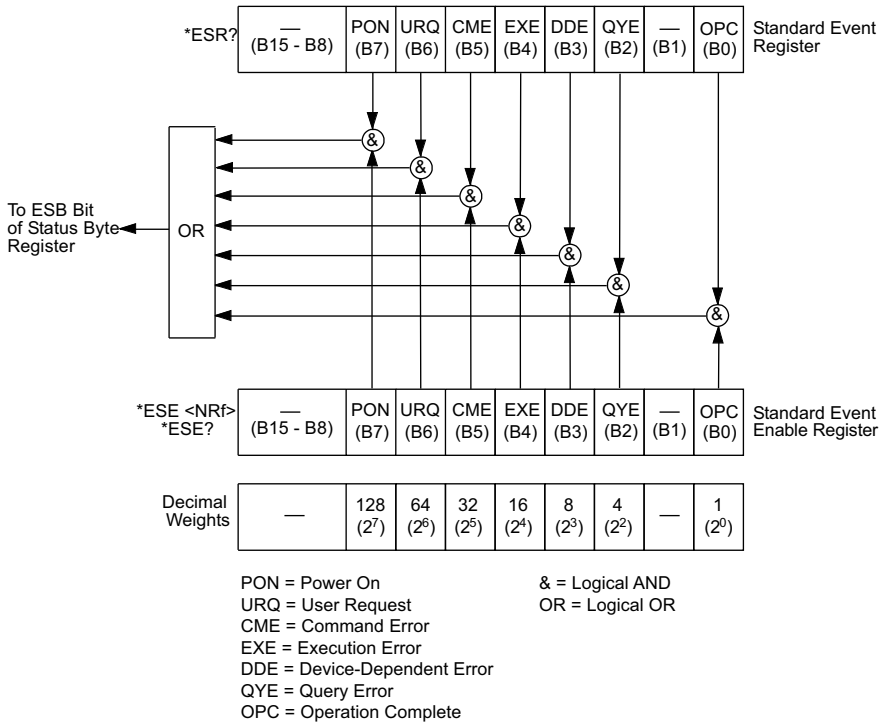
Standard event status

The used bits of the standard event register (shown in *Figure 7-3*) are described as follows:

- **Bit B0, operation complete (OPC)** - Set bit indicates that all pending selected device operations are completed and the power supply is ready to accept new commands. This bit only sets in response to the *OPC command (see *Section 8* for details on *OPC).
- **Bit B2, query error (QYE)** - Set bit indicates that you attempted to read data from an empty output queue.
- **Bit B3, device-dependent error (DDE)** - Set bit indicates that an instrument operation did not execute properly due to some internal condition.
- **Bit B4, execution error (EXE)** - Set bit indicates that the power supply detected an error while trying to execute a command.

- **Bit B5, command error (CME)** - Set bit indicates that a command error has occurred. Command errors include:
  - EEE-488.2 syntax error - power supply received a message that does not follow the defined syntax of the IEEE-488.2 standard.
  - Semantic error - power supply received a command that was misspelled or received an optional IEEE-488.2 command that is not implemented.
  - The instrument received a group execute trigger (GET) inside a program message.
- **Bit B6, user request (URQ)** - Set bit indicates that the LOCAL key on the power supply front panel was pressed.
- **Bit B7, power ON (PON)** - Set bit indicates that the power supply has been turned off and turned back on since the last time this register has been read.

Figure 7-3
Standard event status



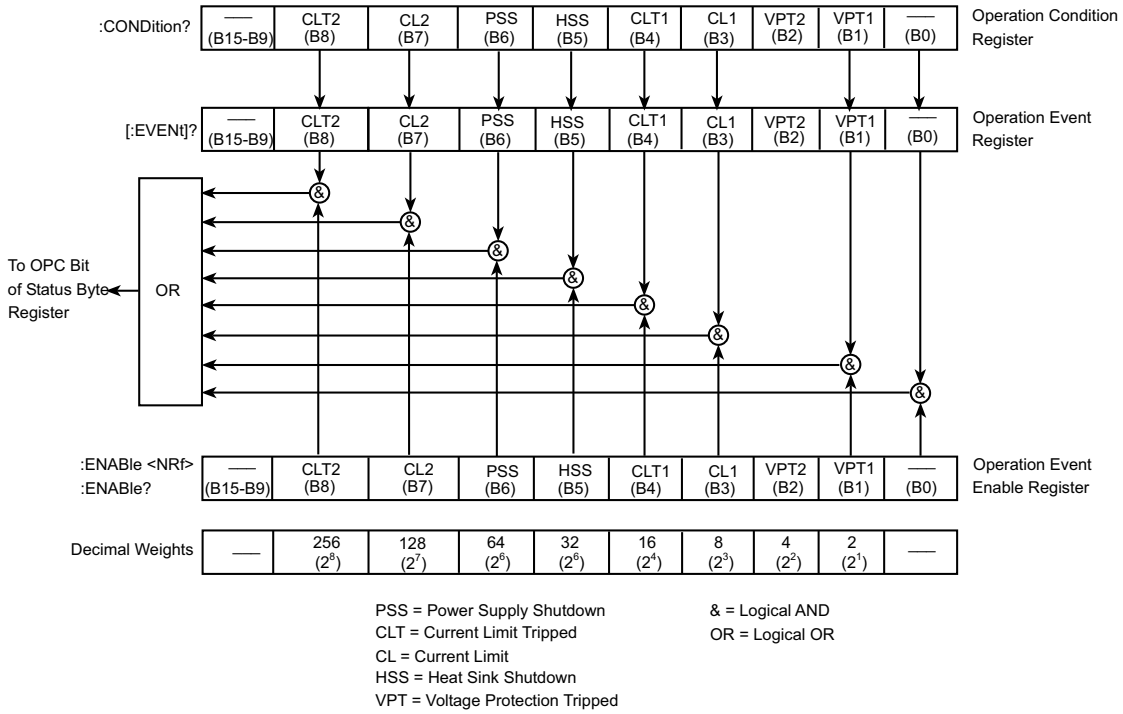
Operation event status

The used bits of the operation event register (shown in *Figure 7-4*) are described as follows:

- **Bit B1, voltage protection channel #1 (VPT1)** - Set bit indicates that the battery channel (#1) is in voltage protection mode. In this mode, the output has been turned off and the front panel displays "VPT" (battery channel only - for the charger channel, see Bit 2). If the display mode is set to DUAL V AND I then, the VPT message will not appear on the display.
- **Bit B2, voltage protection channel #2 (VPT2)** - Set bit indicates that the charger channel (#2) is in voltage protection mode. In this mode, the output has been turned off and the front panel displays "VPT" (charger channel only - for the battery channel, see Bit 1). If the display mode is set to DUAL V AND I then, the VPT message will not appear on the display.
- **Bit B3, current limit #1 (CL1)** - Set bit indicates that the battery channel's (#1) output is in current limit. This bit clears when the instrument is no longer in current limit (battery channel only — for the charger channel, see Bit 7).

- **Bit B4, current limit tripped #1 (CLT1)** - Set bit indicates that the battery channel's (#1) output has turned off due to a current limit trip condition. This bit clears when the output is turned back on (battery channel only - for the charger channel, see Bit 8).
- **Bit B5, heat sink shutdown (HSS)** - This bit indicates that the output has turned off due to the output stage heat sink overheating.
- **Bit B6, power supply shutdown (PSS)** - This bit indicates that the output has turned off due to the main AC/DC power supply heat sink overheating.
- **Bit B7, current limit #2 (CL2) -** Set bit indicates that the charger channel's (#2) output is in current limit. This bit clears when the instrument is no longer in current limit (charger channel only - for the battery channel, see Bit 3).
- **Bit B8, current limit tripped #2 (CLT2)** - Set bit indicates that the charger channel's (#2) output has turned off due to a current limit trip condition. This bit clears when the output is turned back on (charger channel only - for the battery channel, see Bit 4).

Figure 7-4
Operation event status

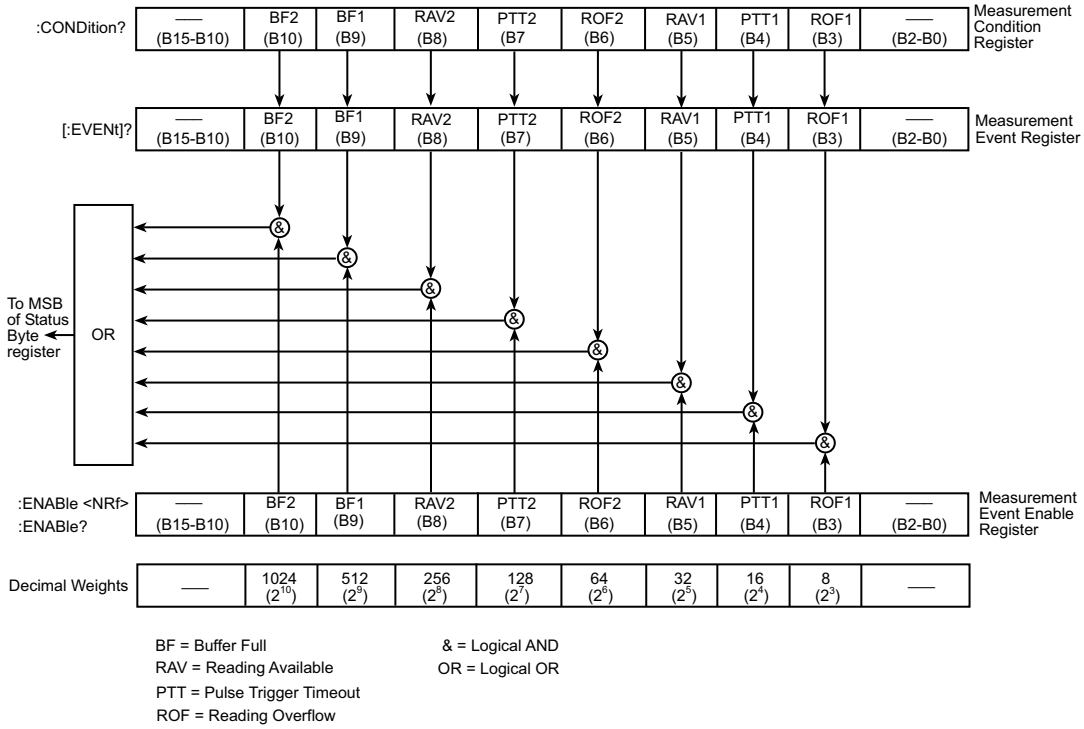


Measurement event status

The used bits of the measurement event register (shown in *Figure 7-5*) are described as follows:

- **Bit B3, reading overflow #1 (ROF1)** - Set bit indicates that the battery channel's (#1) reading exceeds the measurement range of the instrument (battery channel only - for the charger channel, see Bit 6).
- **Bit B4, pulse trigger timeout #1 (PTT1)** - Set bit indicates that a battery channel (#1) current pulse has not been detected. This bit applies to pulse current and long integration functionality (battery channel only - for the charger channel, see Bit 7).
- **Bit B5, reading available #1 (RAV1)** - Set bit indicates that a battery channel (#1) reading was taken and processed (battery channel only - for the charger channel, see Bit 8).

Figure 7-5
Measurement event status



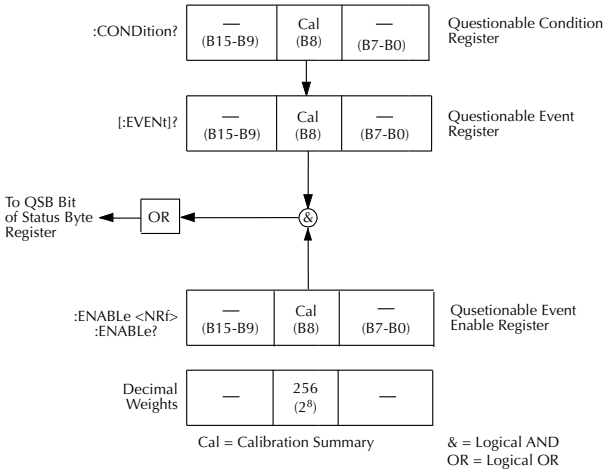
- **Bit B6, reading overflow #2 (ROF2)** - Set bit indicates that the charger channel's (#2) reading exceeds the measurement range of the instrument (charger channel only - for the battery channel, see Bit 3).
- **Bit B7, pulse trigger timeout #2 (PTT2)** - Set bit indicates that a charger channel (#2) current pulse has not been detected. This bit applies to pulse current and long integration functionality (charger channel only - for the battery channel, see Bit 4).
- **Bit B8, reading available #2 (RAV2)** - Set bit indicates that a charger channel (#2) reading was taken and processed (charger channel only - for the battery channel, see Bit 5).
- **Bit B9, buffer full #1 (BF1)** - Set bit indicates that the specified number of battery channel's (#1) readings (average count) have been taken (battery channel only - for the charger channel, see Bit 10).
- **Bit B10, buffer full #2 (BF2)** - Set bit indicates that the specified number of charger channel's (#2) readings (average count) have been taken (charger channel only - for the battery channel, see Bit 9).

Questionable event status

The used bit of the questionable event register (shown in *Figure 7-6*) is described as follows:

- **Bit B8, calibration summary (Cal)** - Set bit indicates that an invalid calibration constant was detected during the power-up sequence. This error will clear after successful calibration of the power supply.

Figure 7-6
Questionable event status



Condition registers

As *Figure 7-1* shows, each status register set (except the standard event register set) has a condition register. A condition register is a real-time, read-only register that constantly updates to reflect the present operating conditions of the instrument. For example, when a current pulse is not detected on the battery channel, bit B4 (PTT1) of the measurement condition register will be set (1). When the pulse is detected, the bit clears (0).

The commands to read the condition registers are listed in *Table 7-4*. For details on reading registers, see *Reading registers*.

Table 7-4
Common and SCPI commands - condition registers

Command	Description
STATus :OPERation:CONDition? :MEASurement:CONDition? :QUEStionable:CONDition?	STATus subsystem: Read operation condition register. Read measurement condition register. Read questionable condition register.

Event registers

As *Figure 7-1* shows, each status register set has an event register. When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. Reading an event register clears the bits of that register. *CLS resets all four event registers.

The commands to read the event registers are listed in *Table 7-5*. For details on reading registers, see *Reading registers*.

Table 7-5
Common and SCPI commands - event registers

Command	Description	Default
*ESR?	Read standard event status register.	(Note)
STATus :OPERation:[:EVENt]? :MEASurement:[:EVENt]? :QUEStionable:[:EVENt]?	STATus subsystem: Read operation event register. Read measurement event register. Read questionable event register.	

Note: Power-up and *CLS resets all bits of all event registers to 0. STATus:PRESet has no effect.

Event enable registers

As *Figure 7-1* shows, each status register set has an enable register. Each event register bit is logically ANDed (&) to a corresponding enable bit of an enable register. Therefore, when an event bit is set and the corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the status byte register.

The commands to program and read the event enable registers are listed in *Table 7-6*. For details on programming and reading registers, see *Programming enable registers* and *Reading registers*.

NOTE The bits of any enable register can be reset to 0 by sending the 0 parameter value with the appropriate enable command (i.e. STATus:OPERation:ENABle 0).

Table 7-6
Common and SCPI commands - event enable registers

Command	Description	Default
*ESE <NRf> *ESE?	Program standard event enable register (see "*Parameters*"). Read standard event enable register.	(Note)
STATus :OPERation :ENABle <NRf> :ENABle? :MEASurement :ENABle <NRf> :ENABle? :QUEStionable :ENABle <NRf> :ENABle?	STATus subsystem: Operation event enable register: Program enable register (see "*Parameters*"). Read enable register. Measurement event enable register: Program enable register (see "*Parameters*"). Read enable register. Questionable event enable register: Program enable register (see "*Parameters*"). Read enable register:	

Note: Power-up and STATus:PRESet resets all bits of all enable registers to 0. *CLS has no effect. STATus:PRESet has no effect on settings for *ESE.

Table 7-6
Common and SCPI commands - event enable registers

Command	Description	Default
Parameters: <NRf> = 0 to 65535 decimal format		

Note: Power-up and STATus:PRESet resets all bits of all enable registers to 0. *CLS has no effect. STATus:PRESet has no effect on settings for *ESE.

Programming example — program and read measurement event register

The following command sequence enables the battery channel (#1) buffer full bit (B9) of the measurement register set, and then reads the event register. After the programmed number of readings (average count) have been taken, reading the event register will return a value that has bit 9 set (bit 9 has a decimal value of 512).

```
STAT:MEAS:ENAB 512          ' Enable BF1 (Buffer Full for battery channel).
*TRG                        ' Trigger buffer data.
STAT:MEAS?                  ' Read Measurement Event Register.
                            ' Once STAT:MEAS? returns a value that has bit 9
                            ' (bit 9 has a decimal value of 512) set,
Language specific           ' talk to the instrument for the data.
FETCh:ARR?                  ' Request the buffer data from Model 2308
Language specific           ' Talk Model 2308 for the array (buffer) data.
```

This slows down the responsiveness of the Model 2308 since while the unit is trying to fill the buffer it has to respond to the STAT:MEAS? to let you know if the buffer is full. Once the buffer is full, it may be talked for the array of data as shown in the example. If the Model 2308 is talked too early for the buffer data, then a GPIB timeout may occur (see *Setting the GPIB timeout for responses*).

The following command sequence enables the battery channel's (#1) buffer full bit (B9) of the measurement register set, and then causes an SRQ when the buffer is full:

```
STAT:MEAS:ENAB 512          ' Enable BF1 (Buffer Full for battery channel).
*SRE 1                      ' Enable MSB bit of status byte.
READ:ARR?                   ' Trigger buffer data.
Language specific           ' Wait for an SRQ on BF1.
Language specific           ' Talk Model 2308 for the array (buffer) data.
```

This method prevents the Model 2308 from being talked too early for data. In addition, this eliminates the concern of knowing the GPIB timeout setting (see *Setting the GPIB timeout for responses*).

Queues

The power supply uses two queues, which are first-in, first-out (FIFO) registers:

Output queue - Used to hold reading and response messages.

Error queue - Used to hold error and status messages.

The power supply status model (*Figure 7-1*) shows how the two queues are structured with the other registers.

Output queue

The output queue holds data that pertains to the normal operation of the instrument. For example, when a query command is sent, the response message is placed in the output queue.

When data is placed in the output queue, the message available (MAV) bit in the status byte register sets. A data message is cleared from the output queue when it is read. The output queue is considered cleared when it is empty. An empty output queue clears the MAV bit in the status byte register.

A message is read from the output queue by addressing the power supply to talk after the appropriate query is sent.

The following command sequence enables the MAV bit (B4) of the status byte register set, and then causes an SRQ:

```
*SRE 16                    ' Enable MAV bit of status byte to cause an SRQ.
Language specific          ' Send a query command to supply.
Language specific          ' Wait for an SRQ indicating ready to read.
Language specific          ' Read the query response.
```

Error queue

The error queue holds error and status messages. When an error or status event occurs, a message that defines the error/status is placed in the error queue.

When a message is placed in the error queue, the error available (EAV) bit in the status byte register is set. An error/status message is cleared from the error queue when it is read. The error queue is considered cleared when it is empty. An empty error queue clears the EAV bit in the status byte register.

The error queue holds up to 10 error/status messages. The commands to read the error queue are listed in *Table 7-7*. When you read a single message in the error queue, the "oldest" message is read and then removed from the queue. If the queue becomes full, the message "350, 'queue overflow'" will occupy the last memory location. On power-up, the error queue is empty. When empty, the message "0, No Error" is placed in the queue.

Messages in the error queue are preceded by a code number. Negative (-) numbers are used for SCPI-defined messages, and positive (+) numbers are used for messages defined by Keithley Instruments. The messages are listed in *Appendix A*.

On power-up, all error messages are enabled and will go into the error queue as they occur. Status messages are not enabled and will not go into the queue. As listed in *Table 7-7*, there are commands to enable and/or disable messages. For these commands, the <list> parameter is used to specify which messages to enable or disable. The messages are specified by their codes. The following examples show various forms for using the <list> parameter.

<list>	= (-110)	Single message
	= (-110:-222)	Range of messages (-110 through -222)
	= (-110:-222, -220)	Range entry and single entry (separated by a comma)

When you enable messages, messages not specified in the list are disabled. When you disable messages, each listed message is removed from the enabled list.

NOTE To prevent all messages from entering the error queue, send the enable command along with the null list parameter as follows:
`STATus:QUEue:ENABle ()`.

Table 7-7
SCPI Commands - error queue

Command	Description	Default
STATus :QUEue [:NEXT]? :ENABle <list> :ENABle? :DISable <list> :DISable? :CLEar	STATus subsystem: Read error queue: Read and clear oldest error/status message. Specify error and status messages for error queue. Read the enabled messages. Specify messages not to be placed in queue. Read the disabled messages. Clear messages from error queue.	 (Note 1) (Note 2) (Note 2)
SYSTem :ERRor? :CLEar	SYSTem subsystem: Read error queue: Clear messages from error queue.	(Note 1)

Notes:
1. Power-up and *CLS empties the error queue. `STATus:PRESet` has no effect.
2. Power-up enables error messages and disables status messages. *CLS and STATus:PRESet have no effect.

Programming example - read error queue

```
STAT:QUE:ENAB (+000:+900)      ' Enable all Keithley defined messages (disable all SCPI
                                 defined messages).
STAT:QUE?                      ' Return oldest message.
```

Section 8
Common Commands

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Overview

Common commands are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard. Common commands are listed in *Table 8-1*. Note that detailed information on the Common Commands to program and read status registers is provided in *Section 7*.

Table 8-1
IEEE-488.2 common commands and queries

Mnemonic	Name	Description
*CLS	Clear status	Clears all event registers and error queue.
*ESE <NRf>	Event enable command	Program the standard event enable register.
*ESE?	Event enable query	Read the standard event enable register.
*ESR?	Event status register query	Read the standard event enable register and clear it.
*IDN?	Identification query	Returns the manufacturer, model number, serial number, and firmware revision levels of the unit.
*OPC	Operation complete command	Set the operation complete bit in the standard event register after all pending commands have been executed.
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.
*RCL <NRf>	Recall command	Returns the power supply to the user-saved setup.
*RST	Reset command	Returns the power supply to the *RST default conditions.
*SAV <NRf>	Save command	Saves the present setup as the user-saved setup.
*SRE <NRf>	Service request enable command	Programs the service request enable register.
*SRE?	Service request enable query	Reads the service request enable register.
*STB?	Status byte query	Reads the status byte register.
*TRG[1]	Trigger command	Sends a battery channel (#1) bus trigger to the power supply.
*TRG2	Trigger command	Sends a charger channel (#2) bus trigger to the power supply.
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.
*WAI	Wait-to-continue command	Wait until all previous commands are executed.

IEEE-488.2 common commands and queries

*IDN?

`*IDN? — identification query` Reads identification code

The identification code includes the manufacturer, model number, serial number, and firmware revision levels as follows:

KEITHLEY INSTRUMENTS INC., MODEL 2308, xxxxxxx, yyyyy/zzzzz

Where: xxxxxxx is the serial number.

yyyyy/zzzzz is the firmware revision levels of the digital board and display board ROMs.

*OPC

`*OPC — operation complete`	Sets OPC bit
`*OPC? — operation complete query`	Places a "1" in output queue

When *OPC is sent, the OPC bit in the standard event register will set after all pending command operations are complete. When *OPC? is sent, an ASCII "1" is placed in the output queue after all pending command operations are complete.

Typically, either one of these commands is sent after a reading or reading array is requested. While the instrument is acquiring readings, all commands (except DCL, SDC, IFC, *TRG and GET) that are sent are not executed.

After all readings are acquired, the instrument returns to the idle at which time all pending commands (including *OPC and/or *OPC?) are executed.

Syntax - The following syntax rules explain how to use *OPC and *OPC? with other commands (refer to *Table 8-2* for examples). *OPC and *OPC? can be used in conjunction with battery channel (#1) commands or charger channel (#2) commands (see *Table 8-2*).

Send *OPC or *OPC?, separated by a semicolon, on the same line with a query (see Ref. A in *Table 8-2*). If sent on separate lines, an error occurs (B). *OPC or *OPC? can also be sent on the same line or a separate line with a command that is not a query (C and D).

Table 8-2
***OPC and *OPC? commands**

Ref	*OPC	*OPC?	Comment
A	`VOLT?; *OPC`	`SENS:NPLC?; *OPC?`	Valid battery channel command line.
	`SOUR2:VOLTage?; *OPC`	`SENS2:NPLC?; *OPC?`	Valid charger channel command line.
B	`VOLTage?` `*OPC`	`SENS:NPLC?` `*OPC?`	Not valid - query interrupted error.
	`SOUR2:VOLT?` `*OPC`	`SENS2:NPLC?` `*OPC?`	Not valid - query interrupted error.
C	`CURR 1; *OPC`	`SENS:NPLC 5; *OPC?`	Valid battery channel command line.
	`SOUR2:CURR 1; *OPC`	`SENS2:NPLC 5; *OPC?`	Valid charger channel command line.
D	`CURR 1` `*OPC`	`SENS:NPLC 5` `*OPC?`	Valid battery channel command line.
	`SOUR2:CURR 1` `*OPC`	`SENS2:NPLC 5` `*OPC?`	Valid charger channel command line.

The first line for each reference applies to the battery channel (#1) while the second line applies to the charger channel (#2).

*SAV <NRf> and RCL <NRf>

`*SAV <NRf> — save`	Save present setup in memory
`*RCL <NRf> — recall`	Return to setup stored in memory

Parameters

0 = Memory location 0
1 = Memory location 1

2 = Memory location 2
3 = Memory location 3

Use the *SAV command to save the present instrument setup configuration in memory for later recall. Any control affected by *RST can be saved by the *SAV command. The *RCL command is used to restore the instrument to the saved setup configuration. Four setup configurations can be saved and recalled. *SAV and *RCL are global commands (not channel specific). Consequently, when a setup is saved or recalled, both channels are affected.

NOTE The output is always off when a memory location is recalled.

*RST

*RST — reset — Return power supply to RST defaults

When the *RST command is sent, the power supply performs the following operations:

1. Returns the instrument to the RST default conditions (see "Default" column of SCPI tables in *Section 11*).
2. Cancels all pending commands.
3. Cancels response to any previously received *OPC and *OPC? commands.

*TRG

*TRG[1] — trigger — Send battery channel (#1) bus trigger to power supply

*TRG2 — trigger — Send charger channel (#2) bus trigger to power supply

Use the *TRG command to trigger a single reading for the function presently selected. If the average count is >1, then the single reading will be the average reading.

*TST?

*TST? — self-test query — Run self test and read result

Use this query command to perform a checksum test on ROM. The command places the coded result (0 or 1) in the output queue. When the power supply is addressed to talk, the coded result is sent from the output queue to the computer.

A returned value of zero (0) indicates that the test passed, and a value of one (1) indicates that the test failed.

*WAI

*WAI - wait-to-continue — Wait until previous commands are completed

Effectively, the *WAI command is a no-op (no operation) for the power supply and therefore, does not need to be used.

Two types of device commands exist:

- Sequential commands - A command whose operations are allowed to finish before the next command is executed.
- Overlapped commands - A command that allows the execution of subsequent commands while device operations of the overlapped command are still in progress.

The *WAI command is used to suspend the execution of subsequent commands until the device operations of all previous overlapped commands are finished. The *WAI command is not needed for sequential commands.

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Section 9

Measurement Commands and Optimizing Measurement Speed

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Overview

The signal-oriented measurement commands are used to acquire readings. You can use these high-level instructions to control the measurement process. These commands are summarized in *Table 9-1*.

Table 9-1
Signal-oriented measurement command summary

Command	Description
:FETCh[1]?	Returns the last reading from battery channel (#1). Triggered before reading(s).
:FETCh[1]:ARRay?	Returns the last array of readings from battery channel (#1). Triggered before reading(s).
:FETCh2?	Returns the last reading from charger channel (#2). Triggered before reading(s).
:FETCh2:ARRay?	Returns the last array of readings from charger channel (#2). Triggered before reading(s).
:READ[1]?	Triggers and returns a new battery channel (#1) reading.
:READ[1]:ARRay?	Triggers and returns a new array of battery channel (#1) readings.
:READ[1]:AMP?	Switch to 5A range then take a measurement on battery channel (#1).
:READ[1]:HUNDred?	Switch to 500mA range then take a measurement on battery channel (#1).
:READ[1]:FIFTy?	Switch to 50mA range then take a measurement on battery channel (#1).
:READ[1]:FIVE?	Switch to 5mA range then take a measurement on battery channel (#1).
:READ2?	Triggers and returns a new charger channel (#2) reading.
:READ2:ARRay?	Triggers and returns a new array of charger channel (#2) readings.
:MEASure[1][:<function>]?	Performs a READ? on the specified battery channel (#1) function.
:MEASure[1]:ARRay[:<function>]?	Performs a READ:ARRay? on the specified battery channel (#1) function.
:MEASure2[:<function>]?	Performs a READ2? on the specified charger channel (#2) function.
:MEASure2:ARRay[:<function>]?	Performs a READ2:ARRay? on the specified charger channel (#2) function.
BOTHTRG	Triggers a reading on channel 1 and then channel 2. After this command completes, the display is set for Channel #2.
BOTHFUNC <name>	Sets the battery channel (#1), then the charger channel (#2), to the function specified by <name>. Valid strings for name are "VOLTage", "CURRent", "PCURrent", or "LINTegration". Since "DVMeter" is a charger-only function, sending this command with a name such as "DVMeter" will generate a string data error (-150) message.
BOTHFETCH?	Responds with channel 1 and channel 2 readings in a single message. The message contains a value for channel 1, a comma, and then a value for channel 2. After this command completes, the display is set for Channel #1.
BOTHREAD?	Triggers reading on channel 1 and then channel 2, then responds with channel 1 and channel 2 readings in a single message. The message contains a value for channel 1, a comma, and then a value for Channel #2. After this command completes, the display is set for Channel #2.

NOTE For all array queries, make sure the computer's buffer is large enough to accommodate all array readings. Overflow readings exponential format = +9.9E37.

For all non-array queries, the overflow readings exponential format also = +9.9E37.

Command notes: Signal-oriented measurement commands and queries

`:FETCh[1]?`	Return last reading for the battery channel (#1)
`:FETCh[1]:ARRay?`	Return last array of readings for the battery channel (#1)
`:FETCh2?`	Return last reading for the charger channel (#2)
`:FETCh2:ARRay?`	Return last array of readings for the charger channel (#2)

The :FETCh? command is used to return the last averaged reading, and the `:FETCh:ARRay?` command is used to return the last array of readings. After sending either one of these commands and addressing the power supply to talk, the averaged reading or reading array is sent to the computer. These commands do not affect the instrument setup.

These commands do not trigger measurements but are triggered before reading(s). They return the last triggered averaged reading or reading array. Note that they can repeatedly return the same reading or reading array. Until there is a new triggered reading(s), these commands continue to return the old triggered reading(s).

The number of readings to average or put in an array is set using the `SENSe:AVERage` (for voltage, current and DVM readings) or `SENSe:PCURrent:AVERage` (for pulse-current readings) command. See *Section 2* and *Section 3* for details.

NOTE

1. `FETCh?` and `FETCh:ARRay?` readings are sent in the form indicated by the *FORMat[:DATA]* setting.
2. There are no AVERage commands for long integration measurements. The array size for long integration readings is fixed at one. Therefore, both `FETCh?` and `FETCh:ARRay?` will return the last reading.

`:READ[1]?`	Trigger and return reading for the battery channel (#1)
`:READ[1]:ARRay?`	Trigger and return array of readings for the battery channel (#1)
`:READ2?`	Trigger and return reading for the charger channel (#2)
`:READ2:ARRay?`	Trigger and return array of readings for the charger channel (#2)

The `:READ?` command is used to trigger and return a single averaged reading, and the `:READ:ARRay?` command is used to trigger and return an array of readings for the currently selected function on the applicable channel (the battery channel being the default and the charger channel requiring a 2 to be appropriately added to the command string). The averaged reading or

reading array is sent to the computer when the power supply is addressed to talk. The averaged reading is displayed on the front panel. The front panel does not show an array of readings, only the average of an array. All :READ commands apply to the presently selected function.

The number of readings to average or put in an array is set using the :SENSe:AVERage (for voltage, current and DVM readings) or :SENSe:PCURrent:AVERage (for pulse-current readings) command. See *Section 2* and *Section 3* for details.

NOTE

1. READ? and READ:ARRay? readings are always sent in form indicated by the *FORMat[:DATA]* setting.
2. There are no AVERage commands for long integration measurements. The array size for long integration readings is fixed at one. Therefore, both READ? and READ:ARRay? will return a single long integration reading.

:READ[1]:AMP?	Switch to 5A range, and then take a measurement on battery channel (#1).
:READ[1]:HUNDred?	Switch to 500mA range, and then take a measurement on battery channel (#1).
:READ[1]:FIFTy?	Switch to 50mA range, and then take a measurement on battery channel (#1).
:READ[1]:FIVE?	Switch to 5 mA range, and then take a measurement on battery channel (#1).

NOTE If auto range is enabled on battery channel (#1), the :READ[1]:AMP?, :READ[1]:HUNDred?, :READ[1]:FIFTy?, and :READ[1]:FIVE? commands will disable auto range.

While sending one of these commands, if the selected function is pulse current and the pulse current step feature is enabled (ON), then a settings conflict error message will be generated. To change current ranges when using the pulse current function with step enabled, use the SENS1:CURR:RANG command to change ranges, then send the READ:ARR? command to take the measurements.

The :READ[1]:AMP?, :READ[1]:HUNDred?, :READ[1]:FIFTy?, and :READ[1]:FIVE? commands only apply to the battery channel. First, the command will change range as indicated by command, if needed. Then, the command will take a measurement on the selected function. These commands do not change the function to current. The setting of function remains unchanged. Therefore, make sure the function is set correctly before using these commands. If needed, use the SENS:FUNC command to switch to the desired function.

:MEASure[1][:<function>]?	Execute :READ? on specified function for battery channel (#1)
:MEASure[1]:ARRay[:<function>]?	Execute :READ:ARRay? on specified function for Battery Channel (#1)
:MEASure2[:<function>]?	Execute :READ2? on specified function for charger channel (#2)
:MEASure2:ARRay[:<function>]?	Execute :READ2:ARRay? on specified function charger channel (#2)

Parameters <function> =CURRent[:DC] Measure current
VOLTage[:DC] Measure voltage
PCURrent Measure pulse-current
DVMeter Measure DVM input, applicable for charger channel commands only
LINTegration Perform long integration current measurements.

When the MEASure? command is sent, the specified function is selected and then the READ? is executed. When the MEASure:ARRay? command is sent, the specified function is selected and the READ:ARRay? command is executed. See READ? and READ:ARRay? for details.

If a function is not specified, the measurement(s) will be performed on the active channel's function that is presently selected.

NOTE There are no AVERage commands for long integration measurements. The array size for long integration readings is fixed at one. Therefore, MEASure:LINTegration? and MEASure:ARRay:LINTegration? are basically the same.

BOTHTRG	Trigger battery channel (#1) then charger channel (#2)
BOTHFUNC	Function changes on battery channel (#1) then charger channel (#2)
BOTHFETCH?	Get channel 1 reading then channel 2 reading
BOTHREAD?	Trigger both channels then get both readings

When sending either of the BOTH commands as listed above, make note that the command is applied to battery channel (#1) first and then to charger channel (#2). These commands allow both channels to be controlled with a single bus command. For queries, the battery channel's (#1) reading appears first in a response message, followed by a comma, and then the charger channel's (#2) reading.

Optimizing measurement speed

Auto Zero State

In general, to optimize speed of any application code, you should turn auto zero off. To turn auto zero off, use the AUTO ZERO STATE option under the Main Menu or send the following command over the bus: SYSTem :AZERo:STATe 0.

The system auto zero state setting indicates whether background readings are taken. A background reading is an internal calibration measurement taken by the power supply between user triggered readings. The selected function dictates how many background readings are taken between user triggered readings. Certain settings, such as changes to integration time, force backgrounds to update regardless of this state. Other changes, such as changing voltage level

settings, don't force backgrounds to update if already updated. When backgrounds are forced to update, all must be refreshed before a user triggered reading can be measured.

When auto zero state is set to ON, background readings continuously refresh by cycling when the instrument is idle. When auto zero state is set to OFF, background readings do not occur after being updated unless a change forces them to update. When a change forces an update, the background readings get updated once and stop until the next change forces an update.

To refresh the backgrounds when the state is OFF, set the state to ON then back to OFF. This will refresh the backgrounds only once and stop after that.

Programming examples

The commands below are examples for techniques that combine commands to speed up measurements:

```
*rst                          ' restore factory default settings
syst:azer:stat 0              ' turn auto zero state off
disp:chan 1                   ' sets active channel to battery
sens:func 'curr'              ' select the current measurement function
volt 3                        ' set output voltage to 3
curr 1                        ' set current limit to 1
sens:nplc 0.5                 ' set nplc to 0.5
```

NOTE	For faster measurements, the NPLC can be as short as 0.002

```
outp on                       ' turn the output on
read:five?                    ' switch to the 5 mA current range, trigger a current reading
                                and return it
```

NOTE	To optimize speed, the `read:five?` command combines range changing, triggering a DC current measurement, and taking a reading.

```
sens:func 'volt'              ' select the voltage measurement function
read:fift?                    ' switch to the 50 mA current range, trigger a voltage reading
                                and return it
```

NOTE	To optimize speed, the `read:fift?` command combines range changing, triggering a DC voltage measurement, and taking a reading.

```
sens:func 'pcur'              ' select the pulse current measurement function
sens:pcur:sync:tlev:hund  0.3 ' set the trigger level to 300 mA for 500 mA current range
sens:pcur:sync:tlev:amp   0.7 ' set the trigger level to 700 mA for 5 A current range
sens:pcur:time:high 350e-6    ' set pulse high time to 350 microseconds
read:hund?                    ' switch to the 500mA current range, trigger a pulse current
                                high reading and return it.
```

NOTE	To optimize speed, the `read:hund?` command combines range changing, triggering a pulse current measurement, and taking a reading.

```
read:amp?                    ' switch to the 5 A current range, trigger a pulse current
                               high reading and return it.
```

NOTE	To optimize speed, the `read:amp?` command combines range changing, triggering a pulse current measurement, and taking a reading. Note that in the command sequence above, the trigger level was set to the 5 A range (using the `sens:pcur:sync:tlev:amp` command) before using the `read:hund` command.

GPIB 488.1 protocol

Model 2308 supports two GPIB protocols: SCPI and 488.1. The 488.1 protocol significantly increases speed over the GPIB.

When using the 488.1 protocol, throughput is enhanced for data sent to the power supply (command messages) and for data returned by the power supply (response messages). The speed of readings sent over the GPIB is also increased. Factory default is SCPI protocol.

With the 488.1 protocol selected, you will still use SCPI commands to program the power supply. Operation differences between the two protocols are discussed below.

Selecting the 488.1 protocol

Perform the following steps to select the 488.1 protocol:

NOTE	The 488.1 protocol is a bus-only feature - there is no front panel support.

When switching between the SCPI and 488.1 protocol, the instrument does not reset. The GPIB protocol setting is saved in EEPROM, and the unit will power up with that selected protocol until changed again.

The GPIB protocol can be changed over the bus. If you use the following query to request the state of Message Exchange Protocol (MEP), you will know which protocol is enabled:

```
:SYSTem:MEP[:STATe]?
```

If a "1" is returned, MEP is enabled, and the SCPI protocol is selected. A "0" indicates that MEP is disabled, and the 488.1 protocol is enabled. To summarize:

1 = SCPI protocol

0 = 488.1 protocol

Send the following commands over the GPIB to change the GPIB protocol between SCPI and 488.1:

```
:SYSTem:MEP[:STATe] <1 or ON> Selects SCPI protocol

:SYSTem:MEP[:STATe] <0 or OFF> Selects 488.1 protocol
```

The following rules must be adhered to when sending this command with either parameter setting:

1. The command must be the only command on the line or it must be the last command in the command string.
2. No command or query can be after this command on a line going to the power supply.
3. After sending this command allow some time for the instrument to switch into the new mode and be ready for new commands before sending another command or query.

For example, the following command strings are valid:

```
SYST:MEP ON

SENS:NPLC 1.5; :SYST:MEP OFF
```

The following command strings are invalid:

```
SYST:MEP ON; SENS:NPLC?
```

SYST:MEP OFF; VOLT 2.5

Changing the GPIB mode over the bus will clear the blinking R that indicates remote mode operation.

Protocol differences

The following information covers the differences between the 488.1 and SCPI protocols.

Message exchange protocol (MEP)

When the 488.1 protocol is selected, the MEP is disabled to speed up GPIB operation. The following guidelines/limitations must be followed when using the 488.1 protocol:

1. If a query is sent, it must be the only command on the line or the last of a multiple command line (this limitation also means no multiple queries can be sent). Otherwise, full SCPI command syntax is still supported including long-form and short-form commands, multiple commands, and MIN/MAX/DEF parameter definitions.

   For example, the following command strings are invalid:

   ```
   :SOUR:VOLT?;*OPC?
   :SENS:CURR:RANG?;:READ?
   :READ?;:READ?
   ```

   The following command strings are valid:

   ```
   :SOUR:VOLT 4;*OPC?
   :SENS:NPLC 1.0;:SENS:CURR:RANG MIN
   :SENS:CURR:RANG? MAX
   :READ?
   ```
2. When a query is sent, either the data must be read back or a Device Clear (DCL) or Interface Clear (IFC) must be performed to reset the query.
3. When sending a command or query, do not attempt to read data from the power supply until the terminator has been sent (usually Line Feed with EOI). Otherwise, a DCL or IFC must be sent to reset the input parser.
4. When receiving data, all data, up to and including the terminator (LF with EOI), must be accepted. Otherwise, a DCL or IFC must be sent to reset the output task.
5. Empty command strings (terminator only) should not be sent.

Using SCPI-based programs

In general, an existing SCPI-based program will run properly and faster in the 488.1 protocol as long as it meets the previous guidelines and limitations.

Bus hold-off

`*OPC`, `*OPC?`, and `*WAI` are still functional but are not needed for the 488.1 protocol. When sending commands, the GPIB is automatically held off when it detects a terminator. The hold-off is

released when all the commands have finished executing, or if there is some parser or command error.

Trigger-on-talk

Trigger-on-talk functionality has been added for the 488.1 protocol. If a query has not been received by the instrument, the power supply will automatically assume a read query command has been sent when it is addressed to talk. This technique increases GPIB speed by decreasing the transmission and parser times for the command. Trigger on talk applies to the active channel (`DISP:CHAN?`). If the active channel is the battery channel (#1), then it assumes a `READ1?`; if channel 2 is active, then `READ2?`.

Message available

The MAV (message available) bit in the Serial Poll byte will be set when the query is finished being processed, not when there is data available in the output buffer (as with the SCPI protocol). For the 488.1 protocol, output data will not be formatted until the first request for data is received. This delay may cause unexpected time-outs when using SRQ on MAV for queries that take a long time to execute.

General operation notes

- The remote blinking R on the front panel still operates since it is critical to fundamental GPIB operation.
- If the unit is in REMote, the GTL command may not put the power supply into the local mode. Only the front-panel LOCAL key is guaranteed to operate, if not in local lockout (LLO). GTL will still disable LLO.
- IEEE-488 bus commands and features (GET, IFC, SDC, DCL, LLO, Serial Poll, and SRQ) are still fully supported.
- Multiple TALKs on the same query are supported as in the SCPI protocol. This feature is useful when reading back long ASCII strings.

Trigger on talk both channels

Trigger on talk will return a reading for the active channel `(DISPlay:CHANnel?)` unless you have enabled (ON) the setting for Trig on talk to return two readings—one from each channel comma delimited (for example: ch1 reading, ch2 reading). This command maps trigger on talk to `BOTHREAD?` when enabled.

To enable the two readings trig on talk and have it apply to both channels (`READ1?` for channel 1, READ 2? for channel 2), send:

SYSTem:TRIGger:TALK:BOTH ON

To disable the two readings trig on talk, send:

SYSTem:TRIGger:TALK:BOTH OFF

Bus commands

Table 9-2 contains bus commands for trigger on talk,

Table 9-2
Trigger on talk bus commands

Commands	Description	Default

:SYSTem
:TRIGger
:TALK
:BOTH <b>
 	
:BOTH?
	Path to System commands.
	Path to trigger commands.
	Path to talk commands.
	Set <b> to 1 (or ON) to enable 2 reading trig on talk. 0 (or OFF) disable 2 reading trig on talk, but reads the active channel:
	`CH1: READ1?`
	`CH2: READ2?`
	Query trigger on talk.
		
		OFF

Command notes

SYSTem:TRIGger:TALK:BOTH <b>

This command can be sent in 488.1 or SCPI protocol. However, the setting only affects 488.1 protocol functionality and not used in the SCPI protocol. On power up, this mode is set to disabled (OFF). This setting is not saved in user setups and is not affected by recalling a user setup or sending a `*RST` command. If enabled (ON), the trigger on talk maps to a `BOTHREAD?`. If disabled (OFF), then trigger on talk maps to a `READ1?` if channel 1 is active channel, or a `read2?` if channel 2 is active channel.

After enabling this command and doing a trigger on talk to get the two readings, the active channel (`DISP:CHAN?`) will be the charger channel (#2). Therefore, when the command is disabled the active channel is charger channel (#2).

Trigger continuous mode

While in continuous trigger mode, as soon as a reading is triggered and calculated, the next reading is triggered. On the first reading, the A/D is configured for the desired measurement. While in this mode, a special task is running to acquire the readings. Therefore, do not send any commands to the supply that changes how it is configured. Instead disable the mode, make the changes, and then enable the mode again. While in the mode, it is okay to send query commands.

Bus commands

Table 9-3 contains trigger continuous bus commands.

Table 9-3
Trigger continuous bus commands

Commands	Description	Default
:SYSTem :TRIGger :CONTinuous <b> :CONTinuous?	Path to System commands. Path to trigger commands. Set <b> to 1 (or ON) to enable trigger continuous mode which automatically turns display OFF. 0 (or OFF) disables mode and automatically turns display back ON. Query trigger continuous mode.	 OFF

Command notes

`SYSTem:TRIGger:CONTinuous <b>` Applies to active channel

Trigger continuous mode was designed for use in conjunction with the 488.1 protocol (SYST:MEP:STAT 0). When trigger continuous mode is enabled, the continuous trigger does not cycle background readings, process commands that affect the measurement configuration such as output state, function or integration time, etc., or service the other channel (if the instrument has two channels).

On power up, this mode is set to disabled (OFF). This setting is not saved in user setups. While this mode is enabled, do not recall a user setup or send an `*RST` command.

Using trigger continuous mode

Trigger continuous mode provides a faster reading rate. The fastest reading rate is achieved by enabling this mode along with enabling the 488.1 protocol (`SYST:MEP:STAT 0`). Also, the format for readings can affect speed. Selecting SREal format will provide a faster reading rate than when in ASCII mode. Enabling trigger continuous mode turns display OFF while disabling it turns it back ON.

488.1 protocol and trigger continuous mode enabled

When the 488.1 protocol and trigger continuous mode are both enabled, talking the instrument returns triggered readings. The query `READ?` does not have to be sent before talking the instrument for a reading. When using this configuration (488.1 protocol and trigger continuous mode enabled), the instrument is continuously taking triggered readings. When the power supply is talked without being asked for data, a recently triggered reading is returned.

Changing instrument configuration

To change instrument configuration, disable trigger continuous mode first. Do not change configuration while trigger continuous mode is enabled. After sending the commands to make the desired changes, enable the trigger continuous mode and resume taking fast readings by just talking the instrument.

Programming sequence example

Table 9-4 shows an example of programming for the trigger continuous mode. This example assumes that the 488.1 protocol is already enabled.

Table 9-4
Trigger continuous mode programming example

Command	Description
*RST	// Set the power supply to default reset conditions
FORM SRE	// Select SREal format for readings
Send commands here to configure the instrument for the desired measurements.	
SYST:TRIG:CONT 1	// Enable Continuous Trigger Mode which turns display OFF.
*OPC?	// Query the power supply for when done processing the commands to configure // instrument for desired measurements
Talk the power supply to get the ASCII one response back for *OPC?	
Talk the power supply for readings	

Table 9-4
Trigger continuous mode programming example

Command	Description
Keep talking the power supply for readings	
If after taking readings and desire to make a change in configuration then...	
SYST:TRIG:CONT 0	// Disable Continuous Trigger Mode before changing other settings. This turns // display ON.
Send commands here to make the desired system change.	
SYST:TRIG:CONT 1	// Enable Continuous Trigger Mode which turns display OFF.
*OPC?	// Query the power supply for when done processing the commands to configure // the instrument for desired measurements
Talk the power supply to get the ASCII one response back for *OPC?	
Resume talking and taking power supply readings in continuous trigger mode.	

Section 10
DISPlay and FORMat

In this section:

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FORMat subsystem	10-4
Command notes (SCPI commands - data format)	10-5

DISPlay subsystem

The display subsystem controls the display of the power supply and is summarized in *Table 10-1*.

Table 10-1
SCPI commands - display

Command	Description	Default
:DISPlay		
:ENABle <b>	Turn display on or off.	(see Notes 1, 3)
:BRIGhtness <NRf>	Set brightness for VFD display. Range 0–1.0 Blank display:<NRf> = 0 1/4 brightness:<NRf> ≤ 0.25 1/2 brightness:<NRf> ≤ 0.50 3/4 brightness:<NRf> ≤ 0.75 Full brightness:<NRf> ≤ 1.0	1.0
:DUALvi	Enables (1) or disables (0) dual v and i display.	(see Note 4)
:CHANnel <NRf>	Changes the active display channel (1 for battery and 2 for charger).	1
[:WINDow[1]]		
:TEXT	Text messages:	(see Note 1)
:DATA <a>	Define ASCII message "a" (up to 32 characters).	
:STATe <b>	Enable or disable text message mode.	(see Note 2)

Note:
1. *RST or *RCL have no effect on the display circuitry and user-defined text messages.
2. :STATe <b> when power cycle enable is off <b> =(0)
3. This command is valid if DISP:ENAB is ON after a power cycle.
4. Power on value is 0. See *DISPlay:DUALvi <b>* for more details.

Command notes (SCPI commands - display)

`DISPlay:ENABle <b>` Control display circuitry

Parameters <b> = 0 or OFF Disable display circuitry
1 or ON Enable display circuitry

This command is used to enable and disable the front-panel display circuitry. When disabled, the instrument operates at a higher speed. While disabled, the display is blank.

All front-panel controls (except LOCAL) are disabled. Normal display operation can be resumed by using the `:ENABle` command to enable the display or by putting the power supply into local.

`DISPlay:BRIGhtness <NRf>` Set brightness for VFD display

Parameters <NRf> = 0–1
Blank display: <NRf> = 0
1/4 brightness: <NRf> ≤0.25
1/2 brightness: <NRf> ≤0.50
3/4 brightness: <NRf> ≤0.75
Full brightness: <NRf> ≤1.0

This command is ignored if the remote module is connected. Dependent on the revision level of the firmware, the VFD BRIGHTNESS menu choice may or may not be present in the main menu. If present, the front-panel menu choices are as follows:

FULL BRIGHTNESS
BRIGHTNESS OFF
1/4 BRIGHTNESS
1/2 BRIGHTNESS
3/4 BRIGHTNESS

NOTE Setting this option when a remote is connected via remote or through the bus will be ignored. No error message will be generated.

`DISPlay:DUALvi <b>` Control dual mode

Parameters <b> = 0 or OFF Disable dual mode
1 or ON Enable dual mode

This command is used to enable and disable the front panel DUAL DISPLAY V AND I readings for both channels. When disabled, the instrument operates with SINGLE DISPLAY V AND I, PULSE CURRENT, LONG INTEGRATION, or DVM readings displayed for a single channel, as indicated by the active channel setting (`DISPlay:CHANnel`).

Note that when the unit powers up, the setting is initialized with a zero value (OFF). Saving (`*SAV`) a setup will not save this setting, and a reset (`*RST`) command will not change this setting.

Using the command to recall (`*RCL`) a setup, may change the setting. If the recall setup has a channel function set to something other than VOLTage or CURRent then this setting is disabled (OFF) otherwise the setting is left unchanged.

Enabling Dual V and I mode switches function to VOLTage for each channel unless the function is already VOLTage or CURRent . Dual V and I will be disabled (set to 0) if you change the function on either channel to be PCUR, LINT, or DVM (Channel #2 only). The function can be changed by using the sense function or measure function commands. See the `:FUNCtion` command (SENSe subsystem in *Section 2*) and *Measurement Commands and Optimizing Measurement Speed* for more information.

All front-panel controls are enabled.

`DISPlay:CHANnel <NRf>` Sets active display channel

Parameters <NRf> = 1 or 2
To set front panel to battery channel active:<NRf> = 1
To set front panel to charger channel active:<NRf> = 2

This command sets the active channel on the front-panel display. To set the front-panel display to battery channel active, send a parameter of 1. To set the front-panel display to charger channel active, send a parameter of 2.

From the front-panel, the ◄ or ► keys will toggle the active display channel between battery channel (#1) and charger channel (#2). Note that changing active channels using this method (◄ or ► keys) is only available from one of the following areas:

- display menu,
- main menu,
- pulse current top level menu,
- long integration top level menu,

- and display of data readings.

`DISPlay:TEXT:DATA <a>` Define message on display
`:DISPlay[:WINDow[1]]:TEXT:DATA <a>`

Parameters <a> = ASCII characters for message
Types: String 'aa...a' or "aa...a"
Indefinite Block #0aa...a

This command defines a text message for the display. A message is made up of 32 characters and starts on the top line of the display and wraps down to the bottom line. Spaces are counted as characters and can be used to properly position the message on the display. If your message is less than 32 characters, the appropriate number of spaces are added at the end. If your message is greater than 32 characters, it will not be displayed. On power-up, the message is a string of 32 spaces.

An indefinite block message must be the only command in the program message or the last command in the program message. If you include a command after an indefinite block message (on the same line), it will be treated as part of the message and is displayed instead of executed.

NOTE Use `DISPlay:TEXT:STATe <b>` to enable the text message mode.

`DISPlay:TEXT:STATe <b>` Control message
`:DISPlay[:WINDow[1]]:TEXT:STATe <b>`

Parameters :<b> = 0 or OFF Disable text message
1 or ON Enable text message

This command enables or disables the text message mode. When enabled, the text message is displayed. If no message is defined, a string of 32 spaces is displayed. When disabled, the message is removed from display. The display returns to the normal display state.

A text message remains displayed only as long as the instrument is in remote. Taking the instrument out of remote (by pressing the **LOCAL** key or sending GTL) cancels the message and disables the text message mode.

FORMat subsystem

The commands for this subsystem are used to select the data format for transferring instrument readings over the bus. These commands are summarized in *Table 10-2*.

Table 10-2
SCPI commands - data format

Command	Description	Default
FORMat [:DATA] <type> :BORDer <name>	 Specify data format; ASCii, SREal or DREal. Specify byte order; NORMal or SWAPped.	 ASCii SWAP

Command notes (SCPI commands - data format)

`FORMat[:DATA] <type>` Select data format

Parameters <type> = ASCii ASCII format
SREal IEEE-754 single precision format
DREal IEEE-754 double precision format

This command is used to select the data format for transferring readings over the bus. The reading(s) that is sent depends on the presently selected function (voltage, current, pulse-current, DVM or long integration). See the `:FUNCtion` command (`SENSe` subsystem in *Section 2*) and *Measurement Commands and Optimizing Measurement Speed* for more information.

NOTE Regardless of which data format for output strings is selected, the power supply will only respond to input commands using the ASCII format.

ASCII format

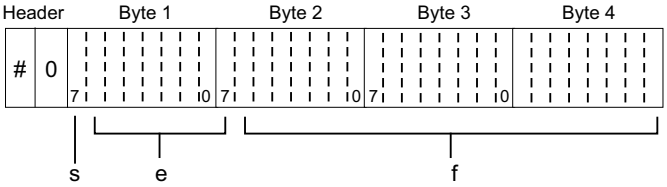
The ASCII data format is in a direct readable form for the operator. Most Basic languages easily convert ASCII mantissa and exponent to other formats. However, some speed is compromised to accommodate the conversion. The following shows the ASCII format for a reading of 10.058 volts.

+1.00580000 E+01

IEEE-754 formats

SREal will select the binary IEEE-754 single precision data format. *Figure 10-1* shows the normal byte order format for each data element (voltage, current, etc.). Note that the data string for each reading conversion is preceded by a 2-byte header that is the binary equivalent of an ASCII # sign and 0. Not shown in *Figure 10-1* is a byte for the terminator that is attached to the end of each data string.

Figure 10-1
IEEE-754 single precision data format



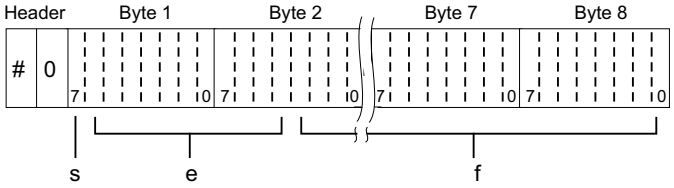
s = sign bit (0 = positive, 1 = negative)
e = exponent bits (8)
f = fraction bits (23)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 4, Byte 3, Byte 2, Byte 1.

The Header is only sent once for each measurement conversion.

DREal selects the binary IEEE-754 double precision data format and is shown in *Figure 10-2* (normal byte order shown). This format is similar to the single precision format except that it is 64 bits long.

Figure 10-2
IEEE-754 double precision data format



Bytes 3, 4, 5, and 6 not shown.

s = sign bit (0 = positive, 1 = negative)
e = exponent bits (11)
f = fraction bits (52)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 8, Byte 7 .... Byte 1.

The Header is only sent once for each measurement conversion.

During binary transfers, never un-talk the power supply until after the data is read (input) to the computer. Also, to avoid erratic operation, the readings of the data string (and terminator) should be acquired in one piece. The header (#0) can be read separately before the rest of the string.

The number of bytes to be transferred can be calculated as follows:

Bytes = 2 + (Rdgs × 4) + 1 for SREAL

Bytes = 2 + (Rdgs × 8) + 1 for DREAL

where: 2 is the number of bytes for the header (#0).

Rdgs is the number of readings to be transferred.

4 or 8 is the number of bytes for each reading.

1 is the byte for the terminator.

For example, assume that the power supply is configured to trigger 10 voltage readings and send the 10 voltage measurements to the computer using the binary format.

Bytes = 2 + (10 × 4) + 1 = 43 for SREAL

Bytes = 2 + (10 × 8) + 1 = 83 for DREAL

`FORMat:BORDer <name>` Specify binary byte order

Parameters <name> = NORMal Normal byte order for binary formats
SWAPped Reverse byte order for binary formats

This command is used to control the byte order for the IEEE-754 binary formats. For normal byte order, the data format for each element is sent as follows:

Byte 1	Byte 2	Byte 3	Byte 4	(Single precision)
Byte 1	Byte 2	• • •	Byte 8	(Double precision)

For reverse byte order, the data format for each element is sent as follows:

Byte 4	Byte 3	Byte 2	Byte 1	(Single precision)
Byte 8	Byte 7	• • •	Byte 1	(Double precision)

The #,0 header is not affected by this command. The header is always sent at the beginning of the data string for each measurement conversion.

Section 11

SCPI Tables

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SCPI command subsystems reference tables

Tables 11-1 to 11-7 summarize the commands for each SCPI subsystem. The following list includes the table numbers and page numbers for each SCPI subsystem command summary.

Table 11-1 DISPlay command summary 11-3
Table 11-2 FORMat command summary 11-4
Table 11-3 OUTPut command summary 11-5
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General notes

- Brackets ([ ]) are used to denote optional character sets. These optional characters do not have to be included in the program message. Do not use brackets in the program message.
- Angle brackets (<>) are used to indicate parameter type. Do not use angle brackets in the program message.
- SCPI - A checkmark (✓) indicates that the command and its parameters are SCPI confirmed. An unmarked command indicates that it is a SCPI command but does not conform to the SCPI standard set of commands. It is not a recognized command by the SCPI consortium. SCPI confirmed commands that use one or more non-SCPI parameters are explained by notes.
- Refer to *Section 6* for GPIB operation.
- Refer to *Section 8* for common commands.
- Refer to each table above for specific command information.

DISPlay command summary

Table 11-1
DISPlay command summary (refer to Display subsystem in *Section 10*)

Command	Description	Default parameter	SCPI
:DISPlay			
:ENABle <b>	Enable or disable display.	ON (Note 1)	✓
:ENABle?	Query state of display.		✓
:BRIGhtness <NRf>	Set brightness for VFD display. Range 0.000–1.000 Blank display: <NRf> = 0 1/4 brightness:<NRf> ≤ 0.25 1/2 brightness:<NRf> ≤ 0.50 3/4 brightness:<NRf> ≤ 0.75 Full brightness:<NRf> ≤ 1.0	1 (Full brightness)	
:BRIGhtness?	Query brightness of display.	(Note 4)	
:DUALvi	Enables (1) or disables (0) dual V and I display.	(Note 5)	
:DUALvi?	Query the dual V and I setting.		
:CHANnel <NRf>	Changes the active display channel (1 for battery and 2 for charger).	1	
:CHANnel?	Query the active display channel setting.		
[:WINDow[1]]	Path to locate message to display:		✓
:TEXT	Control user text message:	(Note 2)	✓
:DATA <a>	Define ASCII message "a" (up to 32 characters).	String of 32 spaces	✓
:DATA?	Query text message.		✓
:STATe <b>	Enable or disable message mode.	OFF (Note 3)	✓
:STATe?	Query state of message mode.		✓

Notes:
1. *RST and *RCL have no effect on display circuitry. Cycling power enables (ON) the display circuit.
2. *RST and *RCL have no effect on a user-defined message. Cycling power cancels all user-defined messages.
3. *RST and *RCL have no effect on the state of the message mode. Cycling power disables (OFF) the message mode.
4. Power on value = 0.
5. Power on value is 0. See *DISPlay:DUALvi <b>* for more details.

FORMat command summary

Table 11-2
FORMat command summary (refer to Format subsystem in *Section 10*)

Command	Description	Default parameter	SCPI
:FORMat			
[:DATA] <type>	Specify data format (ASCii, SREal, or DREal).	ASCii	✓
[:DATA]?	Query data format.		✓
:BORDer <name>	Specify byte order (NORMal or SWAPped).	SWAPped	✓
:BORDer?	Query byte order.		✓

OUTPut command summary

Table 11-3
OUTPut command summary (refer to *Table 2-3* and *Table 5-2*)

Command	Description	Default parameter	SCPI
:OUTPut[1]	OUTPut subsystem for battery channel (#1)		✓
[:STATe] <b>	Turn output ON or OFF.	OFF	✓
[:STATe]?	Query state of output.		✓
:BANDwidth	Specifies HIGH or LOW bandwidth when the output state is ON. When output is OFF, the bandwidth is LOW and the user setting is not applied. Once the output is ON, the user setting takes effect.	LOW	
:BANDwidth?	Query bandwidth setting for when output is ON.		
:IMPedance <NRf>	Specifies the output impedance to apply 0 (OFF) to 1 Ω (max) in 10 mΩ steps.	0	
:IMPedance?	Query impedance setting.		
:RELay1 <name>	Close (ONE) or open (ZERO) relay control circuit for relay 1.	ZERO	
:RELay1?	Query the value at relay 1 port pin digital I/O.		
:RELay2 <name>	Close (ONE) or open (ZERO) relay control circuit for relay 2	ZERO	
:RELay2?	Query the value at relay 2 port pin digital I/O.		
:RELay3 <name>	Close (ONE) or open (ZERO) relay control circuit for relay 3.	ZERO	
:RELay3?	Query the value at relay 3 port pin digital I/O.		
:RELay4 <name>	Close (ONE) or open (ZERO) control circuit for relay 4.	ZERO	
:RELay4?	Query the value at relay 4 port pin digital I/O.		
:OUTPut2	OUTPut subsystem for channel #2 (charger channel)		✓
[:STATe] <b>	Turn output ON or OFF.	OFF	✓
[:STATe]?	Query state of output.		✓
:BANDwidth	Specifies HIGH or LOW bandwidth when the output state is ON. When output is OFF, the bandwidth is LOW and the user setting is not applied. Once the output is ON, the user setting takes effect.	LOW	
:BANDwidth?	Query bandwidth setting for when output is ON.		
:BOTHOUTON* :BOTHOUTOFF*	Turns both power supply channels ON. Turns both power supply channels OFF.		

*No query or short form exists.

SENSe command summary

Table 11-4
SENSe command summary (refer to *Table 2-3*, *Table 3-2*, and *Table 4-2*)

Command	Description	Default parameter	SCPI
:SENSe[1]	SENSe subsystem for battery channel (#1)		
:FUNCtion <name>	Select measurement function ("VOLTage," "CURRent," "PCURrent," or "LINTegration").	VOLT	
:FUNCtion?	Query measurement function.		
:NPLCycles <n>	Specify integration rate (in line cycles) for voltage and current (0.002 to 10).	1	✓
:NPLCycles?	Query integration rate.		✓
:AVERage <NRf>	Specify the average count for voltage and current (1 to 10).	1	
:AVERage?	Query average count.		
:CURRent[:DC]	Path to configure the current measurement function:		✓
:RANGe	Current measurement range:		✓
[:UPPer] <NRf>	Change ranges based on NRf value. NRf value setting will designate one of four ranges: 5 mA, 50 mA, 500 mA and 5 A.	5.0	✓
[:UPPer]?	Query current measurement range.		✓
:AUTO <b>	Enable or disable auto range.	OFF	✓
:AUTO?	Query state of auto range.		
:PCURrent	Path to configure the pulse-current measurement function (see *Section 3*):		
:AVERage <NRf>	Specify average count (dependent on SYNC:STAT): pulse-current measurements: 1 to 100 (sync ON) pulse current digitization: 1 to 5000 (sync OFF)	1	
:AVERage?	Query average count (dependent on SYNC:STAT).		
:MODE <name>	Select pulse-current measurement mode (HIGH, LOW, or AVERage).	HIGH	
:MODE?	Query pulse-current measurement mode.		
:TIME	Path to set pulse-current integration times:		
:AUTO	Power supply sets integration times - accounts for internal trigger delay but not user delay (:DEL).		
:HIGH <NRf>	Specify integration time (in sec) for high pulse measurements (33.33E-06 to 0.8333) - accounts neither for internal trigger delay nor user delay. Setting applies when SYNC:STATe is ON.	3.333E-05	
:HIGH?	Query high integration time.		

*No query or short form exists.

Table 11-4
SENSe command summary (refer to *Table 2-3*, *Table 3-2*, and *Table 4-2*)

Command	Description	Default parameter	SCPI
:LOW <NRf>	Specify integration time (in sec) for low pulse measurements (33.33E-06 to 0.8333) - accounts neither for internal trigger delay nor user delay. Setting applies when SYNC:STATe is ON.	3.333E-05	
:LOW?	Query low integration time when SYNC:STATe is ON.		
:AVERage <NRf>	Set integration time in seconds for measurement of pulse AVERage time -accounts neither for internal trigger delay nor user delay. Setting applies when SYNC:STATe is ON.	3.333E-05	
:AVERage?	Query average integration time when SYNC:STATe is ON.		
:DIGitize <NRf>	Specify integration time (in sec) for digitizing or burst measurements; 33.33e-6 to 0.8333. Setting applies when SYNC:STATe is OFF.	3.333e-5	
:DIGitize?	Query integration time for digitizing or burst measurements when SYNC:STATe is OFF.		
:STEP <b>	To perform a series of step measurements, set to ON.	OFF	
:STEP?	Query state for performing step measurements.		
:UP <NRf>	Specify number of UP steps <0-20> (max is for both up and down combined).	1	
:UP?	Query number of UP steps specified.		
:DOWN <NRf>	Specify number of DOWN steps <0-20> (max is for both up and down combined).	1	
:DOWN?	Query number of DOWN steps specified.		
:TIME <NRf>	Specify step integration time for UP plus DOWN steps: 33.3µsec–100msec.	200µsec	
:TIME?	Query step integration time specified for UP plus DOWN steps.		
:TimeOUT <NRf>	Step TimeOUT (other than the first step): 2msec–200msec.	2ms	
:TimeOUT?	Query step TimeOUT setting for all steps but the first step.		
:INITial <NRf>	TimeOUT for the first step: 10msec–60secs.	2sec	
:INITial?	Query TimeOUT setting for the first step.		
:DELay <NRf>	Step delay: 0msec–100msec (in 10msec steps).	0	
:SEQuence <NRf, NRf>	Define up to 19 delay sequence values using the index and the time value (e.g. "1,1e-3" sets the first delay to 1ms). Ranges: 1-19 (parameter 1) and 0 to 100e-3 (parameter 2).	0	

*No query or short form exists.

Table 11-4
SENSe command summary (refer to *Table 2-3*, *Table 3-2*, and *Table 4-2*)

Command	Description	Default parameter	SCPI
:LENgth <NRf>	Define the delay sequence length (0 to 19). Specify zero to always use the PCUR:STEP:DELay value.	0	
:SKIP <b>	Specify whether (1) or not (0) to skip sequential triggers. 1=Only requires 1 trigger 0 = Requires multiple triggers	0	
:DELay?	Query setting for step delay.		
:TLEVx <NRf>	Set trigger level for each TLEV step (*x* equals 1–20) (the maximum settings are based on the selected current range. Therefore, the current range must be selected before setting the step trigger level values) .	0.0	
:TLEVx?	Query setting for trigger level for each TLEV step (*x* equals 1–20).		
:SYNChronize	Pulse detection triggering:		
[:STATe] <b>	Send ON to select pulse current measurements or OFF to select pulse current digitization.	ON	
[:STATe]?	Query pulse current measurement type.		
:TLEVel	Trigger level:		
[:AMP] <NRf>	Set the trigger level in amps for use when on the 5 A current range: 0.0 A-5.0 A in 5 mA steps.	0.0	
[:AMP]?	Query setting for trigger level in amps for use when on the 5 A current range.		
:HUNDred <NRf>	Set the trigger level in amps for use when on the 500 mA current range: 0.0 mA-500 mA in 0.5 mA or 500 μA steps.	0.0	
:HUNDred?	Query setting for trigger level in amps for use when on the 500 mA current range.		
:FIFTy <NRf>	Set the trigger level in amps for use when on the 50 mA current range: 0.0 mA-50 mA in 0.05 mA or 50 μA steps	0.0	
:FIFTy?	Query setting for trigger level in amps for use when on the 50 mA current range.		
:FIVE <NRf>	Set the trigger level in amps for use when on the 5 mA current range: 0.0 mA-5 mA in 0.005 mA or 5 μA steps.	0.0	
:FIVE?	Query setting for trigger level in amps for use on the 5 mA current range.		
:DELay <NRf>	Specify trigger delay in seconds: 0.0–0.1 (pulse current measurements) or 0.0–5.0 (pulse current digitization).	0.0	
:DELay?	Query specified trigger delay (dependent on SYNC:STAT).		

*No query or short form exists.

Table 11-4
SENSe command summary (refer to *Table 2-3*, *Table 3-2*, and *Table 4-2*)

Command	Description	Default parameter	SCPI
:FAST <b>	Enable or disable pulse current fast readings.	OFF	
:FAST?	Query pulse current fast reading setting.		
:SEARch <b>	Enable or disable pulse current search.	ON	
:SEARch?	Query pulse current search setting.		
:DETect <b>	Enable or disable pulse current detection mode.	OFF	
:DETect?	Query pulse current detection mode setting.		
:TimeOUT <NRf>	Specify length of timeout: 5ms - 32s incrementing in 1ms.	1 (sec)	
:TimeOUT?	Query pulse current timeout setting.		
:LINTegration	Path to configure long integration measurements (refer to *Section 4*):		
:TEDGe <name>	Set trigger edge to start long integration measurement (RISING, FALLING, NEITHER).	RISING	
:TEDGe?	Query trigger edge setting.		
:TIME <NRf>	Set integration time in seconds: X to 60 where X is 0.850 for 60Hz line frequency or 0.840 for 50Hz line frequency.	1.00	
:TIME?	Query integration time.		
:AUTO	Power supply sets integration time.		
:TLEVel	Path to set trigger level.		
[:AMP] <NRf>	Set the trigger level in amps for use on the 5 A current range: 0.0 A-5.0 A in 5 mA steps.	0	
[:AMP]?	Query setting for trigger level in amps for use on the 5 A current range.		
:HUNDred <NRf>	Set the trigger level in amps for use on the 500 mA current range: 0.0 mA-500 mA in 0.5 mA or 500 μA steps.	0	
:HUNDred?	Query setting for trigger level in amps for use on the 500 mA current range.		
:FIFTy <NRf>	Set the trigger level in amps for use on the 50 mA current range: 0.0 mA-50 mA in 0.05 mA or 50 uA steps	0	
:FIFTy?	Query setting for trigger level in amps for use on the 50 mA current range.		
:FIVE <NRf>	Set the trigger level in amps for use on the 5 mA current range: 0.0 mA-5 mA in 0.005 mA or 5 μA steps.	0	
:FIVE?	Query setting for trigger level in amps for use on the 5 mA current range trigger level setting.		
:TimeOUT <NRf>	Specify length of timeout: 1 to 63 (seconds).	16	

*No query or short form exists.

Table 11-4
SENSe command summary (refer to *Table 2-3*, *Table 3-2*, and *Table 4-2*)

Command	Description	Default parameter	SCPI
:TimeOUT?	Query timeout.		
:SEARch <b>	Enable or disable pulse search.	ON	
:SEARch?	Query state of pulse search.		
:FAST <b>	Enable or disable long integration fast readings mode.	OFF	
:FAST?	Query long integration fast readings mode.		
:DETect <b>	Enable or disable long integration detect pulse only mode.	OFF	
:DETect?	Query detect mode.		
:SENSe2	SENSe subsystem for channel #2 (charger channel).		
:FUNCtion <name>	Select measurement function ("VOLTage," "CURRent," "DVMeter", "PCURrent," or "LINTegration").	VOLT	
:FUNCtion?	Query measurement function.		
:NPLCycles <n>	Specify integration rate (in line cycles) for voltage, current, and DVM measurements (0.002 to 10).	1	✓
:NPLCycles?	Query integration rate.		✓
:AVERage <NRf>	Specify the average count for voltage, current, and DVM measurements (1 to 10).	1	
:AVERage?	Query average count.		
:CURRent[:DC]	Path to configure the current measurement function:		✓
:RANGe	Current measurement range:		✓
[:UPPer] <NRf>	Specify expected current measurement which will select 5 mA or 5 A for current range.	5.0	✓
[:UPPer]?	Query current measurement range.		✓
:AUTO <b>	Enable or disable auto range.	OFF	✓
:AUTO?	Query state of auto range.		
:PCURrent	Path to configure the pulse-current measurement function (refer to *Section 3*):		
:AVERage <NRf>	Specify average count (dependent on SYNC:STAT): pulse-current measurements: 1 to 100 (sync ON) pulse current digitization: 1 to 5000 (sync OFF)	1	
:AVERage?	Query average count (dependent on SYNC:STAT).		
:MODE <name>	Select pulse-current measurement mode (HIGH, LOW, or AVERage).	HIGH	
:MODE?	Query pulse-current measurement mode.		

*No query or short form exists.

Table 11-4
SENSe command summary (refer to *Table 2-3*, *Table 3-2*, and *Table 4-2*)

Command	Description	Default parameter	SCPI
:SENSe2			
:PCURrent			
:TIME	Path to set pulse-current integration times:		
:AUTO	Power supply sets integration times - accounts for internal trigger delay but not user delay (:DEL).		
:HIGH <NRf>	Specify integration time (in sec) for high pulse measurements (33.33E-06 to 0.8333) - accounts neither for internal trigger delay nor user delay. Setting applies when SYNC:STATe is ON.	3.333E-05	
:HIGH?	Query high integration time when SYNC:STATe is ON.		
:LOW <NRf>	Specify integration time (in sec) for low pulse measurements (33.33E-06 to 0.8333) - accounts neither for internal trigger delay nor user delay. Setting applies when SYNC:STATe is ON.	3.333E-05	
:LOW?	Query low integration time when SYNC:STATe is ON.		
:AVERage <NRf>	Set integration time in seconds for measurement of pulse AVERage time - accounts neither for internal trigger delay nor user delay. Setting applies when SYNC:STATe is ON.	3.333E-05	
:AVERage?	Query average integration time when SYNC:STATe is ON.		
:DIGitize <NRf>	Specify integration time (in sec) for digitizing or burst measurements; 33.33e-6 to 0.8333. Setting applies when SYNC:STATe is OFF.	3.333e-5	
:DIGitize?	Query integration time for digitizing or burst measurements when SYNC:STATe is OFF.		
:SYNChronize	Path for pulse detection triggering:		
[:STATe] <b>	Send ON to select pulse current measurements, or OFF to select pulse current digitization.	ON	
[:STATe]?	Query pulse current synchronization selection.		
:DELay <NRf>	Specify trigger delay in seconds (dependent on SYNC:STAT): pulse-current measurements: 0 to 0.1 (sync ON) pulse current digitization: 0 to 5 (sync OFF)	0	
:DELay?	Query specified trigger delay (dependent on SYNC:STAT).		
:TLEVel <NRf>	Set trigger level value 0–5 A in 5 mA steps.	0	
:TLEVel?	Query trigger level setting.		
:FAST <b>	Enable or disable pulse current fast readings.	OFF	
:FAST?	Query pulse current fast reading setting.		

*No query or short form exists.

Table 11-4
SENSe command summary (refer to *Table 2-3*, *Table 3-2*, and *Table 4-2*)

Command	Description	Default parameter	SCPI
:SEARch <b>	Enable or disable pulse current search.	ON	
:SEARch?	Query pulse current search setting.		
:DETect <b>	Enable or disable pulse current detection mode.	OFF	
:DETect?	Query pulse current detection mode setting.		
:TimeOUT <NRf>	Specify length of timeout: 5ms - 32s incrementing in 1ms.	1 (sec)	
:TimeOUT?	Query pulse current timeout setting.		
:LINTegration	Path to configure long integration measurements (refer to *Section 4*):		
:TEDGe <name>	Set trigger edge to start long integration measurement (RISING, FALLING, NEITHER).	RISING	
:TEDGe?	Query trigger edge setting.		
:TIME <NRf>	Set integration time in seconds: X to 60 where X is 0.850 for 60Hz or 0.840 for 50Hz).	1.00	
:TIME?	Query integrations time.		
:AUTO	Power supply sets integrations time.		
:TLEVel <NRf>	Set trigger level value 0–5 A in 5 mA steps.	0	
:TLEVel?	Query trigger level setting.		
:TimeOUT <NRf>	Specify length of timeout: 1 to 63 (seconds).	16	
:TimeOUT?	Query timeout.		
:SEARch <b>	Enable or disable pulse search.	ON	
:SEARch?	Query state of pulse search.		
:FAST <b>	Enable or disable long integration fast readings mode.	OFF	
:FAST?	Query long integration fast readings mode.		
:DETect <b>	Enable or disable long integration detect pulse only mode.	OFF	
:DETect?	Query detect mode.		
:BOTHFUNC <name>*	Sets the battery channel (#1), then the charger channel (#2) to the function specified by <name>. Valid strings for <name> are "VOLTage", "CURRent", "PCURrent", or "LINTegration".		

*No query or short form exists.

SOURce command summary

Table 11-5
SOURce command summary (refer to *Table 2-3*)

Command	Description	Default parameter	SCPI
[:SOURce[1]]	SOURce subsystem for battery channel (#1).		
:VOLTage	Path to set output voltage.		✓
:PROTection <NRf>	Sets VPT offset (0–8V).	8V	
:PROTection?	Query setting for VPT offset.		
:STATe?	Query state of VPT - no associated command.		
:CLAMp <b>	Sets VPT clamp mode ON or OFF.	OFF	
:CLAMp?	Query state of VPT clamp mode.		
[:LEVel]			✓
[:IMMediate]			
[:AMPLitude] <n>	Specify voltage amplitude in volts: 0–15V with 1mV resolution.	0.0	✓
[:AMPLitude]?	Query voltage amplitude.		✓
:CURRent	Path to configure current.		✓
[:LIMit]	Path to configure current limit.		
[:VALue] <NRf>	Specify current limit value in amps: 0.006–5 with 100μA resolution.	0.25	
[:VALue]?	Query current limit.		
:TYPE <name>	Select current limit type: LIMit or TRIP.	LIM	
:TYPE?	Query current limit type.		
:STATe?	Query state of current limit: 1 = in current limit (for LIMit type) or output tripped (for TRIP type), 0 = not in LIMit/TRIP.		
:SOURce2	SOURce subsystem for channel #2 (charger channel).		
:VOLTage	Path to set output voltage.		✓
:PROTection <NRf>	Sets VPT offset (0–8V).	8V	
:PROTection?	Query setting for VPT offset.		
:STATe?	Query state of VPT - no associated command.		
:CLAMp <b>	Sets VPT clamp mode ON or OFF.	OFF	
:CLAMp?	Query state of VPT clamp mode.		
[:LEVel]			✓
[:IMMediate]			
[:AMPLitude] <n>	Specify voltage amplitude in volts: 0–15 with 1mV resolution.	0.0	✓

Table 11-5
SOURce command summary (refer to *Table 2-3*)

Command	Description	Default parameter	SCPI
[:AMPLitude]?	Query voltage amplitude.		✓
:CURRent	Path to configure current.		✓
[:LIMit]	Path to configure current limit.		
[:VALue] <NRf>	Specify current limit value in amps: 0.006–5 with 100μA resolution.	0.25	
[:VALue]?	Query current limit.		
:TYPE <name>	Select current limit type: LIMit or TRIP.	LIM	
:TYPE?	Query current limit type.		
:STATe?	Query state of current limit: 1 = in current limit (for LIMit type) or output tripped (for TRIP type), 0 = not in LIMit/TRIP.		

STATus command summary

Table 11-6
STATus command summary (refer to *Section 7*)

Command	Description	Default parameter	SCPI
:STATus		(Note 1)	✓
:MEASurement	Path to control the measurement event registers:		
[:EVENt]?	Read the event register.	(Note 2)	
:ENABle <NRf>	Program the enable register.	(Note 3)	
:ENABle?	Read the enable register.		
:CONDition?	Read the condition register.		
:OPERation	Path to control the operation status registers:		✓
[:EVENt]?	Read the event register.	(Note 2)	✓
:ENABle <NRf>	Program the enable register.	(Note 3)	✓
:ENABle?	Read the enable register.		✓
:CONDition?	Read the condition register.		✓
:QUEStionable	Path to control the questionable status registers:		✓

Notes:
1. Commands in this subsystem are not affected by *RST. The effects of cycling power, *CLS, and :STATus:PRESet are explained by the following notes.
2. Event registers — Power-up and *CLS - Clears all bits of the registers :STATus:PRESet - No effect
3. Enable registers — Power-up and :STATus:PRESet - Clears all bits of the registers *CLS - No effect
4. Error queue — Power-up and *CLS - Clears the error queue :STATus:PRESet - No effect
5. Enable/disable error queue messages — Power-up - Clears list of messages *CLS and :STATus:PRESet - No effect

Table 11-6
STATus command summary (refer to *Section 7*)

Command	Description	Default parameter	SCPI
[:EVENt]?	Read the event register.	(Note 2)	✓
:ENABle <NRf>	Program the enable register.	(Note 3)	✓
:ENABle?	Read the enable register.		✓
:CONDition?	Read the condition register.		✓
:PRESet	Return status registers to default states.		✓
:QUEue	Path to access error queue.		✓
[:NEXT]?	Read the least recent error message.	(Note 4)	✓
:ENABle <list>	Specify error and status messages for queue.	(Note 5)	✓
:ENABle?	Read the enabled list of messages.		✓
:DISable <list>	Specify messages not to be placed in queue.	(Note 5)	✓
:DISable?	Read the disabled messages.		
:CLEar	Clear all messages from error queue.		

Notes:
1. Commands in this subsystem are not affected by *RST. The effects of cycling power, *CLS, and :STATus:PRESet are explained by the following notes.
2. Event registers — Power-up and *CLS - Clears all bits of the registers; :STATus:PRESet - No effect
3. Enable registers — Power-up and :STATus:PRESet - Clears all bits of the registers; *CLS - No effect
4. Error queue — Power-up and *CLS - Clears the error queue :STATus:PRESet - No effect
5. Enable/disable error queue messages — Power-up - Clears list of messages; *CLS and :STATus:PRESet - No effect

SYSTem command summary

Table 11-7
SYSTem command summary (refer to System subsystem in *Section 10*)

Command	Description	Default parameter	SCPI
:SYSTem			
:VERSion?	Query SCPI version level.		✓
:ERRor?	Read and clear oldest message in error queue.		
:CLEar	Clears error queue.		
:LFRequency?	Query power line frequency setting.		
:POSetup <name>	Select power-on setup: RST or SAVx, where: x = 0 to 3	RST	
:POSetup?	Query power-on setup.		

Table 11-7
SYSTem command summary (refer to System subsystem in *Section 10*)

Command	Description	Default parameter	SCPI
:MEP	Path to select GPIB protocol.		
[:STATe] <b>	Select 488.1 (OFF) or SCPI (ON) protocol.	ON	
[:STATe]?	Query selected protocol.		
:AZERo	Path to control auto zero.		
:STATe <b>	Enable (ON) or disable (OFF) auto zero.	ON	
:STATe?	Query auto zero state.		
:TRIGger	Path to trigger commands		
:TALK	Path to talk commands.		
:BOTH <b>	Set <b> to 1 (or ON) to enable 2 reading trig on talk. 0 (or OFF) disable 2 reading trig on talk, but reads the active channel: CH1: READ1? CH2: READ2?	OFF	
:BOTH?	Query trigger on talk.		
:CONTinuous <b>	Set <b> to 1 (or ON) to enable trigger continuous mode which automatically turns display OFF. 0 (or OFF) disables mode and automatically turns display back ON.	OFF	
:CONTinuous?	Query trigger continuous mode.		

Section 12
Performance Verification

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Introduction

The procedures in this section verify that measurement accuracy is within the limits stated in the accuracy specifications. Perform these verification procedures:

- When you first receive the unit to make sure that it was not damaged during shipment.
- To verify that the unit meets factory specifications.
- To determine if calibration is required.
- Following calibration to make sure it was performed properly..

WARNING	***The information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.***

Verification test requirements

NOTE	If the unit is still under warranty, and its performance is outside specified limits, contact your Keithley Instruments representative or the factory to determine the correct course of action.

Be sure that you perform the verification tests:

- Under the proper environmental conditions.
- After the specified warm-up period.
- Using the correct line voltage.
- Using the proper test equipment.
- Using the specified output signals and reading limits.

Environmental conditions

Conduct your performance verification procedures in a test environment with:

- An ambient temperature of 18-28°C (65-82°F).
- A relative humidity of less than 70% unless otherwise noted.

Warm-up period

Allow the Model 2308 to warm up for at least one hour before conducting the verification procedures.

If the unit has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

The Model 2308 requires a line voltage of 100 to 240 V and a line frequency of 50 or 60 Hz. Verification tests must be performed within this range.

Recommended test equipment

Table 12-1 summarizes recommended verification equipment. You can use alternate equipment as long as that equipment has specifications at least four times better than corresponding Model 2308 specifications. Keep in mind, however, that test equipment accuracy will add to the uncertainty of each measurement.

Table 12-1
Recommended verification equipment

Description	Manufacturer/Model	Specifications
Digital Multimeter	Keithley 2001	DC Voltage* 20 V: ± 22 ppm 2 V ± 20 ppm Resistance* 20 Ω: ± 59 ppm 200 Ω ± 43 ppm 20k Ω: ± 36 ppm
Precision Resistor		1 Ω, 0.1%, 100 W**
Precision Resistor		30 Ω, 0.1%, 50 W***
Precision Resistor		3k Ω, 0.1%, 0.25 W**

*Full-range, 90-day, 23°C various measurement points.
**Characterize resistor using 4-wire ohms function of DMM before use.
***Characterize resistor using 4-wire ohms function and 200Ω range of DMM before use. See *Resistor considerations* for temperature coefficient.

Resistor connections

When performing the verification tests that use the precision resistors, be sure to connect the OUTPUT #1 or OUTPUT #2 SENSE leads and Model 2001 DMM test leads as close to the resistor body as possible.

Resistor considerations

The test resistors should be characterized using the lowest possible range and the 4-wire ohms function of the DMM recommended in *Table 12-1* to measure the resistance values. Use the measured resistance values to calculate the actual currents during the test procedures.

NOTE The temperature coefficient and temperature change of the 1 Ω resistor when passing current at full load must be low enough so that the change in resistance does not cause incorrect readings. This is summarized in the following equation:

$$\frac{V_{OUT}}{(R + \Delta R)} < 25\% \text{ of Model 2308 amps specification}$$

Where: VOUT is the output voltage

R is the characterized value of the resistor

DR is the change in resistance caused by heating

Verification limits

The verification limits stated in this section have been calculated using only the Model 2308 accuracy specifications, and they do not include test equipment uncertainty. If a particular measurement falls outside the allowable range, recalculate new limits based both on Model 2308 specifications and corresponding test equipment specifications.

Example limits calculation

As an example of how verification limits are calculated, assume you are testing the unit using a 10 V output value. Using the voltage output accuracy specification of ±(0.05% of output + 3 mV offset), the calculated output limits are:

Output limits = 10 V ± [(10 V X 0.05%) + 3 mV]

Output limits = 10 V ± (0.005 + 0.003)

Output limits = 10 V ± 0.008 V

Output limits = 9.992 V to 10.008 V

Performing the verification test procedures

Test summary

- DC voltage output accuracy

- DC voltage readback accuracy
- DC current output accuracy
- DC current readback accuracy
- Digital voltmeter input accuracy

If the Model 2308 is not within specifications and out of warranty, see the calibration procedures in *Section 13* for information on calibrating the unit.

Test considerations

When performing the verification procedures:

- Make sure that the test equipment is properly warmed up and connected to the correct OUTPUT #1 or OUTPUT #2 terminals on the rear panel, as appropriate for the channel you are testing.
- Before setting output values, select battery channel (#1) or charger channel (#2) as required. Press the ◄ or ► keys to toggle between battery channel (#1) (OUTPUT #1 terminals) and charger channel (#2) (OUTPUT #2 terminals).
- Be sure the test equipment is set up for the proper function and range.
- Do not connect test equipment to the Model 2308 through a scanner, multiplexer, or other switching equipment.
- Be sure that the Model 2308 output is turned on before making measurements.
- Allow the unit output signal to settle before making a measurement.

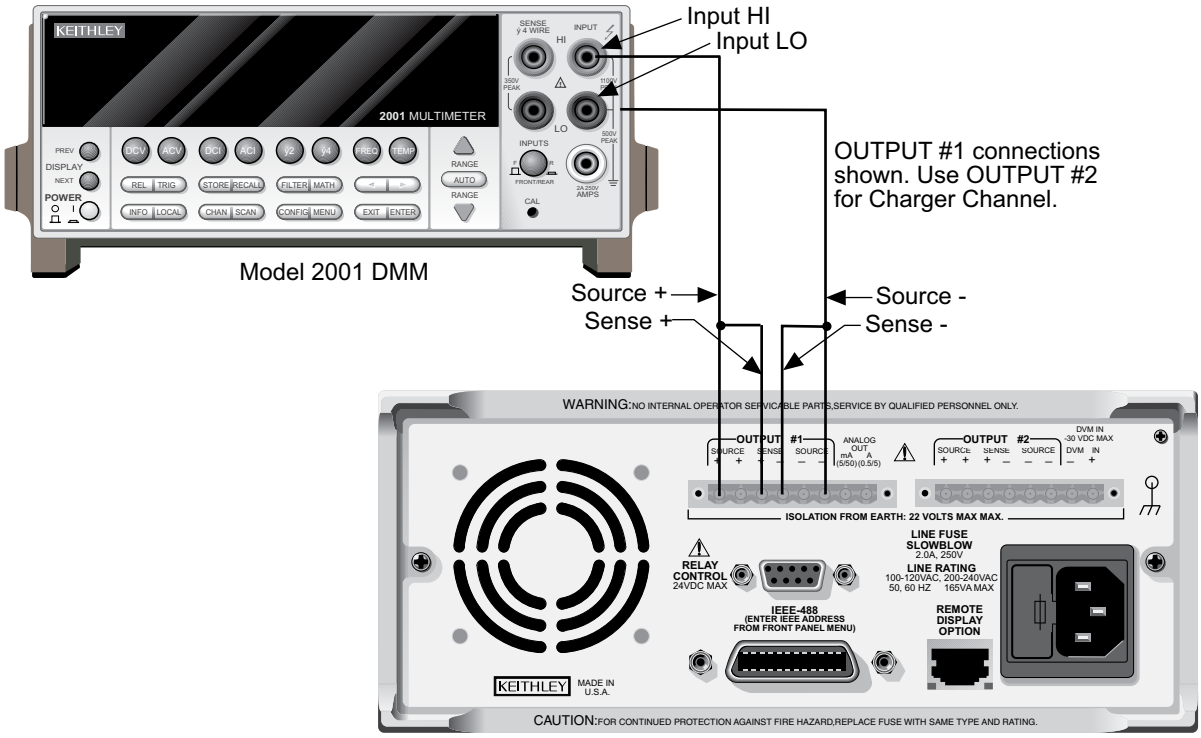
Output voltage accuracy

NOTE	When verifying the battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

Follow the steps below to verify that the output voltage accuracy is within specified limits. This test involves setting the output voltage to specific values and measuring the voltages with a precision digital multimeter.

1. With the power supply's output off, connect the digital multimeter to the OUTPUT #1 SOURCE and SENSE terminals, as shown in *Figure 12-1*. Be sure to observe proper polarity (SOURCE + and SENSE + to INPUT HI; SOURCE - and SENSE - to INPUT LO).

Figure 12-1
Connections for voltage verification tests



2. Select the multimeter DC volts measuring function, and enable auto-ranging.
3. Press the ◄ or ► keys to select Channel **#1**. Make sure the output is turned on.
4. Verify output voltage accuracy for each of the voltages listed in *Table 12-2*. For each test point:
   - Set the output voltage to the indicated value.
   - A value of current compliance of 0.25 A is sufficient.
   - Allow the reading to settle.
   - Verify that the multimeter reading is within the limits given in the table.
5. Repeat steps 1 through 4 for Channel #2 (use the ◄ or ► keys to toggle between Channel #1 and Channel #2)

Table 12-2
Output voltage accuracy limits*

Model 2308 output voltage setting	**Output voltage limits (2 Years, 18°C-28°C)**
5.00 V	4.9945 to 5.0055 V
10.00 V	9.992 to 10.008 V
15.00 V	14.9895 to 15.0105 V

*Check the complete Model 2308 Specifications at

Voltage readback accuracy

NOTE	When verifying the battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

Follow the steps below to verify that the voltage readback accuracy is within specified limits. The test involves setting the source voltage to specific values, as measured by a digital multimeter, and then verifying that voltage readback readings are within required limits.

To verify that voltage readback accuracy is within specified limits:

1. With the power supply's output off, connect the digital multimeter to the OUTPUT #1 SOURCE and SENSE terminals, as shown in *Figure 12-1*. Be sure to observe proper polarity (SOURCE + and SENSE + to INPUT HI; SOURCE - and SENSE - to INPUT LO).
2. Select the multimeter DC volts function, and enable auto-ranging.
3. Select Channel **#1** by pressing the ◄ or ► keys to toggle between Channel **#1** and Channel **#2**. Make sure actual voltage readings are being displayed (use DISPLAY).
4. Turn on the output.
5. Verify voltage readback accuracy for each of the voltages listed in *Table 12-3*. For each test point:
   - Set the output voltage to the indicated value as measured by the digital multimeter. If it is not possible to set the voltage source precisely to the specified value, use the closest possible setting and modify reading limits accordingly.
   - Set compliance current to 0.25 A (or 250 mA).
   - Allow the reading to settle.
   - Verify that the actual voltage reading is within the limits given in the table.
6. After changing connections to OUTPUT #2, repeat steps 1 through 4 for Channel **#2** (use the ◄ or ► keys to toggle between Channel #1 and Channel #2).

Table 12-3
Voltage readback accuracy limits*

Model 2308 output Voltage setting**	Voltage readback limits (2 Years, 18°C-28°C)
5.00 V	4.995 to 5.005 V
10.00 V	9.992 to 10.008 V
14.00 V	13.990 to 14.010 V

*Check the complete Model 2308 Specifications at

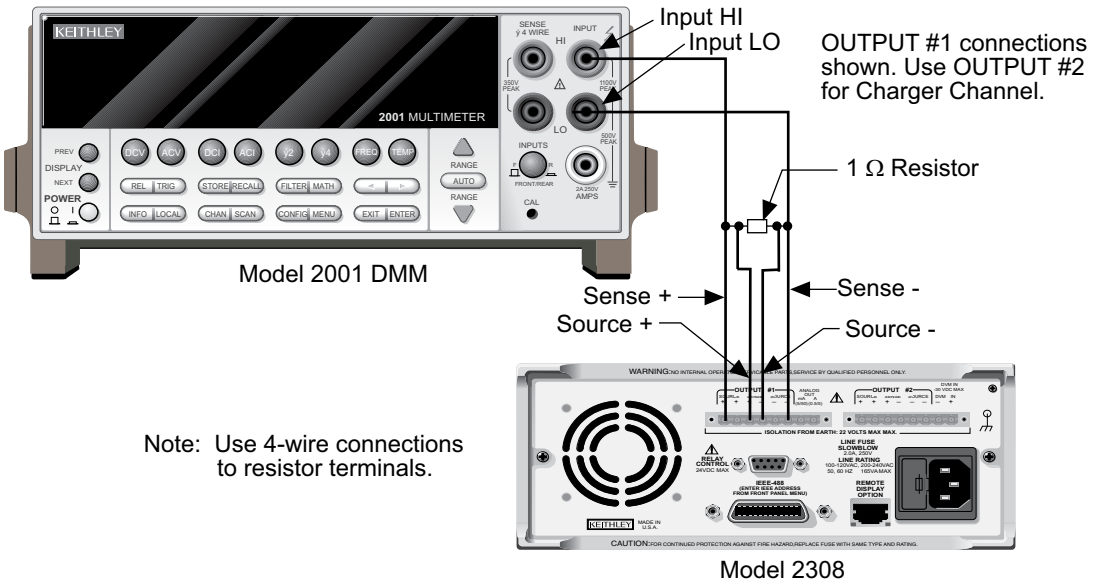
Compliance current accuracy

NOTE	When verifying the battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

Follow the steps below to verify compliance current accuracy is within specified limits. The test involves setting the compliance current to specific values and determining the actual current by measuring the voltages across a characterized 1 Ω resistor with a precision digital multimeter.

1. With the power supply's output off, connect the digital multimeter and characterized 1 Ω resistor to OUTPUT #1 SOURCE terminals, as shown in *Figure 12-2*. Be sure to observe proper polarity (SOURCE + to INPUT HI; SOURCE - to INPUT LO). Be sure to use 4-wire connections to the resistor terminals.

Figure 12-2
Connections for output current and 5 A range current verification tests



2. Select the multimeter DC voltage measuring function, and enable auto-ranging.
3. Select Channel **#1** by pressing the ◄ or ► keys to toggle between Channel **#1** and Channel **#2**. Make sure actual voltage readings are being displayed (use DISPLAY).
4. Turn on the output.
5. Verify compliance current accuracy for the currents listed in *Table 12-4*. For each test point:

- Set the output voltage to 8 V, and set the compliance current to the value being tested.
- Note and record the digital multimeter voltage reading.
- Calculate the current from the voltage reading and actual 1 Ω resistor value: I = V/R.
- Verify that the current is within the limits given in the table.

6. Repeat steps 1 through 4 for Channel **#2** (use the ◄ or ► keys to toggle between Channel #1 and Channel #2).

Table 12-4
Compliance current accuracy limits*

Model 2308 compliance current setting	Compliance current limits (2 Years, 18°C-28°C)
1.000 A	0.993 to 1.007 A
2.000 A	1.992 to 2.008 A
3.000 A	2.990 to 3.010 A
4.000 A	3.989 to 4.011 A
4.500 A	4.488 to 4.512 A

*Check the complete Model 2308 Specifications at

Current readback accuracy

The test used to verify that current readback accuracy is within specified limits involves setting the output current to specific values as measured with a resistor and precision digital multimeter.

5 A range readback accuracy

NOTE	When verifying the battery channel (#1), make sure to connect the source + and source - to the same pair of pins (both in or both out) on the connector. Do not mix them due to the internal resistance present on the inner ones. Doing so will generate incorrect verification data.

To verify that current readback accuracy is within specified limits:

1. With the power supply's output off, connect the digital multimeter and characterized 1 Ω resistor to the OUTPUT #1 SOURCE terminals, as shown in *Figure 12-2*. Be sure to observe proper polarity (SOURCE + to INPUT HI; SOURCE - to INPUT LO). Be sure to use 4-wire connections to the resistor terminals.
2. Select the multimeter DC volts measuring function, and enable auto-ranging.
3. Press the ◄ or ► keys to select Channel **#1**. Select the 5 A readback range. Make sure actual current readings are displayed.
4. Turn on the output.
5. Verify 5A range current readback accuracy for the currents listed in *Table 12-5*. For each test point:

- By changing the output voltage, adjust the current to the correct value, as determined from the multimeter voltage reading and characterized resistance value. When setting the voltage, be sure to set the compliance current to 5 A.
- Note that it may not be possible to set the output current to the exact value. Set the current to the closest possible value, and modify reading limits accordingly.
- Allow the reading to settle.
- Verify that the actual current reading is within the limits given in the table.

6. After changing connections to OUTPUT #2, repeat steps 1 through 5 for Channel #2 (use the ◄ or ► keys to toggle between Channel #1 and Channel #2).

Table 12-5
5 A range current readback accuracy limits*

Nominal output Voltage	Model 2308 output current**	Current readback limits (2 Years, 18°C-28°C)
1 V	1.000 A	0.9978 to 1.0022 A
2 V	2.000 A	1.9958 to 2.0042 A
3 V	3.000 A	2.9938 to 3.0062 A
4 V	4.000 A	3.9918 to 4.0082 A
4.5 V	4.500 A	4.4908 to 4.5092 A

*
updated current readback accuracy limits before verification.
**As measured by digital multimeter and 1 Ω resistance value.

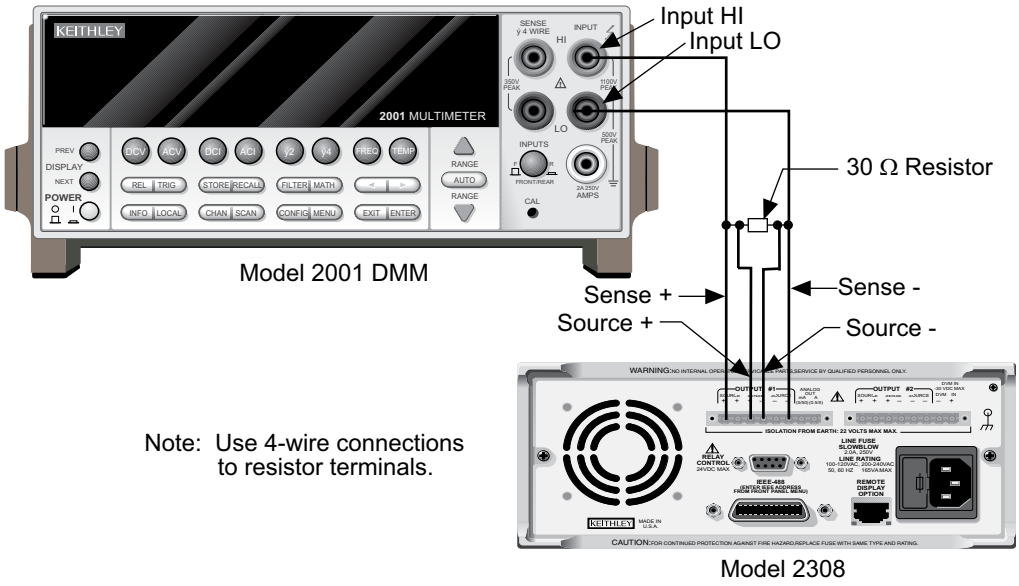
500 mA range readback accuracy

NOTE When verifying the battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

To verify that current readback accuracy is within specified limits:

1. With the power supply's output off, connect the digital multimeter and characterized 30 Ω resistor to the OUTPUT #1 terminals, as shown in *Figure 12-3*. Be sure to observe proper polarity and connections (30 Ω resistor between SOURCE + and DMM INPUT HI; SOURCE - to DMM INPUT LO).

Figure 12-3
Battery channel connections for 500 mA current verification tests



2. Select the multimeter DC volts measuring function, and enable auto range.
3. Press the ◄ or ► keys to select Channel **#1**. Select the 500 mA readback range and actual current reading data.
4. Turn on the output.
5. Verify 500 mA range current readback accuracy for the currents listed in *Table 12-6*. For each test point:

- Set the output current to the correct value, as determined from the digital multimeter voltage reading and 30 Ω resistance value.

NOTE It may not be possible to set the output current to the exact value. In that case, set the current to the closest possible value, and modify reading limits accordingly.

- Allow the reading to settle.
- Verify that the actual current reading is within the limits given in the table.

Table 12-6
500 mA range current readback accuracy limits*

Nominal output Voltage	Model 2308 output current**	Current readback limits (2 Years, 18°C-28°C)
3 V	100.00 mA	99.76 to 100.24 mA
6 V	200.00 mA	199.56 to 200.44 mA
9 V	300.00 mA	299.36 to 300.64 mA
12 V	400.00 mA	399.16 to 400.84 mA

*
updated current readback accuracy limits before verification.
**As measured by digital multimeter and 30 Ω resistance value.

Table 12-6
500 mA range current readback accuracy limits*

Nominal output Voltage	Model 2308 output current**	Current readback limits (2 Years, 18°C-28°C)
14.7 V	490.00 mA	488.98 to 491.02 mA

*
updated current readback accuracy limits before verification.
**As measured by digital multimeter and 30 Ω resistance value.

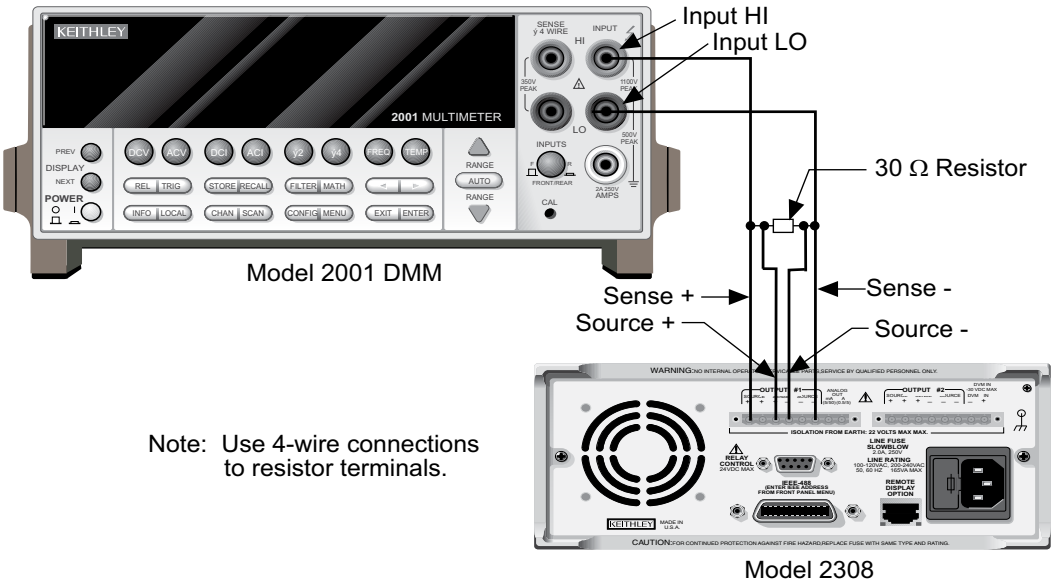
50 mA range readback accuracy

NOTE	When verifying the battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

To verify that current readback accuracy is within specified limits:

1. With the power supply's output off, connect the digital multimeter and characterized 30 Ω resistor to the OUTPUT #1 terminals, as shown in *Figure 12-4*. Be sure to observe proper polarity and connections (30 Ω resistor between SOURCE + and DMM INPUT HI; SOURCE - to DMM INPUT LO).

Figure 12-4
Battery channel connections for 50 mA current verification tests



2. Select the multimeter DC volts measuring function, and enable auto range.
3. Press the ◄ or ► keys to select Channel **#1**. Select the 50 mA readback range and actual current reading data.
4. Turn on the output.

5. Verify 50 mA range current readback accuracy for the currents listed in *Table 12-7*. For each test point:

- Set the output current to the correct value, as determined from the digital multimeter voltage reading and 30 Ω resistance value.

NOTE It may not be possible to set the output current to the exact value. In that case, set the current to the closest possible value, and modify reading limits accordingly.

- Allow the reading to settle.
- Verify that the actual current reading is within the limits given in the table.

Table 12-7
50 mA range current readback accuracy limits*

Nominal output Voltage	Model 2308 output current**	Current readback limits (2 Years, 18°C-28°C)
0.3 V	10 mA	9.975 to 10.025
0.6 V	20 mA	19.955 to 30.065
0.9 V	30 mA	29.935 to 30.065
1.2 V	40 mA	39.915 to 40.085
1.47 V	49 mA	48.897 to 49.103

*
range readback accuracy limits before verification.
**As determined from digital multimeter voltage reading and 30 Ω resistance value.

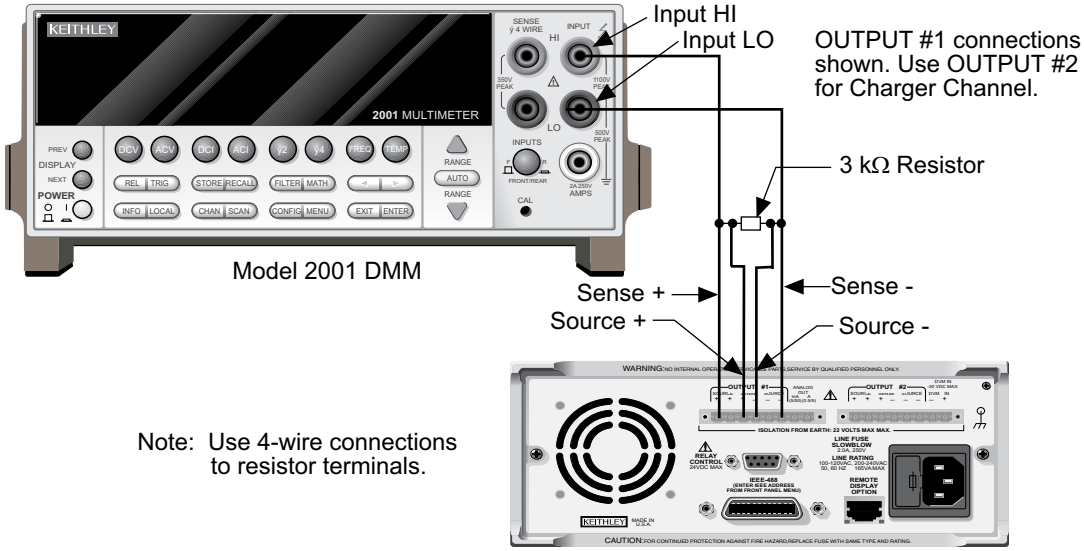
5 mA range readback accuracy

NOTE When verifying the battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

To verify that current readback accuracy is within specified limits:

1. With the power supply's output off, connect the digital multimeter and characterized 3 kΩ resistor to the OUTPUT #1 terminals, as shown in *Figure 12-5*. Be sure to observe proper polarity and connections (3 kΩ resistor between SOURCE + and DMM INPUT HI; SOURCE - to DMM INPUT LO).

Figure 12-5
Connections for 5 mA current verification tests



2. Select the multimeter DC volts measuring function, and enable auto range.
3. Press the ◄ or ► keys to select channel **#1**. Select the 5 mA readback range and actual current reading data.
4. Turn on the output.
5. Verify 5 mA range current readback accuracy for the currents listed in *Table 12-8*. For each test point:
   - Set the output current to the correct value, as determined from the digital multimeter voltage reading and 3 kΩ resistance value.

NOTE	It may not be possible to set the output current to the exact value. In that case, set the current to the closest possible value, and modify reading limits accordingly.

   - Allow the reading to settle.
   - Verify that the actual current reading is within the limits given in the table.
6. Repeat steps 1 through 5 for Channel #2 (use the ◄ or ► keys to toggle between Channel #1 and Channel #2).

Table 12-8
5 mA range current readback accuracy limits*

Nominal output Voltage	**Model 2308 output current****	**Current readback limits (2 Years, 18°C-28°C)**
3 V	1.0000 mA	0.9970 to 1.0030 mA

*
current readback accuracy limits before verification.
** As measured by digital multimeter voltage reading and 3 kΩ resistance value.

Table 12-8
5 mA range current readback accuracy limits*

Nominal output Voltage	Model 2308 output current**	Current readback limits (2 Years, 18°C-28°C)
6 V	2.0000 mA	1.9950 to 2.0050 mA
9 V	3.0000 mA	2.9930 to 3.0070 mA
12 V	4.0000 mA	3.9910 to 4.0090 mA
14.7 V	4.9000 mA	4.8892 to 4.9108 mA

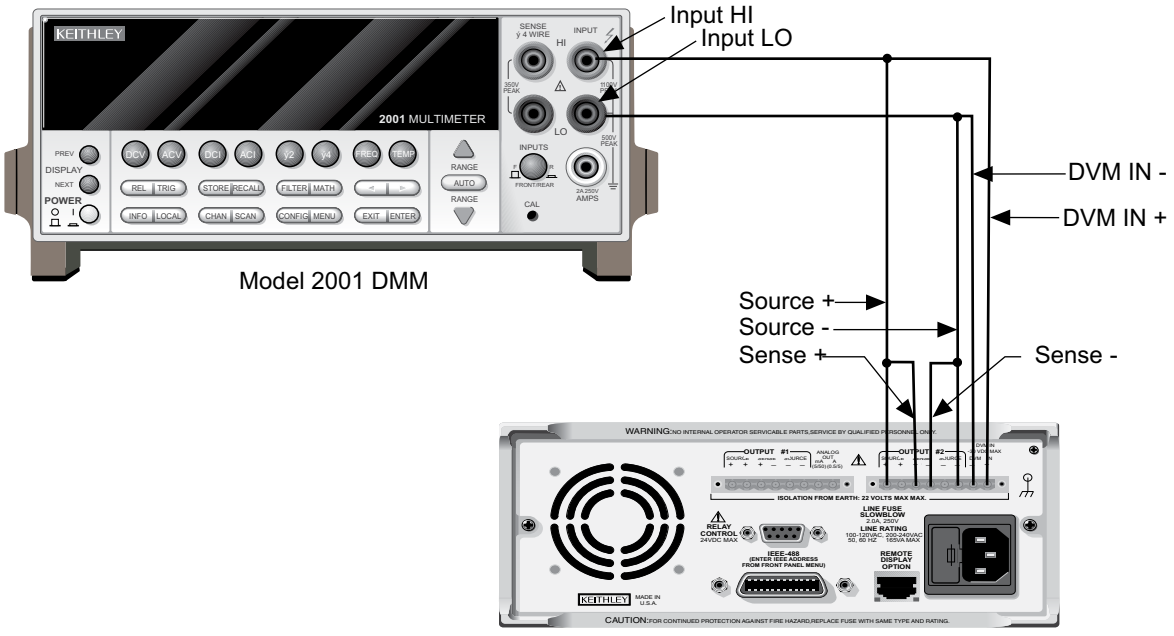
*
current readback accuracy limits before verification.
** As measured by digital multimeter voltage reading and 3 kΩ resistance value.

Digital voltmeter input accuracy

Follow the steps below to verify the digital voltmeter input accuracy is within specified limits. The test involves setting the voltage applied to the DVM input to accurate values and then verifying that the digital voltmeter input readings are within required limits.

1. With the power supply's output off, connect the OUTPUT #2 DVM IN, SOURCE, and SENSE terminals to the digital multimeter, as shown in *Figure 12-6*. Be sure to observe proper polarity (DVM IN +, SOURCE + and, SENSE + to DMM INPUT HI; also DVM IN -, SOURCE -, and SENSE - to DMM INPUT LO).

Figure 12-6
Charger channel connections for DVM accuracy verification



2. Select the DMM DC volts function, and enable auto-ranging.
3. Press the ◄ or ► keys to select Channel **#2**. Enable the DVM input.
4. Turn on the source output.
5. Verify digital voltmeter input accuracy for each of the voltages listed in *Table 12-9*. For each test point:

- Set the voltage to the indicated value as measured by the digital multimeter.
- Set current compliance to 0.25 A.
- Allow the reading to settle.
- Verify that the voltage reading is within the limits given in the table.

Table 12-9
Digital voltmeter input accuracy limits*

Model 2308 output Voltage setting**	**Digital voltmeter input reading limits (2 Years, 18°C-28°C)**
5.00 V	4.995 to 5.005 V
10.00 V	9.992 to 10.008 V
14.00 V	13.990 to 14.010 V

*
updated accuracy limits before verification.
**As measured by digital multimeter.

Section 13
Calibration

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Introduction

Use the procedures in this section to calibrate the Keithley Instruments Model 2308. These procedures require accurate test equipment to measure precise DC voltages and currents. Calibration can be performed either from the front panel or by sending SCPI calibration commands over the IEEE-488 bus with the aid of a computer.

WARNING	***The information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.***

Environmental conditions

Temperature and relative humidity

Conduct the calibration procedures at an ambient temperature of 18-28°C (65-82°F) with a relative humidity of less than 70% unless otherwise noted.

Warm-up period

Allow the Model 2308 to warm up for at least one hour before performing calibration.

If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

The Model 2308 requires a line voltage of 100 to 240 V at line frequency of 50 or 60 Hz. The instrument must be calibrated while operating from a line voltage within this range.

Calibration considerations

When performing the calibration procedures:

- Make sure that the test equipment is properly warmed up and connected to the appropriate Model 2308 OUTPUT #1 or OUTPUT #2 terminals, depending on which channel you are calibrating.
- Always allow the source signal to settle before calibrating each point.
- Do not connect test equipment to the Model 2308 through a scanner or other switching equipment.
- Calibration must be performed in the sequence outlined in this manual or an error will occur.
- Both channels are calibrated during calibration.
- If an error occurs during calibration, the Model 2308 will generate an appropriate error message. See *Appendix B* for more information.

WARNING	***The maximum common-mode voltage (voltage between LO and chassis ground) is 22VDC. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.***

Calibration cycle

Perform calibration at least once every two years to ensure the unit meets or exceeds its specifications.

Recommended calibration equipment

Table 13-1 lists the recommended equipment for the calibration procedures. You can use alternate equipment as long as that equipment has specifications at least four times better than corresponding Model 2308 specifications. See also *Resistor considerations* later in this section for important temperature coefficient information.

Table 13-1
Recommended calibration equipment

Description	Manufacturer/ Model	Specifications
Digital Multimeter	Keithley 2001	DC Voltage* 20 V: ±22 ppm 2 V ± 20 ppm Resistance* 20 Ω: ±59 ppm 20k Ω: ±36 ppm
Precision Resistor		4 Ω, 0.1%, 100 W**
Precision Resistor		3 kΩ, 0.1%, 0.125 W**

*Full-range, 90-day, 23°C ±5°C accuracy specifications of ranges required for various measurement points.
**Characterize resistor using 4-wire ohms function of DMM before use.

Resistor connections

When performing calibration steps that use either the 4 Ω or 3k Ω resistor, connect the Model 2308 OUTPUT #1 or OUTPUT #2 SENSE leads and Model 2001 DMM test leads as close to the resistor body as possible.

Resistor considerations

The test resistors should be characterized using the 4-wire ohms function of the DMM recommended in *Table 13-1* to measure the resistance values. Use the measured resistance values to calculate the actual currents during the calibration procedures.

NOTE The temperature coefficient and temperature change of the 4 Ω resistor when passing current at full load must be low enough so that the change in resistance does not cause incorrect readings. This is summarized in the following equation:

$$\frac{V_{OUT}}{(R + \Delta R)} < 25\% \text{ of Model 2308 amps specification}$$

Where: VOUT is the Model 2308 output voltage
R is the characterized value of the resistor

ΔR is the change in resistance caused by heating

Front panel calibration

Use the following procedure to calibrate the Model 2308 from the front panel. *Table 13-2* summarizes calibration steps.

NOTE	Calibration must be performed in the following sequence, or an error will occur. To abort calibration and revert to previous calibration constants at any time during the procedure, press the **MENU** key. Follow message prompts to abort calibration. Use ▲ and ▼ keys to select desired response.

Step 1: Prepare the Model 2308 for calibration

1. Turn on the Model 2308 and the digital multimeter, and allow them to warm up for at least one hour before performing calibration.
2. Press the **MENU** key, then choose **CALIBRATE UNIT**, and press **ENTER**. The instrument will display the date last calibrated:
   CALIBRATE UNIT
   LAST ON 07/01/2008
3. Press the ▲ key. The instrument will display the number of times it was calibrated:
   CALIBRATE UNIT
   TIMES = 1
4. Press the ▲ key. The unit will then prompt you to run calibration:
   CALIBRATE UNIT
   RUN
5. Press **ENTER**. The unit will then prompt for the calibration code:
   CALIBRATE UNIT
   Cal Code KI002308
6. Using the edit keys, set the display to the current calibration code, then press **ENTER** (default: KI002308). The unit will then prompt you as to whether or not to change the code:
   CALIBRATE UNIT
   Change Code NO
7. Be sure NO is selected (use the ▲ and ▼ keys), press **ENTER**, then follow the steps below to calibrate the unit (see *Changing the calibration code* to change the code).

Table 13-2
Model 2308 front panel calibration summary

Steps*	Description	Nominal calibration signal**	Test connections
0	Full-scale (14 V) output.	14 V	*Figure 13-1*
1	Full-scale output calibration	14 V	*Figure 13-1*
2	Full-scale measure calibration	14 V	*Figure 13-1*
3, 16	Source 5 A full-scale current calibration	1.9 A	*Figure 13-2*
4, 17	5 A current limit calibration	1.9 A	*Figure 13-2*
5, 18	5 A measure calibration	1.9 A	*Figure 13-2*

*Step numbers correspond to `:CAL:PROT:STEP` command numbers. See *Table 13-3*.
Steps 0 through 11 calibrate battery channel (#1). Steps 12 through 20 calibrate charger channel (#2).
**Factory default display values shown

Table 13-2
Model 2308 front panel calibration summary

Steps*	Description	Nominal calibration signal**	Test connections
6	Source 500 mA full-scale current	450 mA	*Figure 13-2*
7	500 mA measure cal.	450 mA	*Figure 13-2*
8	Source 50 mA full scale current	45 mA	*Figure 13-2*
9	50 mA measure calibration	45 mA	*Figure 13-2*
10, 19	Source 5 mA full-scale.	4.5 mA	*Figure 13-3*
11, 20	5 mA range measure calibration	4.5 mA	*Figure 13-3*
12	Full-scale (14 V) output.	14 V	*Figure 13-4*
13	Full-scale output calibration	14 V	*Figure 13-4*
14	Full-scale measure calibration	14 V	*Figure 13-4*
15	DVM full-scale calibration	14 V	*Figure 13-4*

*Step numbers correspond to `:CAL:PROT:STEP` command numbers. See *Table 13-3*.
Steps 0 through 11 calibrate battery channel (#1). Steps 12 through 20 calibrate charger channel (#2).
**Factory default display values shown

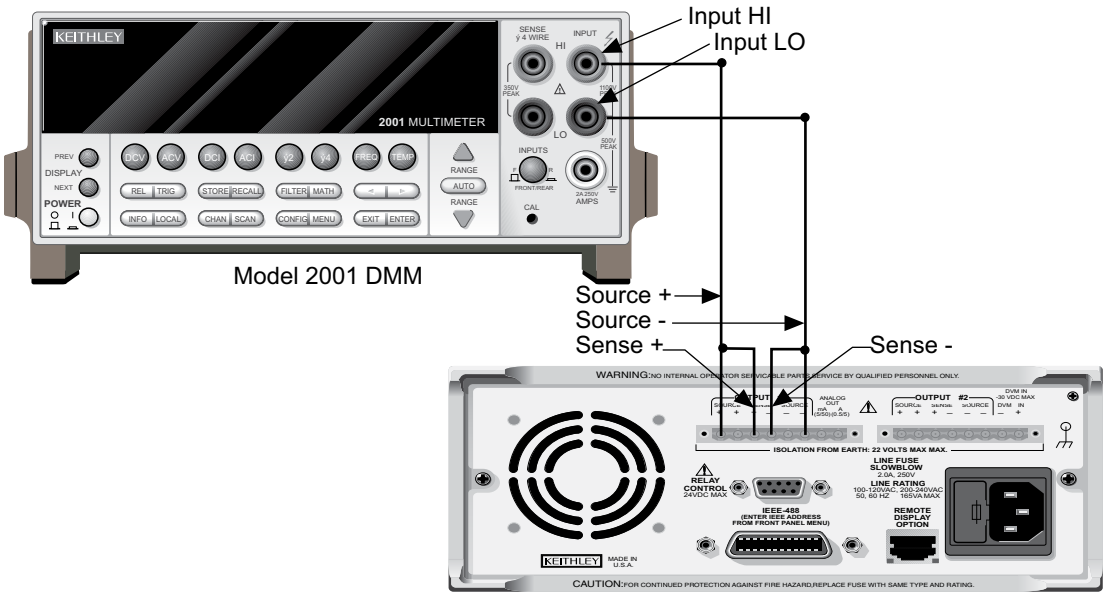
Step 2: Perform battery channel calibration steps

NOTE The unit will display the most recently calibrated values. Factory defaults are shown in this manual.

When calibrating the battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

1. Connect the OUTPUT #1 SOURCE and SENSE terminals to the DMM, as shown in *Figure 13-1*.
2. DMM Input connections:
   HI: SOURCE +, and SENSE +
   LO: SOURCE - and SENSE -
3. At this point, the Model 2308 will prompt you to set the full-scale Channel #1 output voltage:
   CAL VOLTS CHAN 1
   SET 14.0000 V
4. Use the edit keys to set the voltage to 14.0000V, then press **ENTER**.

Figure 13-1
Battery channel connections for voltage calibration



5. The unit will prompt you for the DMM reading, which will be used to calibrate the Channel #1 full-scale output voltage:

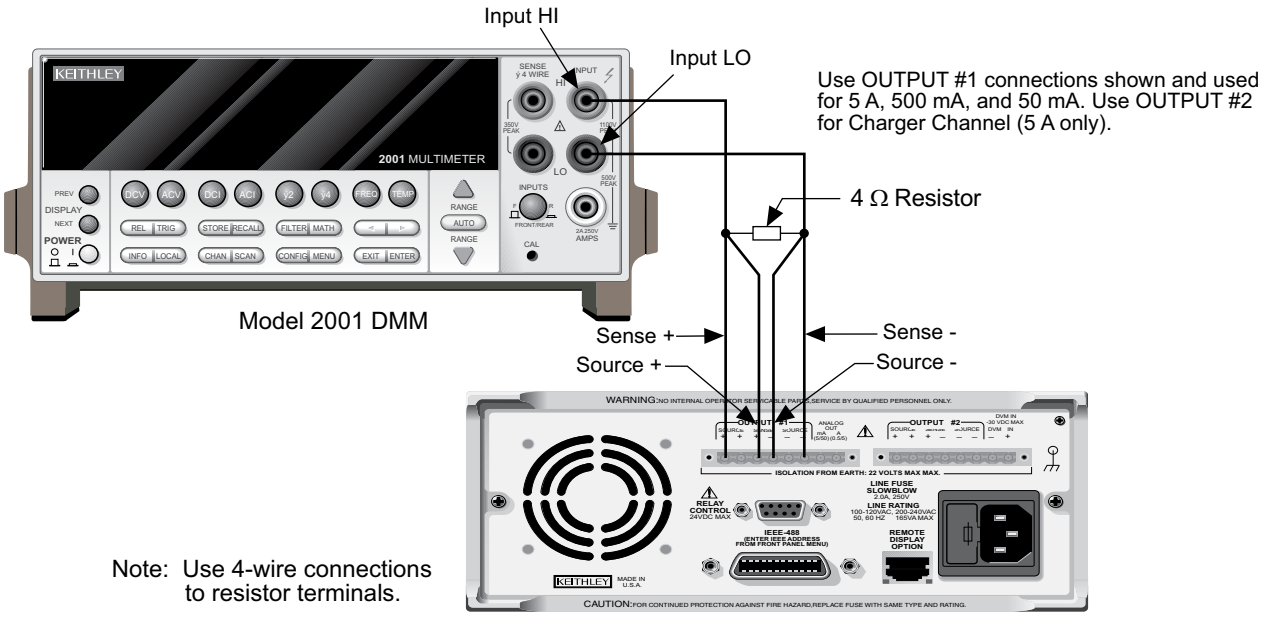
   CAL VOLTS CHAN 1
   READ1 14.0000 V

6. Using the edit keys, adjust the Model 2308 voltage display to agree with the DMM voltage reading, then press **ENTER**. The unit will then prompt for another DMM reading, which will be used to calibrate the full-scale Channel #1 measurement function:

   CAL VOLTS CHAN 1
   READ2 14.0000 V

7. Connect the digital multimeter volts input and characterized 4 Ω resistor to the Model 2308 OUTPUT #1 SOURCE terminals, as shown in *Figure 13-2*. Be sure to observe proper polarity (SOURCE + to DMM INPUT HI; SOURCE - to INPUT LO).
8. Be sure the digital multimeter DC volts function and auto-ranging are still selected.

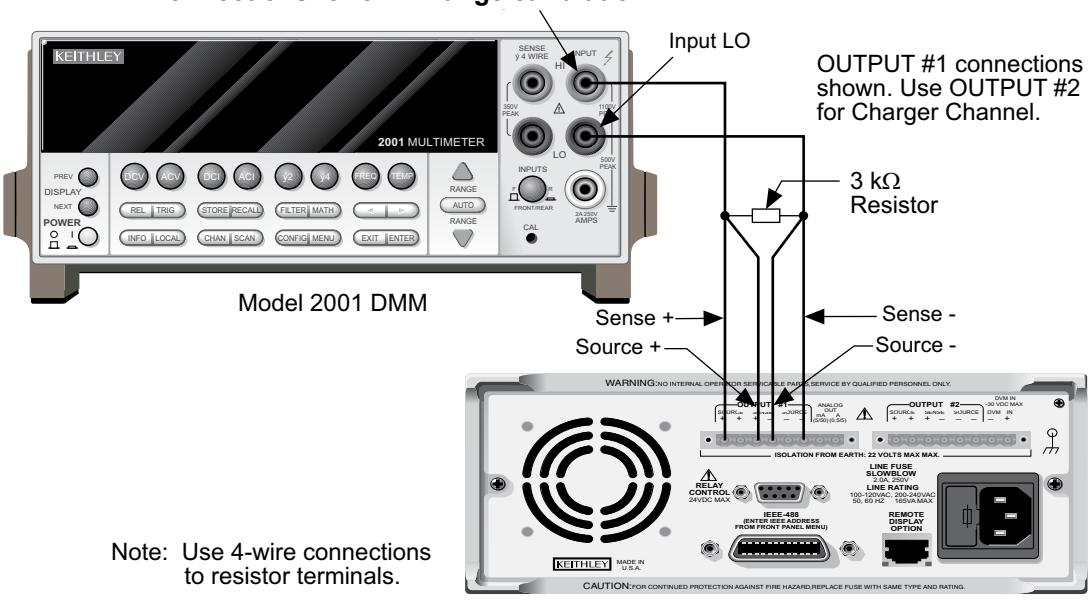
Figure 13-2
Connections for 5 A, 500 mA, and 50 mA current calibration



9. At this point, the unit will prompt for 5 A Channel #1 full-scale calibration output:
   CAL 5 A CHAN 1
   SET 1.90000 A
10. Using the edit keys, adjust the set value to 1.9000 A, then press **ENTER**. The unit will prompt you for the DMM reading, which calibrates the 5 A current limit for Channel #1:
    CAL 5 A CHAN 1
    READ1 1.90000 A
11. Note the DMM voltage reading, then calculate the current from that reading and the actual 4Ω resistance value: I = V/R. Adjust the Model 2308 current display value to agree with the calculated current value, and press **ENTER**.
12. The Model 2308 will prompt for another DMM reading, which is used for 5 A measurement calibration of Channel #1:
    CAL 5 A CHAN 1
    READ2 1.90000 A
13. Again, calculate the current from the new DMM reading and 4 Ω resistor value. Adjust the Model 2308 current display reading to agree with the new current, then press **ENTER**.
14. The unit will now prompt you for Channel #1 500 mA full-scale calibration:
    CAL 500mA CHAN 1
    ALL READY TO DO?
15. Press **ENTER**.
16. The unit will then prompt you for the DMM reading:
    CAL 500mA CHAN 1
    READ1 450.000 mA
17. Note the DMM voltage reading, then calculate the current from that reading and the actual 4Ω resistance value: I = V/R. Adjust the Model 2308 current display value to agree with the calculated current value, and press **ENTER**.
18. The unit will prompt for Channel #1 50 mA full-scale calibration:
    CAL 50mA CHAN 1
    ALL READY TO DO?

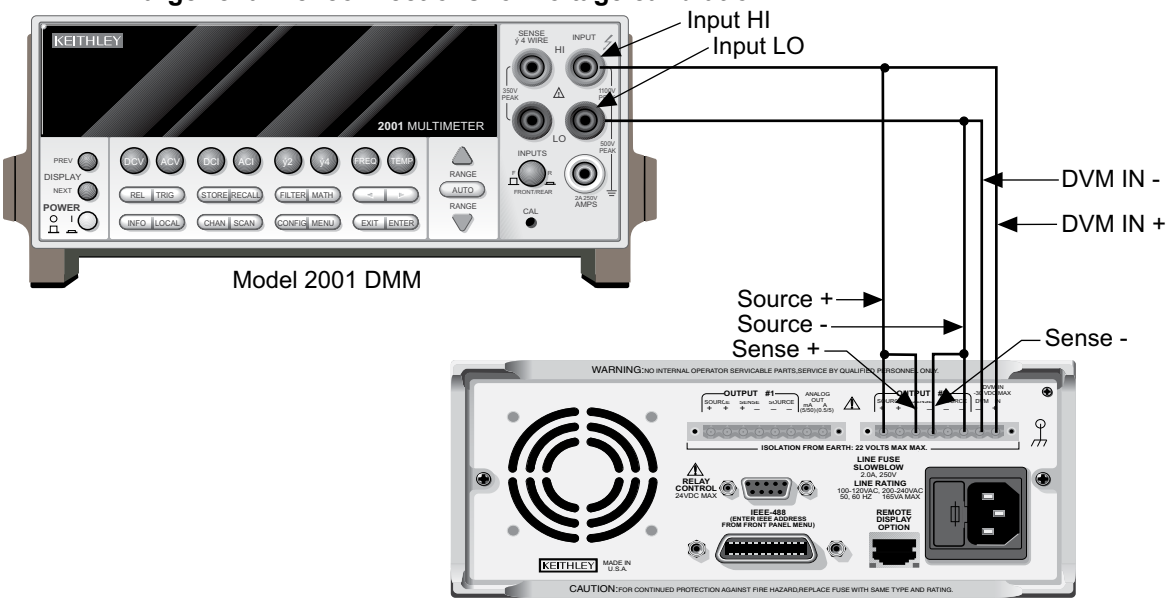
19. Press **ENTER**.
20. The unit will then prompt you for the DMM reading:
    CAL 50mA CHAN 1
    READ1 45.0000 mA
21. Note the DMM voltage reading, then calculate the current from that reading and the actual 4 Ω resistance value: I = V/R. Adjust the Model 2308 current display value to agree with the calculated current value, and press **ENTER**.
22. Disconnect the 4 Ω resistor, then connect the 3 kΩ resistor in its place (use the connections shown in *Figure 13-3*).
23. Make sure the DMM DC volts function and auto-ranging are still selected.
24. The unit will prompt you for Channel #1 5 mA full-scale calibration:
    CAL 5mA CHAN 1
    ALL READY TO DO?
25. Press **ENTER**.
26. The unit will then prompt you for the DMM reading:
    CAL 5mA CHAN 1
    READ1 4.50000 mA
27. Note the DMM voltage reading, then calculate the current from that reading and the actual 3 kΩ resistance value: I = V/R. Adjust the Model 2308 current display value to agree with the calculated current value, and press **ENTER**.

Figure 13-3
Connections for 5 mA range calibration



Step 3: Perform charger channel calibration steps

Figure 13-4
Charger channel connections for voltage calibration



1. Connect the OUTPUT #2 SOURCE, SENSE, and DVM IN terminals to the DMM as shown in *Figure 13-4*.

   DMM input connections:
   HI: SOURCE +, SENSE +, and DVM IN +
   LO: SOURCE -, SENSE -, and DVM IN -
2. The Model 2308 will prompt you to set the full-scale Channel #2 output voltage:

   CAL VOLTS CHAN 2
   SET 14.0000 V
3. Use the edit keys to set the voltage to 14.0000V, then press **ENTER**.
4. The unit will prompt you for the DMM reading, which will be used to calibrate the Channel #2 full-scale output voltage:

   CAL VOLTS CHAN 2
   READ1 14.0000 V
5. Using the edit keys, adjust the Model 2308 voltage display to agree with the DMM voltage reading, then press **ENTER**. The unit will prompt for another DMM reading, which will be used to calibrate the full-scale Channel #1 measurement function:

   CAL VOLTS CHAN 2
   READ2 14.0000 V
6. Using the edit keys, adjust the display to agree with the new DMM voltage reading, then press **ENTER**. The unit will prompt for Channel #2 DVM full-scale calibration:

   CAL DVM CHAN 2
   ALL READY TO DO?
7. Press **ENTER** to complete Channel #2 DVM full-scale calibration.
8. Connect the digital multimeter volts input and characterized 4 Ω resistor to the Model 2308 OUTPUT #2 SOURCE terminals using the same general connections shown in *Figure 13-2*. Be sure to observe proper polarity (SOURCE + to DMM INPUT HI; SOURCE - to INPUT LO).
9. Be sure the digital multimeter DC volts function and auto-ranging are still selected.

10. At this point, the unit will prompt for 5 A Channel #2 full-scale calibration output:
    CAL 5 A CHAN 2
    SET 1.90000 A
11. Using the edit keys, adjust the set value to 1.9000A, then press **ENTER**. The unit will prompt you for the DMM reading, which calibrates the Channel #2 5 A current limit:
    CAL 5 A CHAN 2
    READ1 1.90000 A
12. Note the DMM voltage reading, then calculate the current from that reading and the actual 4Ω resistance value: I = V/R. Adjust the Model 2308 current display value to agree with the calculated current value, and press **ENTER**.
13. The Model 2308 will prompt for another DMM reading, which is used for Channel #2 5 A measurement calibration:
    CAL 5 A CHAN 2
    READ2 1.90000 A
14. Again, calculate the current from the new DMM reading and 4 Ω resistor value. Adjust the 2308 current display reading to agree with the new current, then press **ENTER**.
15. Disconnect the 4 Ω resistor, then connect the 3k Ω resistor in its place (use the connections in *Figure 13-3* except make connections to the OUTPUT #2 terminals).
16. Make sure the DMM DC volts function and auto-ranging are still selected.
17. At this point, the unit will prompt to output approximately 5 mA for Channel #2 5mA range full-scale calibration:
    CAL 5 mA CHAN 2
    ALL READY TO DO?
18. Press **ENTER** to output approximately 5 mA. The unit will then prompt you for the DMM reading:
    CAL 5 mA CHAN 2
    READ1 4.50000 mA
19. Note the DMM voltage reading, then calculate the current from that voltage reading and actual 3k Ω resistance value. Adjust the Model 2308 current display value to agree with that value and press **ENTER**.

Step 4: Enter calibration dates, and save calibration

1. After completing all Channel #1 and Channel #2 calibration steps, the unit will prompt if you wish to save calibration:
    CALIBRATE UNIT
    Save Cal Data YES
2. To save new calibration constants, select YES, then press **ENTER**. If you wish to exit calibration without saving new calibration constants, select NO, then press **ENTER**. In that case, the unit will revert to prior calibration constants.
3. The unit will then prompt you to enter the calibration date:
    CALIBRATE UNIT
    Cal Date 07/01/2008
4. Using the edit keys, set the calibration date to today's date, then press **ENTER**. The unit will display the following:
    CALIBRATE UNIT
    EXITING CAL
5. Press **ENTER** to complete the calibration procedure and return to the menu display. Calibration is now complete.

Remote calibration

Follow the procedure outlined below to perform Model 2308 remote calibration by sending SCPI commands over the IEEE-488 bus. The remote commands and appropriate parameters are separately summarized for each step.

Remote calibration display

The Model 2308 will display the following while being calibrated over the bus:
CALIBRATING UNIT
FROM THE BUS R

NOTE	The "R" located on the lower right hand corner of the display indicates remote operation.

Remote calibration procedure

Use the following procedure to calibrate the Model 2308. *Table 13-3* summarizes the calibration steps in the proper sequence. See *Appendix B* for command details.

NOTE	Calibration steps must be performed in the following sequence, or an error will occur. You can abort the procedure and revert to previous calibration constants before `:SAVE` by sending the `:CAL:PROT:LOCK` command. Calibration is performed on both channels at the same time - it is not possible to only calibrate one channel.

Step 1: Prepare the Model 2308 for calibration

1. Connect the Model 2308 to the controller IEEE-488 interface using a shielded interface cable.
2. Turn on the Model 2308 and the test equipment, and allow them to warm up for at least one hour before performing calibration.
3. Make sure the IEEE-488 primary address of the Model 2308 is the same as the address specified in the program you will be using to send commands.
4. Send the following command with the correct code to unlock calibration:
   `:CAL:PROT:CODE '<code>'`
   For example, with the factory default code of KI002308, send:
   `CAL:PROT:CODE 'KI002308'`
5. Send the following command to initiate calibration:
   `:CAL:PROT:INIT`

Step 2: Perform battery channel calibration steps

NOTE Allow the Model 2308 to complete each calibration step before going on to the next one (see *Detecting calibration step completion*).

When calibrating the Battery channel (#1), make sure you connect the source + and source - to the same pair of pins (either both in or both out) on the connector. Do not mix them because the internal resistance present on the inner pins will cause incorrect verification data to be returned.

1. Connect the OUTPUT #1 SOURCE and SENSE terminals to the digital multimeter, as shown in *Figure 13-1* (connect SOURCE + and SENSE +, SOURCE - and SENSE -).
2. Send the following command to output 14 V:
   :CAL:PROT:STEP0 14

NOTE At this point, the source output is turned on and will remain on until calibration is completed or aborted with the `:CAL:PROT:LOCK` command.

3. Note and record the DMM reading, then send that reading as the parameter for the following command:
   `:CAL:PROT:STEP1 <DMM_Reading>`
   For example, if the DMM reading is 14.012 V, the command would be:
   `:CAL:PROT:STEP1 14.012`
4. Note and record a new DMM reading, then send that reading as the parameter for the following command:
   `:CAL:PROT:STEP2 <DMM_Reading>`
5. Connect the Model 2308 OUTPUT #1 SOURCE terminals to the DMM volts input and characterized 4Ω resistor, as shown in *Figure 13-2*. Be sure to observe proper polarity (SOURCE + to INPUT HI; SOURCE - to INPUT LO).
6. Make sure the digital multimeter DC volts function and auto-ranging are still selected.
7. Send the following command to output 1.9 A for 5 A full-scale calibration:
   `:CAL:PROT:STEP3 1.9`
8. Note and record the DMM voltage reading, then calculate the current from that reading and characterized 4Ω resistor value. Send the following command using that calculated current as the parameter:
   `:CAL:PROT:STEP4 <Calculated_Current>`
   For example, with a current value of 1.894 A, the command would appear as follows:
   `:CAL:PROT:STEP4 1.894`
9. Note and record a new DMM voltage reading, then again calculate the current from the voltage and resistance. Send the calculated current value as the parameter for the following command:
   `:CAL:PROT:STEP5 <Calculated_Current>`
10. Send the following command to output 450 mA for 500 mA full-scale calibration:
    `:CAL:PROT:STEP6`
11. Send the following command to output 450 mA for 500 mA full-scale calibration:
    `:CAL:PROT:STEP7 <Calculated_Current>`
    For example, if the current value is 450 mA, the command would be:
    `:CAL:PROT:STEP7 450e-3`

12. Send the following command to output 45 mA for 50 mA full-scale calibration:
    `:CAL:PROT:STEP8`
13. Send the following command to output 45 mA for 50 mA full-scale calibration:
    `:CAL:PROT:STEP9 <Calculated_Current>`
    For example, if the current value is 45 mA, the command would be:
    `:CAL:PROT:STEP9 45e-3`
14. Connect the characterized 3 kΩ resistor in place of the 4 Ω resistor (*Figure 13-3*).
15. Make sure the DMM DC volts function and auto range are still selected.
16. Send the following command:
    `:CAL:PROT:STEP10`
17. Note and record the DMM voltage reading, then calculate the current from the voltage reading and actual resistance value. Send that current value as the parameter for the following command:
    `:CAL:PROT:STEP11 <Calculated_Current>`
    For example, if the current value is 4.5 mA, the command would be
    `:CAL:PROT:STEP10 4.5e-3`

Step 3: Perform charger channel calibration steps

1. Connect the OUTPUT #2 SOURCE, SENSE, and DVM IN terminals to the digital multimeter. Use the same connections shown in *Figure 13-4*.
2. Send the following command to output 14 V:
    `:CAL:PROT:STEP12 14`
3. Note and record the DMM reading, then send that reading as the parameter for the following command:
    `:CAL:PROT:STEP13 <DMM_Reading>`
    For example, if the DMM reading is 14.012 V, the command would be:
    `:CAL:PROT:STEP13 14.012`
4. Note and record a new DMM reading, then send that reading as the parameter for the following command:
    `:CAL:PROT:STEP14 <DMM_Reading>`
5. Send the following command for DVM full-scale calibration:
    `:CAL:PROT:STEP15`
6. Connect the Model 2308 OUTPUT #2 SOURCE terminals to the DMM volts input and characterized 4Ω resistor. Use the connections shown in *Figure 13-2*, but make your connections to the OUTPUT #2 terminals instead. Be sure to observe proper polarity (SOURCE + to INPUT HI; SOURCE - to INPUT LO).
7. Make sure the digital multimeter DC volts function and auto-ranging are still selected.
8. Send the following command to output 1.9 A for 5 A full-scale calibration:
    `:CAL:PROT:STEP16 1.9`
9. Note and record the DMM voltage reading, then calculate the current from that reading and 4Ω resistor value. Send the following command using that calculated current as the parameter:
    `:CAL:PROT:STEP17 <Calculated_Current>`
    For example, if the current value is 1.894 A, the command would appear as follows:
    `:CAL:PROT:STEP17 1.894`
10. Note and record a new DMM voltage reading, then again calculate the current from the voltage and resistance. Send the calculated current value as the parameter for the following command:
    `:CAL:PROT:STEP18 <Calculated_Current>`

11. Connect the characterized 3 kΩ resistor in place of the 4 Ω resistor (*Figure 13-3*).
12. Make sure the DMM DC volts function and auto range are still selected.
13. Send the following command to output approximately 5 mA for 5 mA full-scale calibration:
    `:CAL:PROT:STEP19`
14. Note and record the DMM voltage reading, then calculate the current from the voltage reading and actual 3 kΩ resistance value. Send that current value as the parameter for the following command:
15. `:CAL:PROT:STEP20 <Calculated_Current>`
    For example, if the current value is 4.5 mA, the command would be
    `:CAL:PROT:STEP20 4.5e-3`

Step 4: Program calibration date

Use following command to set the calibration date:

```
:CAL:PROT:DATE <yyyy>, <mm>, <dd>
```

Note that the year, month, and date must be separated by commas. The allowable range for the year is from 2008 to 2107, the month is from 1 to 12, and the date is from 1 to 31.

Step 5: Save calibration constants and lock out calibration

Calibration is now complete, so you can store the calibration constants in EEROM by sending the following command:

```
:CAL:PROT:SAVE
```

NOTE Calibration will be temporary unless you send the `SAVE` command. Calibration data will not be saved if (1) calibration is locked, (2) invalid data exists, or (3) all steps were not completed in the proper sequence. In that case, the unit will revert to previous calibration constants.

After saving constants, lock out calibration by sending:

```
:CAL:PROT:LOCK
```

Table 13-3
Remote calibration summary

Step*	Command	Description	Test connections**
	`:CAL:PROT:CODE 'KI002308'`	Unlock calibration.	None
	`:CAL:PROT:INIT`	Initiate calibration.	None
0	`:CAL:PROT:STEP0 14`	Full-scale (14 V) output.	*Figure 13-1*
1	`:CAL:PROT:STEP1 <DMM_Reading>`	Full-scale output cal.	*Figure 13-1*
2	`:CAL:PROT:STEP2 <DMM_Reading>`	Full-scale measure cal.	*Figure 13-1*

*Step numbers correspond to :STEP commands. Steps 0 through 11 calibrate battery channel (#1). Steps 12 through 20 calibrate charger channel (#2).
**Connect to OUTPUT #1 terminals for Steps 0 through 11. Connect to OUTPUT #2 terminals for Steps 12 through 20.

Table 13-3
Remote calibration summary

Step*	Command	Description	Test connections**
3	:CAL:PROT:STEP3 1.9	Source 5 A full-scale current cal.	*Figure 13-2*
4	:CAL:PROT:STEP4 <Current>	5 A current limit cal.	*Figure 13-2*
5	:CAL:PROT:STEP5 <Current>	5 A measure cal.	*Figure 13-2*
6	:CAL:PROT:STEP6	Source 500 mA full scale current	*Figure 13-2*
7	:CAL:PROT:STEP7 <Current>	500 mA range measure cal	*Figure 13-2*
8	:CAL:PROT:STEP8	Source 50 mA full scale current	*Figure 13-2*
9	:CAL:PROT:STEP9 <Current>	50 mA range measure cal	*Figure 13-2*
10	:CAL:PROT:STEP10	Source 5 mA full-scale.	*Figure 13-3*
11	:CAL:PROT:STEP11 <Current>	5 mA range measure cal.	*Figure 13-3*
12	:CAL:PROT:STEP12 14	Full-scale (14 V) output.	*Figure 13-4*
13	:CAL:PROT:STEP13 <DMM_Reading>	Full-scale output cal.	*Figure 13-4*
14	:CAL:PROT:STEP14 <DMM_Reading>	Full-scale measure cal.	*Figure 13-4*
15	:CAL:PROT:STEP15	DVM full-scale cal.	*Figure 13-4*
16	:CAL:PROT:STEP16 1.9	Source 5 A full-scale current cal.	*Figure 13-2*
17	:CAL:PROT:STEP17 <Current>	5 A current limit cal.	*Figure 13-2*
18	:CAL:PROT:STEP18 <Current>	5 A measure cal.	*Figure 13-2*
19	:CAL:PROT:STEP19	Source 5 mA full-scale current.	*Figure 13-3*
20	:CAL:PROT:STEP20 <Current>	5 mA range measure cal.	*Figure 13-3*
	:CAL:PROT:DATE <yyyy,mm,dd>	Program calibration date.	None
	:CAL:PROT:SAVE	Save calibration data.	None
	:CAL:PROT:LOCK	Lock out calibration.	None

*Step numbers correspond to :STEP commands. Steps 0 through 11 calibrate battery channel (#1). Steps 12 through 20 calibrate charger channel (#2).
**Connect to OUTPUT #1 terminals for Steps 0 through 11. Connect to OUTPUT #2 terminals for Steps 12 through 20.

Changing the calibration code

The default calibration code may be changed from the front panel or via remote as discussed below.

Changing the code from the front panel

Follow the steps below to change the code from the front panel:

1. Press the **MENU** key, then choose **CALIBRATE UNIT**, and press **ENTER**. The instrument will display the last date calibrated:
   CALIBRATE UNIT
   LAST ON 07/01/2008
2. Press the ▲ key. The instrument will display the number of times it was calibrated:
   CALIBRATE UNIT
   TIMES = 1
3. Press the ▲ key. The unit will then prompt you to run calibration:
   CALIBRATE UNIT
   RUN
4. Press **ENTER**. The unit will then prompt for the calibration code:
   CALIBRATE UNIT
   Cal Code KI002308
5. Using the edit keys, set the display to the current present calibration code then press **ENTER** (default: KI002308). The unit will prompt you as to whether or not to change the code:
   CALIBRATE UNIT
   Change Code NO
6. Select YES then press **ENTER**. The instrument will prompt you to change the code:
   CALIBRATE UNIT
   New Code: KI002308
7. Use the edit keys to set the new code then press **ENTER** to accept the new code.
8. Press the **MENU** key to exit calibration and return to the main menu.

Changing the code by remote

To change the calibration code by remote, first send the present code, then send the new code. For example, the following command sequence changes the code from the 'KI002308' remote default to 'KI_CAL':

```
:CAL:PROT:CODE 'KI002308'
:CAL:PROT:CODE 'KI_CAL'
```

Use any combination of letters and numbers up to a maximum of eight characters.

Resetting the calibration code

If you forget the calibration code, you can reset the code by sending the following bus command: `CALibration:PROTected:CODE:RESET`. This command will change and save the password to the default setting of "KI002308". The following message appears briefly on the front panel while this command is being processed:

```
SAVED  NEW

CALIBRATION CODE
```

Once, the command is processed, you may unlock calibration using "KI002308" as the code. If you want to change this code then, see *Changing the calibration code***.**

Viewing calibration date and count

Viewing date and count from the front panel

Follow the steps below to view the calibration date and count from the front panel:

1. Press the **MENU** key then choose **CALIBRATE UNIT**, and press **ENTER**. The instrument will display the last date calibrated:
   CALIBRATE UNIT
   LAST ON 07/01/2008
2. Press the ▲ key. The instrument will display the number of times it was calibrated:
   CALIBRATE UNIT
   TIMES= 1
3. Press **MENU** to return to the menu structure.

Acquiring date and count by remote

Use the `CAL:PROT:DATE?` and `CAL:PROT:COUN?` queries to determine the calibration date and count respectively (see *Miscellaneous commands*).

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Appendix A
Error and Status Messages

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Error and status message definitions

Table A-1
Error and status messages (all models)

Number	Description	Event
-440	Query unterminated after indefinite response	EE
-430	Query deadlocked	EE
-420	Query unterminated	EE
-410	Query interrupted	EE
-363	Input buffer overrun	SYS
-350	Queue overflow	SYS
-330	Self-test failed	EE
-314	Save/recall memory lost	EE
-315	Configuration memory lost	EE
-260	Expression error	EE
-241	Hardware missing	EE
-230	Data corrupt or stale	EE
-225	Out of memory	EE
-224	Illegal parameter value	EE
-223	Too much data	EE
-222	Parameter data out of range	EE
-221	Settings conflict	EE
-220	Parameter error	EE
-200	Execution error	EE
-178	Expression data not allowed	EE
-171	Invalid expression	EE
-170	Expression error	EE
-161	Invalid block data	EE
-160	Block data error	EE
-158	String data not allowed	EE
-154	String too long	EE
-151	Invalid string data	EE
-150	String data error	EE

EE = error event
SE = status event
SYS = system error event

Table A-1
Error and status messages (all models) (cont.)

Number	Description	Event
-148	Character data not allowed	EE
-144	Character data too long	EE
-141	Invalid character data	EE
-140	Character data error	EE
-124	Too many digits	EE
-123	Exponent too large	EE
-121	Invalid character in number	EE
-120	Numeric data error	EE
-114	Header suffix out of range	EE
-113	Undefined header	EE
-112	Program mnemonic too long	EE
-111	Header separator error	EE
-110	Command header error	EE
-109	Missing parameter	EE
-108	Parameter not allowed	EE
-105	GET not allowed	EE
-104	Data type error	EE
-103	Invalid separator	EE
-102	Syntax error	EE
-101	Invalid character	EE
-100	Command error	EE
+000	No error	SE
+101	Operation complete	SE
+301	Reading overflow battery channel	SE
+302	Pulse trigger detection timeout battery channel	SE
+306	Reading available battery channel	SE
+307	Reading overflow charger channel	SE
+308	Pulse trigger detection timeout charger channel	SE
+309	Reading available charger channel	SE
+310	Buffer full battery channel	SE
+311	Buffer full charger channel	SE
+320	Current limit event battery channel	SE
+321	Current limit tripped event battery channel	SE
+322	Heatsink shutdown event	SE
+323	Power supply shutdown event	SE
+324	Current limit event charger channel	SE
+325	Current limit tripped event charger channel	SE
+326	Overvoltage protection	SE
+327	Overvoltage protection	SE

EE = error event
SE = status event
SYS = system error event

Table A-1
Error and status messages (all models) (cont.)

Number	Description	Event
	Calibration messages:	
+404	Volt full scale cal prepare error battery channel	EE
+405	Volt full scale cal output error battery channel	EE
+406	Volt full scale cal meas error battery channel	EE
+409	Amp source cal prepare error battery channel	EE
+410	Amp source cal output error battery channel	EE
+411	Amp source cal measure error battery channel	EE
+412	500mA source cal prepare error battery channel	EE
+413	500mA source cal measure error battery channel	EE
+414	50mA source cal prepare error battery channel	EE
+415	50mA source cal measure error battery channel	EE
+416	5mA source cal prepare error battery channel	EE
+417	5mA source cal measure error battery channel	EE
+429	Volt full scale cal prepare error charger channel	EE
+430	Volt full scale cal output error charger channel	EE
+431	Volt full scale cal meas error charger channel	EE
+432	DVM full scale cal meas error charger channel	EE
+434	Amp source cal prepare error charger channel	EE
+435	Amp source cal output error charger channel	EE
+436	Amp source cal measure error charger channel	EE
+437	mA source cal prepare error charger channel	EE
+438	mA source cal measure error charger channel	EE
+445	Date of calibration not set	EE
+500	Calibration data invalid	EE
+510	Reading buffer data lost	EE
+511	GPIB address lost	EE
+512	Power-on state lost	EE
+514	DC Calibration data lost	EE
+515	Calibration dates lost	EE
+522	GPIB communication data lost	EE
+610	Questionable calibration	SE
+900	Internal system error	EE

EE = error event
SE = status event
SYS = system error event

Appendix B
Calibration Reference

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Introduction

This appendix contains detailed information on remote calibration commands, calibration error messages, and methods to detect the end of each calibration step.

Section 13 of this manual contains detailed calibration procedures.

Command summary

Table B-1 summarizes calibration commands. These commands are described in detail in the following paragraphs.

Miscellaneous commands

Miscellaneous commands are those commands that perform such functions as saving calibration constants, locking out calibration, and programming date parameters.

:CODE

(:CALibration:PROTected:CODE)

Purpose To unlock calibration so that you can perform the calibration procedure.

Format :cal:prot:code '<code>'

Parameter Up to an 8-character ASCII string, including letters and numbers.

Description The `:CODE` command sends the calibration code and enables calibration when performing these procedures via remote. The correct code must be sent to the unit before sending any other calibration command. The default remote code is KI002308.

NOTE The `:CODE` command should be sent only once before performing calibration. Do not send `:CODE` before each calibration step.

To change the code, first send the present code then send the new code.

The code parameter must be enclosed in single quotes.

Example `:CAL:PROT:CODE 'KI002308'` Send default code of KI002308.

Table B-1
Remote calibration command summary

Command	Description
:CALibration	Calibration subsystem.
:PROTected	Cal commands protected by password.
:CODE '<code>'	Unlock cal; changes code if cal is already unlocked (default code: KI002308).

* Calibration data will not be saved if:
1. Calibration was not unlocked with `:CODE` command.
2. Invalid data exists. (For example, cal step failed or was aborted.)
3. Incomplete number of cal steps were performed.
4. Calibration was not performed in the proper sequence.

Table B-1
Remote calibration command summary

Command	Description
:COUNt?	Query number of times 2308 has been calibrated.
:DATE <yyyy>,<mm>,<dd>	Program calibration year, month, day.
:DATE?	Query calibration year, month, day.
:INIT	Initiate calibration (must be sent before other cal steps).
:SAVE	Save calibration data to EEPROM.*
:LOCK	Lock out calibration. (Abort if calibration is incomplete.)
:STEP0 <nrf>	Output Ch. 1 full-scale voltage (14 V).
:STEP1 <nrf>	Calibrate Ch. 1 output voltage using external DMM reading.
:STEP2 <nrf>	Calibrate Ch. 1 voltage measuring using external DMM reading.
:STEP3 <nrf>	Output current (1.9 A) for Ch. 1, 5 A full-scale cal.
:STEP4 <nrf>	Calibrate Ch. 1 output current limit using calculated current.
:STEP5<nrf>	Calibrate Ch. 1, 5 A measurement range using calculated current.
:STEP6	Output 500 mA nominal current for Ch. 1, 500 mA range full-scale cal.
:STEP7<nrf>	Calibrate Ch. 1, 500 mA measurement range.
:STEP8	Output 50 mA nominal current for Ch. 1, 50 mA range full-scale cal.
:STEP9<nrf>	Calibrate Ch. 1, 50 mA measurement range.
:STEP10	Output 5mA nominal current for Ch. 1 5mA range full-scale cal.
:STEP11 <nrf>	Calibrate Ch. 1, 5 mA measurement range.
:STEP12<nrf>	Output Ch. 2 full-scale voltage (14 V).
:STEP13 <nrf>	Calibrate Ch. 2 output voltage setting using DMM reading.
:STEP14 <nrf>	Calibrate Ch. 2 voltage measuring using external DMM reading.
:STEP15	Perform Ch. 2 DVM input full-scale (14 V) cal.
:STEP16 <nrf>	Output current (1.9 A) for Ch. 2, 5 A full-scale cal.
:STEP17<nrf>	Calibrate Ch. 2 output current limit using calculated current.
:STEP18 <nrf>	Calibrate Ch. 2, 5 A measurement range using calculated current.
:STEP19	Output 5 mA nominal current for Ch. 2, 5 mA range full-scale cal.
:STEP20 <nrf>	Calibrate Ch. 2, 5 mA measurement range.

* Calibration data will not be saved if:
1. Calibration was not unlocked with `:CODE` command.
2. Invalid data exists. (For example, cal step failed or was aborted.)
3. Incomplete number of cal steps were performed.
4. Calibration was not performed in the proper sequence.

:COUNT?

(:CALibration:PROTected:COUNt?)

Purpose To request the number of times the Model 2308 has been calibrated.

Format `:cal:prot:count?`

Response Number of times calibrated.

Description The `:COUNT?` query may be used to determine the total number of times the Model 2308 has been calibrated. The calibration count will also be displayed during the front-panel calibration procedure.

Example :CAL:PROT:COUNT? Request calibration count.

:DATE

(:CALibration:PROTected:DATE)

Purpose To program the calibration date.

Format :cal:prot:date <yyyy>, <mm>, <dd>

Parameter <yyyy> = 2008 to 2107

<mm> = 1 to 12
<dd> = 1 to 31

Query Response `:cal:prot:date?`
<yyyy> , <mm> , <dd>

Description The :DATE command allows you to store the calibration date in instrument EEROM for future reference. You can read back the date from the instrument by using the :DATE? query. The calibration date will also be displayed during the front-panel calibration procedure.

NOTE The year, month, and day parameters must be delimited by commas.

Example `:CAL:PROT:DATE 2008,3,1` Send cal date (3/1/2008).

:INIT

(:CALibration:PROTected:INIT)

Purpose To initiate calibration.

Format :cal:prot:init

Description The `:INIT` command initiates the calibration process and must be sent before all other commands except `:CODE`.

NOTE The :INIT command should be sent only once at the beginning of the calibration procedure. Do not send `:INIT` before each calibration step.

Example `:CAL:PROT:INIT` Initiate calibration.

`:SAVE`
`(:CALibration:PROTected:SAVE)`

Purpose To save calibration constants in EEROM after the calibration procedure.

Format `:cal:prot:save`

Description The `:SAVE` command stores internally calculated calibration constants derived during comprehensive in EEROM. EEROM is non-volatile memory, and calibration constants will be retained indefinitely once saved. :SAVE is sent after all other calibration steps.

NOTE Calibration will be only temporary unless the `:SAVE` command is sent to permanently store calibration constants. Calibration data will not be saved if:

1. Calibration was not unlocked by sending the `:CODE` command
2. Invalid data exists (for example, cal step failed).
3. An incomplete number of cal steps were performed.
4. Calibration was performed out of sequence.

Example `:CAL:PROT:SAVE` Save calibration constants

:STEP
(:CALibration:PROTected:STEP<n>)

Purpose To perform various calibration steps.

Format :cal:prot:step<n>

Parameters See *Table B-1*.

Description The :CAL:PROT:STEP<n> command performs calibration at the various points listed in *Table B-2*. See *Section 13* for details on test equipment and connections.

NOTE Calibration steps must be performed in the order listed in *Table B-2*, or an error will occur.

Example `:CAL:PROT:STEP0 14` Perform cal step 0 (Ch. 1 full-scale output).

Detecting calibration errors

If an error occurs during any calibration step, the Model 2308 will generate an appropriate error message. Several methods to detect calibration errors are discussed below.

Reading the error queue

As with other Model 2308 errors, any calibration errors will be reported in the error queue. Use the `:SYST:ERR?` query to read the error queue.

Error summary

Table B-2 summarizes calibration errors.

Status byte EAV (Error Available) bit

Whenever an error is available in the error queue, the EAV (Error Available) bit (bit 2) of the status byte will be set. Use the `*STB?` query to obtain the status byte, then test bit 2 to see if it is set. If the EAV bit is set, an error has occurred, and you can use the appropriate error query to read the error and at the same time clear the EAV bit in the status byte.

Generating an SRQ on error

To program the instrument to generate an IEEE-488 bus SRQ (Service Request) when an error occurs, send the following command: `*SRE 4`. This command will enable SRQ when the EAV bit is set. You can then read the status byte and error queue as outlined above to check for errors and to determine the exact nature of the error.

Table B-2
Calibration errors

Error number	Error message
+404	Volt fullscale cal prepare error chan 1
+405	Volt fullscale cal output error chan 1
+406	Volt fullscale cal meas error chan 1
+409	5 Amp source cal prepare error chan 1
+410	5 Amp source cal output error chan 1
+411	5 Amp source cal measure error chan 1
+412	500 mA source cal prepare error chan 1
+413	500 mA source cal measure error chan1
+414	50 mA source cal prepare error chan 1
+415	50 mA source cal measure error chan1
+416	5 mA source cal prepare error chan 1
+417	5 mA source cal measure error chan 1
+429	Volt fullscale cal prepare error chan 2
+430	Volt fullscale cal output error chan 2
+431	Volt fullscale cal meas error chan 2
+432	DVM full scale cal meas error chan 2
+434	5 Amp source cal prepare error chan 2
+435	5 Amp source cal output error chan 2
+436	5 Amp source cal measure error chan 2
+437	5 mA source cal prepare error chan 2
+438	5 mA source cal measure error chan 2

Detecting calibration step completion

When sending remote calibration commands, you must wait until the instrument completes the current operation before sending another command. You can use either `*OPC` or `*OPC?` to determine when each calibration step is completed.

Using the *OPC command

Using *OPC is the preferred method to detect the end of each calibration step. To use `*OPC`, do the following:

1. Enable operation complete by sending `*ESE 1`. This command sets the OPC (operation complete bit) in the standard event enable register, allowing operation complete status from the standard event status register to set the ESB (event summary bit) in the status byte when operation complete is detected.
2. Send the *OPC command immediately following each calibration command. For example:

   ```
   :CAL:PROT:STEP0 14;*OPC
   ```

   Note that you must include the semicolon (;) to separate the two commands, and that the *OPC command must appear on the same line as the command.
3. After sending a calibration command, repeatedly test the ESB (Event Summary) bit (bit 5) in the status byte until it is set (use `*STB?` to request the status byte).
4. Once operation complete has been detected, clear OPC status using one of two methods: (1) use the *ESR? query, then read the response to clear the standard event status register, or (2) send the *CLS command to clear the status registers. Note that sending `*CLS` will also clear the error queue and operation complete status.

Using the *OPC? query

With the *OPC? (operation complete) query, the instrument will place an ASCII 1 in the output queue when it has completed each step. To determine when the OPC response is ready, do the following:

1. Send the `*OPC?` query immediately following each calibration command. For example:

   ```
   :CAL:PROT:STEP0 14;*OPC?
   ```
2. Wait for an ASCII 1 to be read from the unit after addressing it to talk.

Generating an SRQ on calibration complete

An IEEE-488 bus SRQ (service request) can be used to detect operation complete instead of repeatedly polling the Model 2308. To use this method, send both `*ESE 1` and `*SRE 32` to the instrument, then include the `*OPC` command at the end of each calibration command line, as covered above. Clear the SRQ by querying the ESR (using the `*ESR?` query) to clear OPC status, then request the status byte with the `*STB?` query to clear the SRQ.

Refer to your controller's documentation for information on detecting and servicing SRQs.

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Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❑ Intermittent
❑ Analog output follows display
❑ Particular range or function bad; specify _____
❑ IEEE failure
❑ Obvious problem on power-up
❑ Batteries and fuses are OK
❑ Front panel operational
❑ All ranges or functions are bad
❑ Checked all cables

Display or output (check one)

❑ Drifts
❑ Unable to zero
❑ Unstable
❑ Will not read applied input
❑ Overload

❑ Calibration only
❑ Certificate of calibration required
❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

_____

_____

What power line voltage is used? _____ Ambient temperature?°F _____

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

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