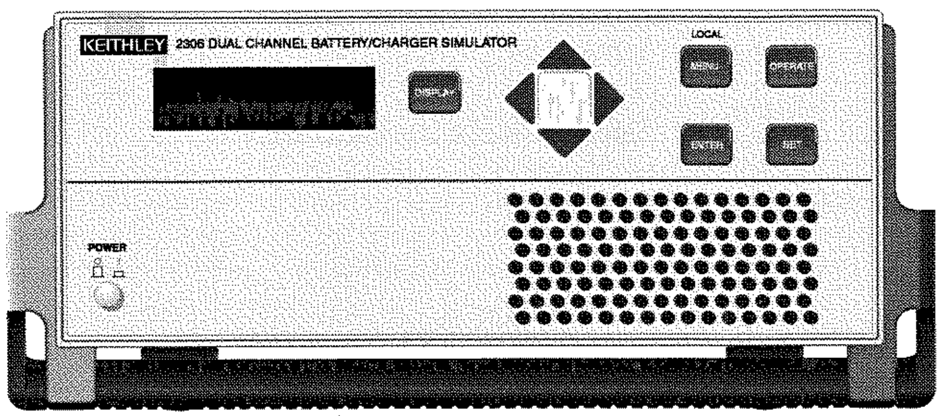
Model 2302/2306
Battery/Charger Simulator
Instruction Manual



Contains Operating, Programming, and Servicing Information

KEITHLEY

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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Model 2302/2306 Battery/Charger Simulator
Instruction Manual

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 2306-901-01) ....March 1999

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 the operating information carefully before using the product.

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, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. 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, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

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.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users 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 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

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, make sure 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.

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 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 manual.

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

The **WARNING** heading in a manual 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 a manual 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., 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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1 Getting Started

2 Basic Power Supply Operation

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6 GPIB Operation

1 Getting Started

- **General information** — Provides general information including warranty information, contact information, safety symbols and terms, inspection and available options and accessories.
- **Power supply overview** — Summarizes the capabilities of the power supply.
- **Remote display option** — Explains how to use the optional Model 2304-DISP Display Module.
- **Power-up** — Covers line power connection, the power up sequence, and fuse replacement.
- **Display modes** — Explains the four display modes of the power supply.
- **Default settings** — Lists the factory default settings, and explains how to save and recall settings.
- **Menu** — Provides a table that summarizes the menu items and includes rules to navigate the menu structure.
- **SCPI programming** — Explains how SCPI commands are presented in this manual.

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

General information

Warranty information

Warranty information is located at the front of this manual. Should your power supply require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

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 only). Worldwide phone numbers are listed at the front of this manual.

Safety symbols and terms

Keithley uses a standard set of safety symbols and terms that may be found on an instrument or in its manual.

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

The ⚡ symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in a manual 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 used in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Specifications

Full power supply specifications can be found in Appendix A of this manual.

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 2306 Dual Channel Battery/Charger Simulator with line cord
- Quick Disconnect Output/DVM Input Connector (2)
- Accessories as ordered
- Certificate of calibration
- Model 2302/2306 Instruction Manual (P/N 2306-901-00)
- Model 2302/2306 Quick Results Guide

If an additional manual is required, order the manual package. The manual package includes a manual and any pertinent addenda.

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

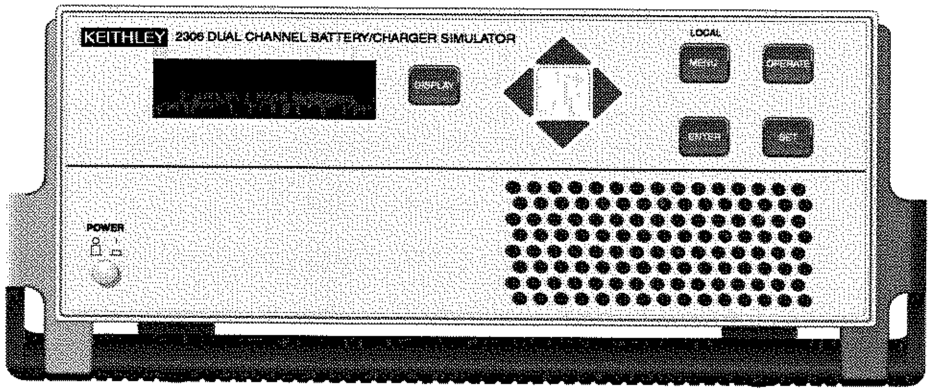
The following options and accessories are available for the power supply.

- 2304-DISP remote display unit
- Shielded IEEE-488 cable, 1m (3.3 ft) (P/N 7007-1)
- Shielded IEEE-488 cable, 2m (6.6 ft) (P/N 7007-2)
- Single fixed rack mount kit (P/N 4288-1)
- Dual fixed rack mount kit (P/N 4288-2)
- IEEE-488 Interface/controller for the PCI bus (P/N KPCI-488)
- IEEE Interface card for IBM PC/AT (full slot) (P/N KPC-488-2AT)

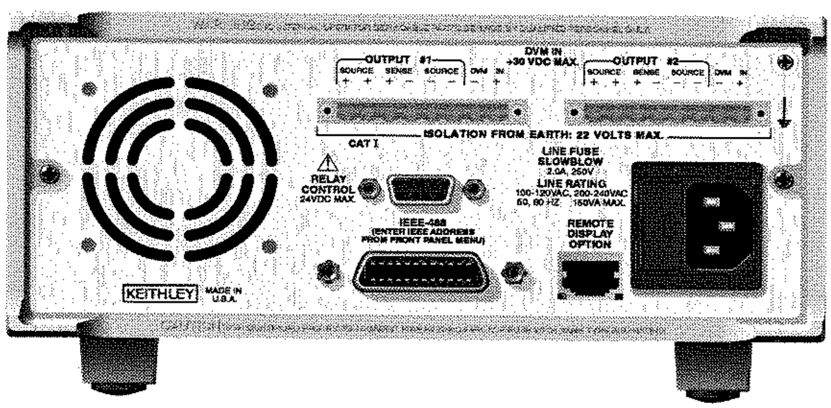
Power supply overview

The Model 2306 power supply (dual channel battery/charger simulator — see Figure 1-1) can simulate a battery (Channel #1) or a charger (Channel #2).

Figure 1-1
Model 2306 dual channel battery/charger simulator



A) Front Panel



B) Rear Panel

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

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

NOTE *When using the power supply as a sink (negative polarity), the power supply is dissipating rather than sourcing power (see "Sink Operation" in Section 2).*

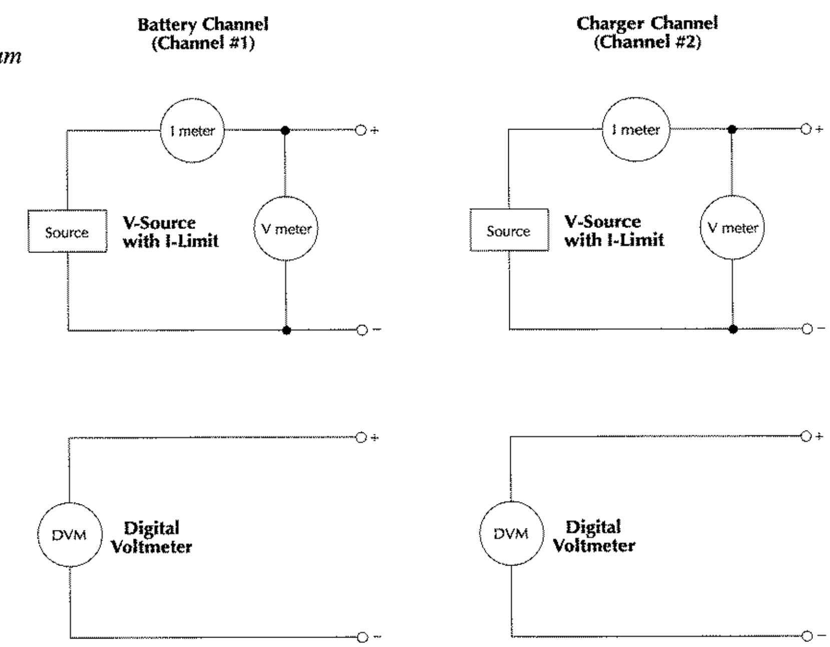
A simplified diagram of the power supply is shown in Figure 1-2. Note that it can read back the output voltage (V_{meter}) and current (I_{meter}). Display resolution for voltage readback is 1mV.

Current Readback Range: The Model 2306 has two ranges for current readback: 5A and 5mA. On the 5A range display resolution is 100μA, and on the 5mA range resolution is 0.1μA.

The power supply also has a digital voltmeter (DVM) that is independent of the power supply circuit. The DVM can measure up to +30V (1mV resolution).

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 1-2
Simplified power supply diagram



Remote display option

If mounting the power supply in a location where the display cannot be seen or the controls are not easily accessible, use the optional Model 2304-DISP Display Module (see Figure 1-3). This remote display module includes all front panel instrument controls/features (with the exception of power). All features/menus work as described for the Model 2306 (exceptions are noted). A 9 foot cable attaches the remote display to the rear of the power supply allowing the unit to be operated remotely.

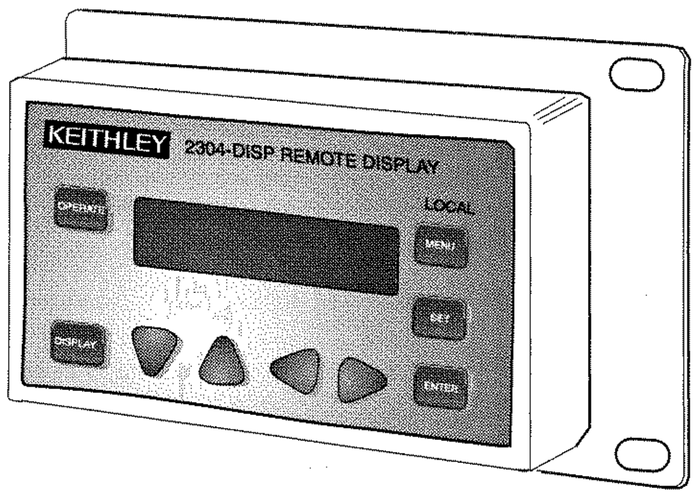


Figure 1-3
Remote display option

NOTE *When using the 2304-DISP remote, VFD BRIGHTNESS may not appear in the main menu (dependent on the firmware revision in the 2304-DISP).*

Plug the remote display module into the rear panel connector labeled "REMOTE DISPLAY OPTION" (see rear panel in Figure 1-1). 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 connecting or disconnecting the 2304-DISP 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 60Hz. 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 (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 2306 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 Inc., 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 or the saved power up settings (*RST or SAV0-4) saved display type with the output off (see "Default settings" on page 1-11). Any missed error messages may be viewed over the bus using the :SYST:ERR? (see "Error Queue" in Section 7).

Fuse replacement

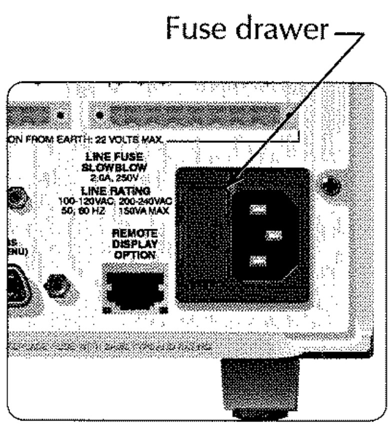
A rear panel fuse protects the power line input of the power supply. If the line fuse needs to be replaced, perform the following steps:

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 1-4). On the right side of the fuse drawer is a small tab. At this location, use a thin-bladed knife or 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 (250V, 2.0A, 5 x 20mm time lag). The Keithley 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 1-4
Fuse drawer location



Display modes

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

- **ACTUAL V AND I** — This display mode is used to read back the actual output voltage and current. This display mode is the RST default. (See Section 2 for details.)
- **DVM INPUT** — This mode is used to display the DC voltage applied to the DVM input of the power supply. (See Section 2 for details.)
- **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 850msec to 60sec (60 Hz line frequency) and 840msec to 60sec (50 Hz line frequency). (See Section 4 for details.)

Any one of the four display modes can be the power-on default. 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 (see "Setups — Save, Power-on, and Recall" on page 1-12 for details). A display mode is selected as follows:

1. Press the DISPLAY key and use the ▲ or ▼ key to display the desired mode: ACTUAL V AND I, DVM INPUT, PULSE CURRENT, or LONG INTEGRATION.
   DISPLAY TYPE #1 or DISPLAY TYPE #2 will be shown on the top line of the display.

NOTE *DISPLAY TYPE #1 is the display mode for the Battery Channel while DISPLAY TYPE #2 is the display mode for the Charger Channel.*

2. Toggle active channel using the ◀ or ▶ keys.

NOTE *If active channel is changed back to the original channel, the initial settings are displayed.*

3. With the desired mode and active channel displayed, press ENTER. Now the display will reflect this desired mode and active channel. Note that after selecting PULSE CURRENT, use the ▲ or ▼ key to select the desired pulse measurement: pulse high, pulse low, or pulse average. Examples of the display modes are shown as follows:

Table 1-1
Display samples

Display mode	Samples for Channel #1 (Battery)	Samples for Channel #2 (Charger)	Reference
Actual V and I:	6.116 V #1 ON 1.2058 A	6.116 V #2 ON 1.2058 A	Section 2
DVM input:	DVM INPUT #1 OFF 4.993 V	DVM INPUT #2 OFF 4.993 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

NOTES *"#1" or "#2" indicates present 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 user-saved setup conditions. The factory default conditions are listed in Table 1-2.

Table 1-2
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	8V, clamp off	8V, clamp off
Display type	Actual V and I	Actual V and I
GPIB address*	No effect (factory set to 16)	
Current range	5 amps (Auto Range OFF)	5 amps (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
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	HIGH	HIGH
Output impedance	0.00Ω	*Not Applicable*
Pulse current:		
High time	33 µsec	33 µsec
Low time	33 µsec	33 µsec
Average time	33 µsec	33 µsec
Average readings	1	1
Trigger delay	0.00000 sec	0.00000 sec
Trigger level:		
Range	5A (Full scale)	*Not Applicable*
5A range	0.000A	0.000A
1A range	0.000A	*Not Applicable*
100mA range	0.0000mA	*Not Applicable*
Long integration:		
Integration time	1 second	1 second
Pulse timeout	16 seconds	16 seconds
Trigger edge	RISING	RISING
Trigger level	Same as "Trigger level" (above)	Same as "Trigger level" (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 1-2 on page 1-11.) Similarly, recalling a setup loads only the channel specific parameters from that setup.

NOTE *Table 1-3 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-SAV4.
- **RECALL SETUP** - Return the power supply to the RST defaults (Table 1-2 on page 1-11), or to one of the user saved setups; SAV0-SAV4. Note the operate state (output) is always recalled as OFF.
- **POWER-ON SETUP** - Select the setup to use at power-up; RST, SAV0-SAV4 (output off).

When powering up to the SAV0, SAV1, SAV2, SAV3, or SAV4 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 for details.) The power-on setup is selected using the SYSTem:POSetup command (Section 10).*

Menu

Many aspects of operation are configured from the menus summarized in Table 1-3. 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 1-3
Main MENU structure (accessed by pressing the MENU key on the Front Panel)

Menu item	Description	Ref
GPIB ADDRESS	Set primary address (0 to 30)	Sect. 6
CURRENT RANGE #1/#2	Select current range:5A, 5mA or AUTO	Sect. 2
NPLC RATE #1/#2	Set integration rate in NPLC (0.01 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–SAV4)	Note 1
RECALL SETUP	Recall setup from memory (RST, SAV0–SAV4)	Note 1
POWER ON SETUP	Select power-on setup (RST, SAV0–SAV4)	Note 1
CALIBRATE UNIT	Calibrate unit (see calibration sections and clamp (ON/OFF) in this manual)	
VOLT PROTECT #1/#2	Set voltage protection range (0–8V)	Sect. 2
CURR LIM MODE #1/#2	Select current limit mode (LIMit or TRIP)	Note 2
OUTPUT RELAYS	Close (1) or open (0) relay control circuitry (relays 1–4)	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.	
AVERAGE READINGS	Set average reading count (1 to 100).	
TRIGGER DELAY	Set trigger delay in seconds (0 to 100msec).	
TRIG LEV RANGE	Set battery channel (#1) trigger level range (5A, 1A, 100mA).	
TRIGGER LEVEL	Sets pulse current trigger level in Amps: Battery channel (#1): A(5.0) 0–5A; A(1.0) 0–1A; mA(100) 0–100mA Charger channel (#2): A(5.0) 0–5A	
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).	
TRIG LEV RANGE	Set battery channel (#1) trigger level range (5A, 1A, 100mA).	
TRIGGER LEVEL	Sets long integration trigger level in Amps: Battery channel (#1): A(5.0) 0–5A; A(1.0) 0–1A; mA(100) 0–100mA Charger channel (#2): A(5.0) 0–5A	

Notes: 1. See "Default settings" on page 1-11 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.
- Use the ▲ and ▼ keys to scroll through the primary menu items.
- Changing channels: When the main menu is displayed, use the ◀ and ▶ keys to change the active channel (each press of the ◀ and ▶ keys will toggle between Channel #1 and Channel #2) .

NOTE *If a channel number is not shown, the ◀ and ▶ key presses will be ignored. Also the ◀ and ▶ key presses will be ignored if a sub-menu only exists on the battery channel (not on the charger channel).*

- The active channel may be changed in the main menu, and the top sub-menus for pulse current and long integration. The active channel cannot be changed in all other sub-menus.
- Select the displayed primary menu item by pressing ENTER. With PULSE CURRENT or LONG INTEGRATION selected, use the ▲ and ▼ 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 ◀ or ▶ to toggle 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 (◀ ▶ ▲ ▼):

  For a setting, use ◀ or ▶ to place the cursor on the desired digit, then use the ▲ and ▼ 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). (Note that if the tens digit is the most significant but is not displayed, place the cursor to the left of the units digit.) To rapidly jump to the minimum value, decrement the first leading zero (or tens digit if there is not a leading zero).

  For a selection, use the ▲ or ▼ keys to display 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 back out of 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.

NOTE *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.)

NOTE *For complete details, see "Programming syntax" in Section 6.*

2
Basic Power Supply Operation

- **Test connections** — Explains how to connect DUT to the power supply output and how to connect an external voltage to the DVM input.
- **Outputting voltage and current** — Explains how to output voltage and current.
- **Output bandwidth** — Details Model 2306 output bandwidth control.
- **Output impedance** — Details Model 2306 variable output impedance feature.
- **SCPI Programming — outputting voltage and current** — Contains SCPI commands related to output voltage and current.
- **Reading back V and I** — Covers the actual V and I display mode, which is used to measure and display the actual voltage and current being delivered to the DUT.
- **SCPI Programming — measure V and I, and DVM input** — Contains SCPI commands related to measuring voltage and current.
- **Independent voltage measurements (DVM)** — Explains how to use the digital voltmeter (DVM) to make DC voltage measurements.
- **SCPI Programming — DVM** — Contains SCPI commands related to DVM measurements.
- **Sink operation** — Explains how to use the power supply to dissipate power, rather than sourcing it.
- **Programming examples** — Provides two examples: one to output and read back voltage and current, and one to measure the DVM input.

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

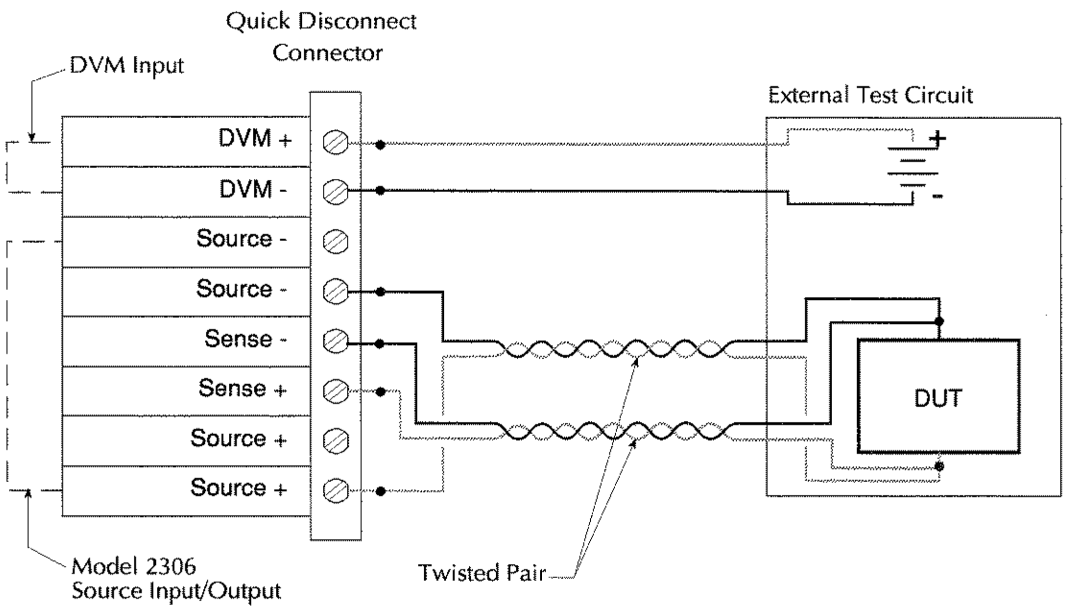
Test connections

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 (see specifications). Failure to do so could result in personal injury or death.**

Test connections to the power supply are made at the rear panel using a quick disconnect OUTPUT/DVM IN 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 shows four wire sense power supply connections to the DUT.

Figure 2-1
Four-wire sense connections for battery and charger channels



Remote sense

As shown in Figure 2-1 the 2306 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 +18V or down to -5V. Use voltage protection to turn off the output and protect against the extremes (refer to "Setting voltage protection value" on page 2-5).

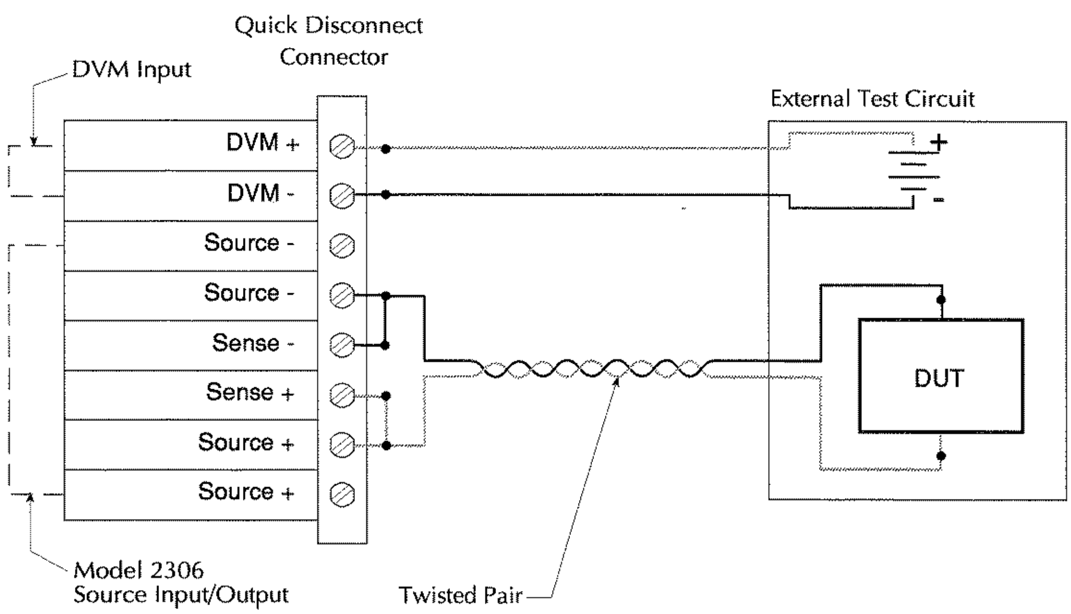
Connect the sense inputs to the supply as close as possible to the load's source inputs through twisted pair leads (refer to Figure 2-1). This is necessary to achieve the maximum transient performance of the supply.

NOTE *Do NOT jumper 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 2306 with dynamic loads when using 4-wire sense.*

Local sense

The 2306 battery and charger channels can be connected to operate with local sense leads (2-wire connection) as shown in Figure 2-2. In this connection scheme, the sense inputs and supply outputs are jumpered at the rear of the supply.

Figure 2-2
Local sense connections



Outputting voltage and current

Setting voltage protection value

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

Voltage protection circuitry (VPT) is provided for the battery and charger channels. This function monitors the SOURCE + pins (see Figure 2-1 on page 2-3 or Figure 2-2 on page 2-4) with respect to the 2306'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. 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=4V, and SET =6V, VPT range is from +2V to +10V. If the SET voltage is changed to 2V and protection clamp set to OFF, the range would equal -2V to +6V. However, if protection clamp is set to ON, the range would equal -0.6V to +6V.

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

NOTE *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.*

Procedure

To set the VPT value from the front panel:

1. Press the MENU key to access the main menu.
2. Select VOLT PROTECT #1 or #2 by scrolling through the primary menu items (use the ▲ and ▼ keys to scroll). Scroll until VOLT PROTECT is displayed on the bottom line.
3. Select channel for VPT. Toggle between VOLT PROTECT #1 or #2 using the ◀ and ▶ keys.
4. Press ENTER.
5. Use the ▲, ▼, ◀ and ▶ keys to key in the desired VPT value and to select cOFF (voltage protection clamp OFF} or cON (voltage protection clamp ON). Setting changes can be canceled by pressing MENU.
6. Press ENTER to save and return to main menu.

Selecting proper current range

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

Power supply current ranges are listed in Table 2-1. With auto range 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
Model 2306	5A, 5mA and AUTO

NOTE Table 1-3 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.

Procedure

To select the CURRENT RANGE from the front panel:

1. Press the MENU key to access the main menu.
2. Select CURRENT RANGE #1 or #2 by scrolling through the primary menu items (use the ▲ / ▼ keys to scroll). Scroll until CURRENT RANGE is displayed on the bottom line.
3. Select channel for CURRENT RANGE. Toggle between CURRENT RANGE #1 or #2 using the ◀/▶ keys. The "#1" (battery channel active) or "#2" (charger channel active) will appear on the bottom line of the display.
4. Press ENTER.
5. Use the ▲ / ▼ keys to display the desired current range value. Setting changes can be canceled by pressing MENU.
6. Press ENTER to save and return to main menu.

Selecting current limit mode

NOTE The current limit mode setting is channel specific. The number after the # 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 - With 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.

TRIP mode - With 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, assuming it does not trip again due to a current limit condition.

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

Procedure

To select the CUR LIM MODE from the front panel:

1. Press the MENU key to access the main menu.
2. Select CUR LIM MODE #1 or #2 by scrolling through the primary menu items (use the ▲ / ▼ keys to scroll). Scroll until CUR LIM MODE is displayed on the bottom line.
3. Select channel for CUR LIM MODE. Toggle between CUR LIM MODE #1 or #2 using the ◀/▶. The "#1" (battery channel active) or "#2" (charger channel active) will appear on the bottom line of the display.
4. Press ENTER.
5. Use the ▲ / ▼ keys to display the desired current limit mode (LIM or TRIP). Setting changes can be canceled by pressing MENU.
6. Press ENTER to save and return to main menu.

Editing output voltage and current limit values

NOTE *Output voltage and current limit values are channel specific. The number after the # 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 (5A, 5mA, or auto).

The current limit setting for the 5 AMPS and AUTO ranges is "remembered" by that range. For the following examples, assume the current limit setting on the 5 amps range is 3A. Selecting the 5 MILLIAMPS range defaults the current limit setting to 1A since that is the maximum allowable setting on that range. Toggling back to the 5 amps range reinstates the 3A limit. If the current limit value on the 5 amps range is ≤ 1A, the limit on the 5mA range will be the same when switching from the 5A range to the 5mA range.

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

Procedure

To edit voltage and current values from the front panel:

NOTE *The following procedure assumes 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. Use the ▲, ▼, ◀ and ▶ keys to key in the desired output voltage value.
   - Cursor position (blinking digit) is controlled by the ◀ and ▶ keys.
   - With the cursor positioned on a digit, increment or decrement the value using the ▲ and ▼ keys.
3. Press SET to move the blinking cursor to the current limit field.
4. Use the ▲, ▼, ◀ and ▶ keys to key in the desired current limit.
5. Press SET to exit from output settings mode.

NOTE *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 ▲, ▼, ◀ and ▶ keys to key in the desired output voltage or current value(s).

NOTE *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 SET 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.

Editing shortcuts

With the output OFF, the following editing shortcuts can be used:

- 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 (0.000V) 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 0.006A by decrementing the first leading zero of the reading. If there is no leading zero, decrement the units digit.

Editing restrictions

With the output ON, the following editing restrictions are in effect:

- 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.

Pressing operate

NOTE Pressing OPERATE is channel specific. The number after the # 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.

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 2306. Since a charger circuit is a voltage regulated circuit, it resembles a high capacitance load to the output of the 2306. For this type of application, the LOW bandwidth output mode provides increased stability and eliminates oscillations that may occur.

To use this setting, there are two requirements: output has to be on and the current range has to be set to 5A. If the output is off or the current range is not 5A, output bandwidth is set to low. This is summarized in Table 2-2.

Table 2-2
Output bandwidth setting for a channel

Output	Current	Bandwidth
ON	5A	LOW or HIGH (user selectable)
OFF	5mA or 5A	LOW
OFF/ON	5mA	LOW

NOTE *The 5mA current range (Table 2-2) may be selected from the front panel, over the bus, or through autoranging.*

Procedure

NOTE *This procedure assumes 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. Select OUT BANDWIDTH #1 or #2 by scrolling through the primary menu items (use the ▲ and ▼ keys to scroll). Scroll until OUT BANDWIDTH is displayed on the bottom line.
3. Select channel for bandwidth. Toggle between OUT BANDWIDTH #1 or #2 using the ◀ and ▶ keys.
4. Press ENTER.
5. Use the ▲ and ▼ keys to set the desired bandwidth setting (HIGH or LOW). Setting changes can be cancelled by pressing MENU.
6. Press ENTER to save and return to main menu.

Output impedance

Keithley's Model 2306 has a variable output impedance feature on the battery channel (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 voltage drop equation). 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 the Applications Guide contained in Appendix E of this manual.*

Changing the battery channel's output impedance

The Model 2306s output impedance can be checked or changed with the output on or off. The output impedance is selectable from 0.00Ω to 1.00Ω in 10 milli-Ω steps (default is 0Ω).

Procedure

NOTE *The following procedure assumes 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. Using the ◀ and ▶ keys, toggle channel indicator until #1 is displayed. (Bandwidth is channel #1 only feature.)
3. Select OUT IMPEDANCE #1 by scrolling through the primary menu items (use the ▲ and ▼ keys to scroll). Scroll until OUT IMPEDANCE is displayed on the bottom line.
4. Press ENTER.
5. Use the ▲ and ▼ keys to set the desired bandwidth setting (HIGH or LOW). Setting changes can be canceled by pressing MENU.
6. Press ENTER to save and return to 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]	SENSe[1] subsystem for Channel #1 (battery channel):	
:CURRent	Current function:	
:RANGe	Set current measurement range:	
[:UPPer] <n>	Specify expected current in amps: 0 to 5.	5.0
:AUTO <b>	Enable or disable auto range.	OFF
SENSe2	SENSe2 subsystem for Channel #2 (charger channel):	
:CURRent	Current function:	
:RANGe	Set current measurement range:	
[:UPPer] <n>	Specify expected current in amps: 0 to 5.	5.0
:AUTO <b>	Enable or disable auto range.	OFF
[SOURce[1]]	[SOURce1] subsystem for Channel #1 (battery channel):	
:VOLTage <n>	Set voltage amplitude in volts: 0 to 15 (1mV resolution).	0.0
:PROTection <NRf>	Sets VPT (voltage protection) range (0–8V).	8V
:STATe? <b>	Query state of VPT—no associated command.	
:CLAMp <b>	Sets VPT clamp mode ON or OFF.	OFF
:CURRent <n>	Set current limit value in amps: 0.006 to 5 (100μA res)	0.25
:TYPe <name>	Select current limit type: LIMit or TRIP.	LIM
:STATe?	Query state of current limit—no associated command.	
SOURce2	SOURce2 subsystem for Channel #2 (charger channel):	
:VOLTage <n>	Set voltage amplitude in volts: 0 to 15 (1mV resolution).	0.0
:PROTection <NRf>	Sets VPT range (0–8V).	8V
:STATe? <b>	Query state of VPT—no associated command.	
:CLAMp <b>	Sets VPT clamp mode ON or OFF.	OFF
:CURRent <n>	Set current limit value in amps: 0.006 to 5 (100μA res).	0.25
:TYPe <name>	Select current limit type: LIMit or TRIP.	LIM
:STATe?	Query state of current limit—no associated command.	
OUTPut[1]	OUTPut [1] subsystem for Channel #1 (battery channel):	
[:STATe] <b>	Turn the power supply output ON or OFF.	OFF
:BANDwidth <name>	Specifies output bandwidth (HIGH or LOW).	HIGH
:IMPedance <NRf>	Specifies output impedance (0–1Ω in 10mΩ steps).	0
OUTPut2	OUTPut2 subsystem for Channel #2 (charger channel):	
[:STATe] <b>	Turn the power supply output ON or OFF.	OFF
:BANDwidth <name>	Specifies output bandwidth (HIGH or LOW).	HIGH

NOTE *Refer to the Programming syntax paragraph of Section 6 for a description of parameters (e.g., <b>, <NRf>, etc.).*

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 is either 5.0000 or 0.0050.

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 is either 5.0000 or 0.0050. If you then disable auto range, the instrument will remain at the last selected range.

[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 the 5mA measurement range selected, the maximum current limit is 1A.
- Sending a value that exceeds 1A is rejected, and the following message is displayed briefly:

  CURRENT LIMIT ON
  mA RANGE ≤ 1A

[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 0–1Ω in 0.01Ω 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 only when the output state is ON and the current range is set to 5A. When the output is OFF or the current range is 5mA, the bandwidth is LOW. This is summarized in Table 2-2.

Reading back V and I

Actual V and I display mode

Measured output voltages and currents are displayed with the actual V and I display mode selected. This display mode is selected as follows:

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).*

1. Press the DISPLAY key to access the display menu. DISPLAY TYPE #1 (battery channel active) or DISPLAY TYPE #2 (charger channel active) will appear on the top line of the display. Use ◀ or ▶ keys to toggle the active channel.
2. Press the ▲ or ▼ keys until "ACTUAL V AND I" is displayed.
3. Press ENTER. Voltage readings are located on the top line of the display, and current readings are located on the bottom line.

NOTE *For details on display modes, see "Display modes" in Section 1.*

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 *Table 1-3 shows 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" on page 2-5 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 (0.01 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 #1/#2 item of the menu is also used to set the reading rate for DVM measurements. Note that it is not used to set the integration rate for pulse current and long integration measurements. These measurements are covered in Sections 3 and 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 #1/#2 menu items are also used to set the average reading count for DVM measurements. Note that it 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 Channel #1 (battery channel):	
:FUNCtion <name>	Select readback function: "VOLTage", "CURRent", or "DVMeter".	VOLT
:NPLCycles <n>	Set integration rate (in line cycles) for voltage, current, and DVM measurements: 0.01 to 10.	1.0
:AVERage <NRf>	Specify the average count for voltage, current, and DVM measurements: 1 to 10.	1
SENSe2	SENSe2 subsystem for Channel #2 (charger channel):	
:FUNCtion <name>	Select readback function: "VOLTage", "CURRent", or "DVMeter".	VOLT
:NPLCycles <n>	Set integration rate (in line cycles) for voltage, current, and DVM measurements: 0.01 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 Channel #1 (battery channel)[1].	
READ[1]:ARRay?	Trigger an array of readings and return them for Channel #1 (battery channel)[1].	
READ2?	Trigger and return one reading for Channel #2 (charger channel)[1].	
READ2:ARRay?	Trigger an array of readings and return them for Channel #2 (charger channel)[1].	

[1]This command applies to the currently selected function.

NOTE *Refer to the Programming syntax paragraph of Section 6 for a description of parameters (e.g., <b>, <NRf>, etc.).*

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)

1. The parameter name can instead be enclosed in single quotes (e.g., 'CURRent').
2. With "DVMeter" selected, the instrument measures the voltage applied to the input of the digital voltmeter (DVM).
3. 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 Sections 3 and 4, respectively.

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

1. 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).
2. Signal oriented measurement commands (e.g., READ?) are covered in Section 9.

Independent voltage measurements (DVM)

The power supply has an independent digital voltmeter (DVM) 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. This display mode is selected as follows:

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).*

1. Press the DISPLAY key to access the display menu. DISPLAY TYPE #1 (battery channel active) or DISPLAY TYPE #2 (charger channel active) will appear on the top line of the display. Use ◀ or ▶ keys to toggle the active channel.
2. Press the ▲ or ▼ key until "DVM INPUT" is displayed.
3. Press ENTER.

NOTE *For details on display modes, see "Display modes" in Section 1.*

Measurement configuration

The NPLC RATE #1/#2 and AVER READINGS #1/#2 for DVM measurements 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 *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 actual V and I measurements. See "Measurement configuration" on page 2-14 for details on NPLC rate and average readings.

SCPI programming — DVM

The commands to perform actual V and I measurements are also used to perform DVM measurements. These commands are documented in Table 2-3.

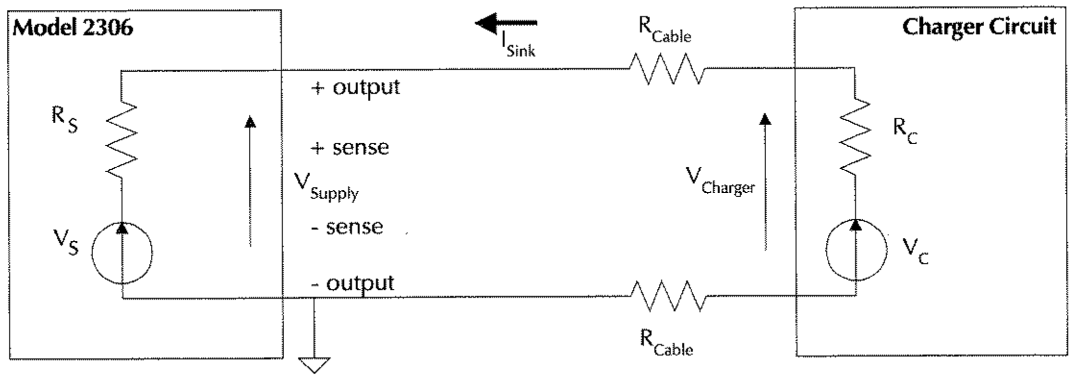
The "DVM measurements" programming example at the end of this section demonstrates how to use these commands to measure the DVM input.

Sink operation

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 2-3 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.

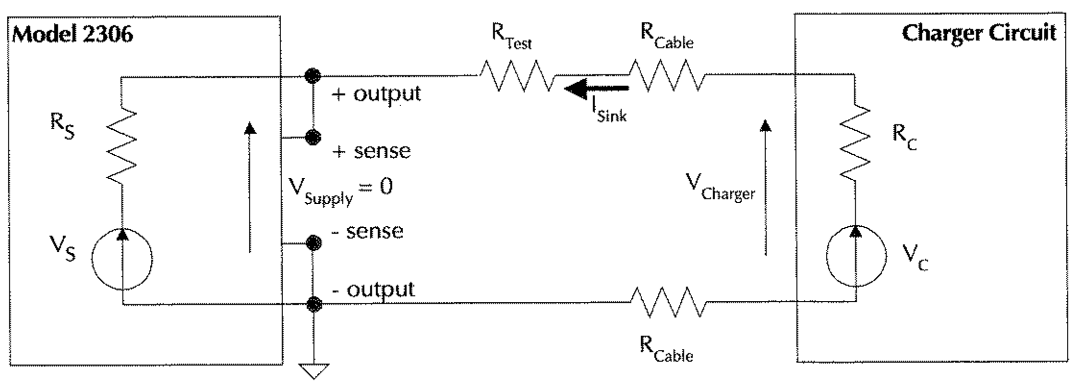
CAUTION **Exceeding current sink capacity (0–5V: 3A max. 5V–15V: Derate 0.2A per volt above 5V) could cause damage to the power supply that is not covered by the warranty.**

Figure 2-3
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 2-4 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 0.00V 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 2-4
Preferred method



NOTE *Figure 2-4 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:

Battery channel (#1)

```
DISP:CHAN 1              ' Set active channel - battery.
SENS:FUNC 'DVM'          ' Select the DVM Input function.
SENS:NPLC 6              ' Set integration rate to 6 PLC.
SENS:AVER 10             ' Set average reading count to 10.
READ:ARR?                ' Trigger and return 10 readings. The average
                           of the 10 readings is displayed on the front
                           panel.
```

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.
```

3
Pulse Current Measurements

- **Overview** — Provides an overview of the pulse current measurement process.
- **Measurement configuration** — Explains how to configure the instrument for pulse current measurements.
- **Pulse current measurement procedure** — Provides the step-by-step procedure to perform pulse current measurements from the front panel.
- **SCPI programming — pulse current measurements** — Documents the commands used to program the instrument for pulse current measurements, and covers pulse current digitization (which can only be performed over the GPIB).
- **Pulse current digitization** — Explains how to digitize a current waveform.
- **Pulse current step method** — Explains use of the pulse current step method to perform a series of different trigger level measurements on the same trigger level range.
- **Programming examples** — Seven programming examples are provided; two for pulse current measurements, two for pulse current digitization, and three for pulse current step method .

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

Overview

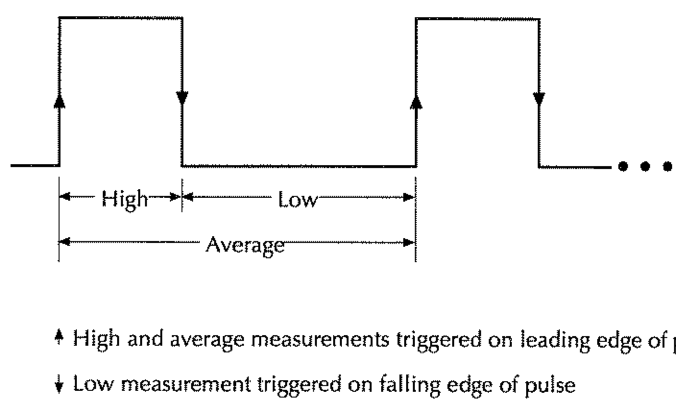
The power supply can perform current measurements for dynamic loads on either battery channel (#1) or charger channel (#2). The built-in measurements include:

- 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. See "Pulse current digitization" on page 3-24 and "Pulse current STEP method (battery channel only)" on page 3-25 for details.*

Figure 3-1
Pulse current measurement



Trigger level

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 5A. The battery channel has three trigger level range settings: 5A, 1A, or 100mA trigger level ranges. For 5A, the level may be set from 0 to 5A. For 1A, the trigger level may be set from 0 to 1A. Likewise, the level may be set from 0 to 100mA for the 100mA trigger level range. These ranges affect trigger level resolution and not the current range selection since pulse current readings are always performed on 5A current range. The trigger level range option on the battery channel allows the user to set a trigger level with greater resolution.

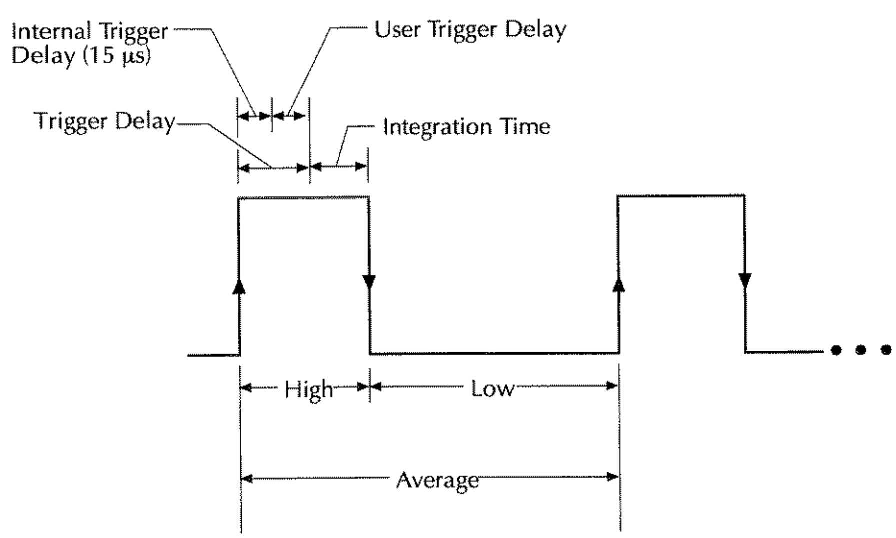
Trigger level range

This setting affects the pulse current trigger level and has no affect on the current range setting since the pulse current measurement is always performed on the 5A current range. Three settings (battery channel only) are available: 5A, 1A, or 100mA. Use the range that provides adequate trigger level resolution (a 100mA range provides a greater available resolution for trigger level than does the 1A 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 15µsec 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 (15 µs) + 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 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 80μsec to 833msec range. Auto time (when used) accounts for the internal trigger delay (15μsec).

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 600μsec, the high integration time must be ≤600μsec. 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 33.3333μsec. This ensures that an integral value of 33.3333μsec 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 15μsec (auto internal time). The auto internal time is then adjusted to be an integral time value of 33.3333μsec (auto integral time). For example:

auto time value = 28.053msec

auto internal time = 28.053ms - 0.015msec = 28.038ms

auto integral time = 28.033ms (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 = 5.040msec

integral time = 5.033ms (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.*

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

NOTES *Current range is selected from the CURRENT RANGE #1/#2 item of the menu. Integration times, average readings count, trigger delay, trigger level range, and trigger level are set from the PULSE CURRENT item of the menu. Details on integration rate, average readings count, trigger delay, trigger level range, and trigger level are provided in the "Overview" starting on page 3-2.*

Table 1-3 shows 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

For pulse current measurements, the AUTO range selection is functionally a no-op (no operation). The instrument will not auto range with the pulse current measurement function selected. Pulse current measurements are always performed on the 5A range. Therefore, selecting pulse current with the 5mA range active will cause the supply to first switch to the 5A range regardless of the current range setting (5mA 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" (in Section 2) 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 while CURRENT RANGE #2 refers to the charger channel).

NOTE *To get better trigger level resolution, make sure the trigger level 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 33.3µsec to 833ms (833333µsec) in 33.3333µsec steps.*

- **HIGH TIME** — Use to set the integration period (in µsec) for high pulse-current measurements. Make sure to account for the internal (15µsec) 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 (15µsec) 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 (15µsec) 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 (15µsec) delay but not the user trigger delay.

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, trigger level range, and trigger level

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

- **TRIGGER DELAY** — Use to specify additional user trigger delay (0 to 100msec in 10µsec steps). See"Trigger delay" on page 3-3 for details. This user trigger delay is in addition to the internal trigger delay of 15µsec.
- **TRIG LEVEL RANGE** — Battery channel (#1) setting only. Use to specify the trigger level range resolution. Possible ranges are:
  ```
  5A FULL SCALE     (0-5A)
  1A FULL SCALE     (0-1A)
  100mA FULL SCALE (0-100mA
  ```
- **TRIGGER LEVEL** — Use to set the trigger level. Pulses less than the specified level are not detected.

Battery Channel (#1) — The trigger level can be set for either the 5A, 1A, or 100mA range.

Trigger level
5A range 0–5A in 5mA steps.
1A range 0–1A in 1mA steps.
100mA range 0–100mA in 0.1mA steps

Trigger hysteresis is built into the hardware. For the 5A range, trigger hysteresis is approximately 10mA. For the 1A range, trigger hysteresis is approximately 2mA. For the 100mA range, trigger hysteresis is approximately 0.2mA. If a pulse does not exceed the appropriate hysteresis level, trigger detection will not occur.

The three trigger level ranges for the battery channel (#1) are displayed as follows:

```
5A Range:     PCUR TRIG LEVEL #1
              A (5.0)    0.000A
1A Range:     PCUR TRIG LEVEL #1
              A (1.0)    0.000A
100mA Range:  PCUR TRIG LEVEL #1
              mA (100)  0.0000A
```

To change the 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 ▲ or ▼ key. 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 5A in 5mA steps. However, there is approximately 10mA of trigger hysteresis built into the hardware. Therefore, if a pulse does not exceed this level, trigger detection will not occur.

Pulse current display mode

Pulse current measurements are displayed with the pulse current display mode selected. This display mode is selected as follows:

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).*

1. Press the DISPLAY key to access the display menu.
2. If the desired active channel is not selected, use the ◀ and ▶ keys to toggle the active channel. The top line of the display will show which channel is active as either `DISPLAY TYPE #1 or DISPLAY TYPE #2.`
3. Press the ▲ or ▼ key until "PULSE CURRENT" is displayed and press ENTER.
4. Use the ▲ or ▼ key to display the desired pulse measurement; PULSE HI, PULSE LO, or PULSE AVG.

NOTE *For details on display modes, see "Display modes" in Section 1.*

Pulse current measurement procedure

The following steps summarize the procedure to perform pulse measurements:

1. Press the MENU key to access the menu.
2. Select PULSE CURRENT #1 or #2 by scrolling through the primary menu items (use the ▲ and ▼ keys to scroll).
3. For the battery channel (#1), select the desired trigger level range (5A, 1A, or 100mA) from the TRIG LEVEL RANGE item of the PULSE CURRENT #1 menu. Pulse measurements for both channels are automatically performed on the 5A current range.
4. From the PULSE CURRENT #1/#2 item of the menu, set the trigger level, trigger delay (optional), integration times, and average readings count (optional). (See NOTE.)
5. As explained in Section 2, set the output voltage and current limit, and press OPERATE.
6. Press the DISPLAY key and select the PULSE CURRENT display type.
7. Use the ▲ or ▼ key to display the desired pulse measurement: PULSE HIGH, PULSE LOW, or PULSE AVG.

NOTES *For the charger channel (#2), the trigger level range is automatically set to the 0–5A range (non-configurable).*

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

No pulses detected

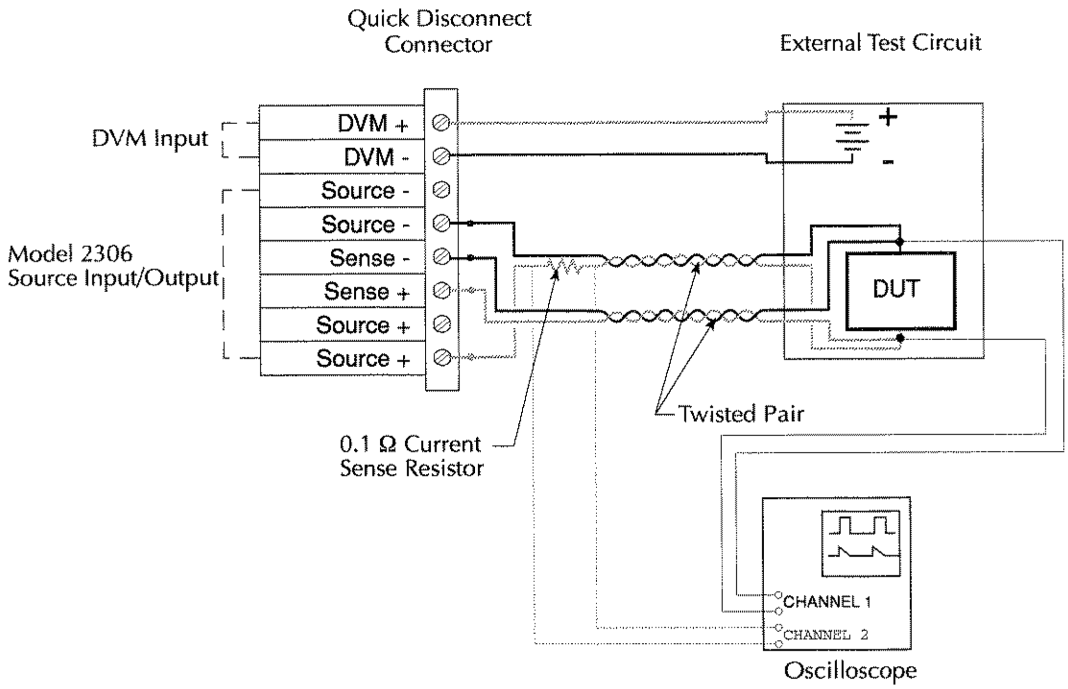
If no pulses are detected, current will not be measured (i.e. -----A) and the "NO PULSE" message will be displayed. The "NO PULSE" message is displayed with dashes or the last valid pulse reading. Dashes are shown if the pulse-current measurement settings are not appropriate for detecting pulses. The 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 2306, 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 with differential inputs, a 0.1Ω resistor used as a current sense resistor, and a voltage probe at the DUT 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



Procedure

1. As explained in Section 2, set the output voltage and current limit.
2. Press OPERATE.
3. Select the pulse current display type. If the trigger level is too low or too high, the "NO PULSE" message will be displayed.
4. Go into the menu, select PULSE CURRENT #1/#2, and then TRIGGER LEVEL.
5. Change the PCUR TRIG LEV #1/#2 and press ENTER. 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" on page 3-10 for more information.)
6. If the message appeared, repeat step 5 until a valid trigger level is found.
7. Use the MENU key to back out of 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 specific TLEV ranges have been set and a trigger has not been detected. Refer to Table 3-1 for the message preconditions.

Table 3-1
TRIG NOT DETECTED message

TLEV setting	TLEV range	TRIG NOT DETECTED Message displayed?
90mA for 100mA range	1A	No (not checked because TLEV setting does not match TLEV range)
90mA for 100mA range	5A	No (not checked because TLEV setting does not match TLEV range)
0.75A for 1A range	1A	May appear[1]
0.1A for 5A range	5A	May appear[1]
3.0A for 5A range	5A	May appear[1]
1.1A for 5A range	100mA	No (not checked because TLEV setting of 5A does not match TLEV range of 100mA)
1.1A for 5A range	1A	No (not checked because TLEV setting of 5A does not match TLEV range of 1A)

[1]May appear depends on OUTPUT:

- If OFF, the message will appear.
- If ON, display of the message will depend on the trigger level setting. If trigger level setting > expected low measurement and also trigger level setting < the expected high measurement, the message will not appear.

For example, if the expected pulse high is 2.2A and the expected pulse low is 0.5A, the output is on, and the TLEV range is 5A, notice the following results:

Setting 0.3A TRIG NOT DETECTED is displayed (setting too low).

Setting 3.0A TRIG NOT DETECTED is displayed (setting too high).

Setting 1.1A The message will not display (setting correct).

See steps 1–3 of the "Pulse current measurement procedure" on page 3-8 for information on setting the trigger level range. For the charger channel #2, the trigger level range setting is not user selectable.

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

SCPI programming — pulse current measurements

The commands for pulse current measurements are summarized in Table 3-2 (a listing following the table contains specific command notes). "Programming examples" on page 3-23 demonstrate how to use these commands.

Table 3-2
SCPI commands — pulse current measurements

Command	Description	Default
SENSe[1]	SENSe subsystem for Channel #1 (battery channel):	
: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
: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 trigger level (in amps) for 5A range: 0.0–5.0	0.0
:ONE <NRf>	Set trigger level (in amps) for 1A range: 0.0–1.0	0.0
:MILLiamp <NRf>	Set trigger level (in amps) for 100mA range: 0.0–0.1	0.0

Table 3-2
SCPI commands — pulse current measurements (cont.)

Command	Description	Default
SENSe[1]		
:PCURrent		
:SYNChronize		
:TLEVel *(cont.)*		
:RANGe <NRf>	Set trigger level range (100mA, 1A, or 5A). The parameter <NRf> sent with this command causes the trigger to be set with the trigger level setting of MILL, ONE, or AMP. Queries receive responses of 0.1, 1.0, or 5.0 accordingly. In other words, if a value of 2.0A is sent with the command, a value of 5A will be returned as a response to a query.	5A
: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 (See “Pulse current step method” on page 3-16	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>	33µsec–100msec	200µsec
:TimeOUT <NRf>	TimeOUT (other than the first): 2msec–200msec	2ms
:INITial <NRf>	First TimeOUT step: 10msec–60secs	2sec
:DELay <NRf>	0msec–100msec (in 10µsec steps)	0
:RANGe <NRf>	Set trigger level range (100mA, 1A, or 5A). The parameter <NRf> sent with this command causes the trigger to be set with the trigger level setting of MILL, ONE, or AMP. Queries receive responses of 0.1, 1.0, or 5.0 accordingly. In other words, if a value of 2.0A is sent with the command, a value of 5A will be returned as a response to a query.	5A
:TLEVx <NRf>	Set trigger level for each TLEV step where *x* equals 1–20 (0.0–maxA where max is 100mA for 100mA RANGe setting, 1A for 1A RANGe setting, and 5A for 5A RANGe setting).	0.0
SENSe2	SENSe subsystem for Channel #2 (charger channel):	
: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

Table 3-2
SCPI commands — pulse current measurements (cont.)

Command	Description	Default
SENSe2		
:PCURrent		
: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
: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
READ[1]?	Trigger and return one reading for Channel #1 (battery channel).	
READ[1]:ARRay?	Trigger an array of readings and return them for Channel #1 (battery channel).	
READ2?	Trigger and return one reading for Channel #2 (charger channel).	
READ2:ARRay?	Trigger an array of readings and return them for Channel #2 (charger channel).	

NOTE *Refer to the Programming syntax paragraph of Section 6 for a description of parameters (e.g., <b>, <NRf>, etc.).*

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 read-

ing. 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 (e.g., 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, make sure that:

1. When manually setting the pulse high, low, and average times, make sure that the integration time only covers the portion of the pulse to be measured.
2. Make sure to factor in trigger delays (both the internal plus the user) when determining integration times. Before the integration process begins after pulse detection, the internal trigger delay of 15μsec (for code execution) in addition to any user specified trigger delay must elapse.
3. AUTO time will account for the internal trigger delay (15msec) but not for any user trigger delay (user trigger delay is set using the DELay command).

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 10μsec. If you specify a smaller step size, it is adjusted up to the next 10μsec step value (e.g., 43μsec is adjusted up to 50μsec).
2. After pulse detection but before the integration process begins, the internal trigger delay of 15μsec (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.

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, readings are generated approximately every 274μs for battery channel (490μs for charger channel) and placed in the instrument measurement output buffer. The 274μs or 490μs time interval is the sum of the integration period, 33μsec, and the period required to convert this information into a measurement, approximately 241μsec for battery channel (457μs for charger channel). 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 (10μsec steps). For digitization, the internal trigger delay is 15μsec.

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 *See "Pulse current digitization" on page 3-24 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 trigger level range. This method is available on the battery channel through GPIB operation — SENS:PCUR:STEP commands (see Table 3-2). 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, timeout setting, and trigger level 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 trigger level 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 3-3). 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" on page 3-20.

Table 3-3
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 3-4 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 3-5. 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" on page 3-19). 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 3-7 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 3-4
Sample pulse forms for step method

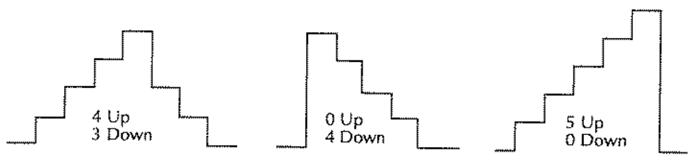
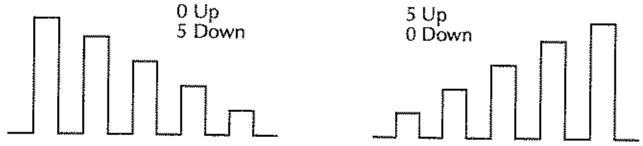


Figure 3-5
Sample one-shot only pulses for step method



Trigger level settings

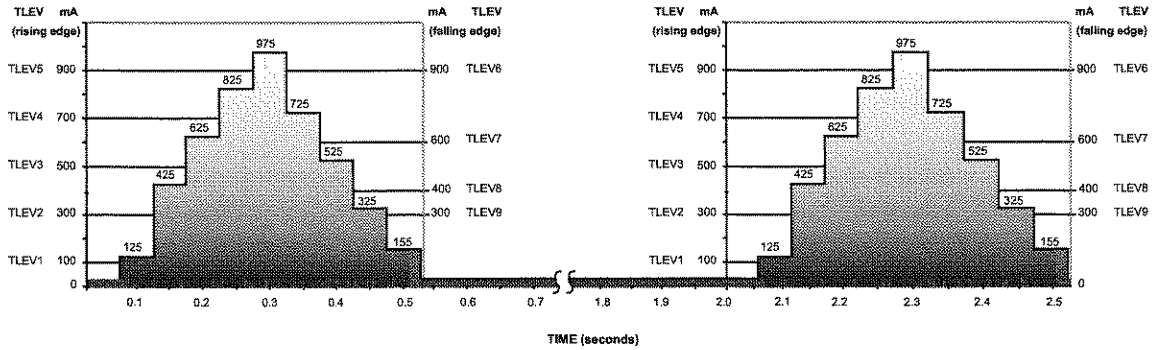
The trigger level may be set to a unique value for each active step. Use the TLEV*x* command to set appropriate trigger levels for each active step in the waveform. Make sure that the maximum setting for the selected trigger level range is not exceeded. (See "Trigger level range" on page 3-22.)

Figure 3-6 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:

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

For a programming example of this sample, see "Sample step method" on page 3-25.

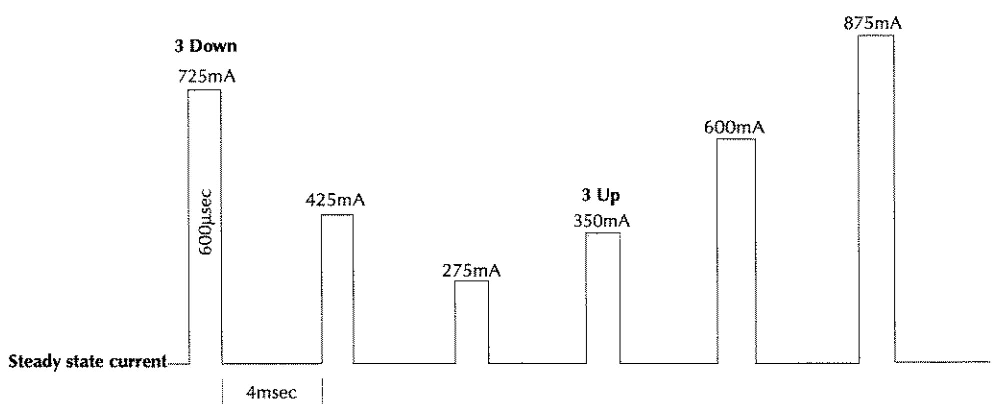
Figure 3-6
Sample :STEP Pulse measurement



Pulse sequences — rising and falling

Consider the pulse form in Figure 3-7. 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 3-7
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 3-7, the TLEV value could not be greater than 275mA). See Table 3-4 for sample trigger level values.

Table 3-4
Sample TLEV values for Figure 3-7

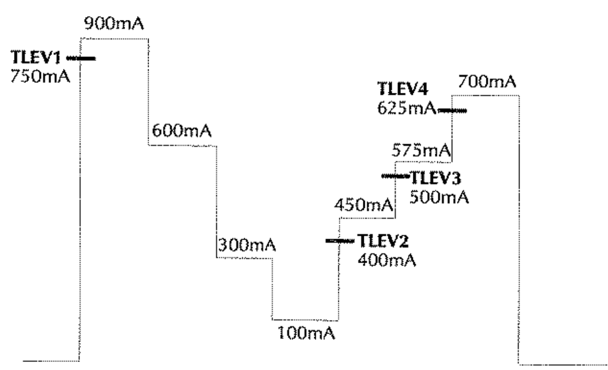
TLEV*x*	Unique TLEV*x* value	Same TLEV*x* value
TELV1	550mA	200mA
TELV2	325mA	200mA
TELV3	200mA	200mA
TELV4	300mA	200mA
TELV5	500mA	200mA
TELV6	800mA	200mA

Use the one-shot method for measuring the pulses since this pulse sequence rises and falls between steps. To accomplish this, configure the Model 2306 for measuring the pulse sequence then generate the pulse sequence. (See the programming example "One-shot pulse" on page 3-26).

Pulse sequences — down steps first

Consider the pulse form in Figure 3-8. This pulse form has three DOWN steps followed by three UP steps but does not rise or fall between the steps.

Figure 3-8
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 3-8, the UP steps are set to 4 and DOWN steps to 0. (If UP steps are set to a non-zero value, the Model

2306 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 3-8, 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 3-8, the following expected measurement values and TLEVs were used:

Expected measurements

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

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

TLEVs (all rising)

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

This pulse sequence can be measured using the continuous pulse method (see the programming example "Continuous pulse train" on page 3-27). 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 (15µsec 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 2306 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 2306 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 2306 to complete the previous measurement conversion and become ready for the next pulse edge. With this in mind, Table 3-5 lists appropriate integration times. Integration time applies to all active steps when step measurements are requested — each step has the same integration time.

Table 3-5
Sample integration times

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

Trigger level range

Select an appropriate trigger level range for the desired measurements. Three trigger level ranges are available: 5 amps, 1 amp and 100 milliamps. Make sure all TLEV values are valid in the selected trigger level range. There is only one trigger level range for all active steps — each step does not have a unique trigger level 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., 5A for 5A range, 1A for 1A range, or 100mA for 100mA range). If just one of the active step TLEV values exceeds the maximum setting for the new range, then all step TLEV values are set to 0A.

For example: When changing from the 5 amp range to the 1 amp range, a TLEV greater than 1 amp zero's out all active trigger level values. On the other hand, if changing from the 5 amp range to the 1 amp range and no trigger level settings exceed 1 amp, the previous settings will be used for the 1 amp 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:RANG 5                      ' Select 5A 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:RANG 0.5     ' Select the 1A trigger level range.
SENS:PCUR:SYNC:TLEV:ONE 0.1      ' Set trigger level to 100mA for 1A trigger
                                   level range.
SENS:PCUR:TIME:AUTO              ' Set integration times automatically.
SENS:FUNC "PCUR"                 ' Select pulse current function.
SENS:PCUR:MODE HIGH              ' Configure to measure peak pulse.
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:RANG 5                     ' Select 5A range.
SOUR2:VOLT 15                    ' Set output voltage to 15V.
SOUR2:CURR 0.75                  ' Set current limit to 750mA.
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 100mA.
SENS2:PCUR:TIME:HIGH 600e-3      ' Set integration high time to 600ms.
SENS2:PCUR:SYNC:DEL 50e-3        ' Set trigger delay to 50msec.
SENS2:FUNC "PCUR"                ' Select pulse current function.
SENS2:PCUR:MODE HIGH             ' Configure to measure peak pulse (trigger
                                 ' on rising edge).
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:RANG 5                      ' Select 5A range.
VOLT 15                          ' Set output voltage to 15V.
CURR 0.75                        ' Set current limit to 750mA.
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:RANG 0.5     ' Select the 1A trigger level range.
SENS:PCUR:SYNC:TLEV:ONE 0.1      ' Set trigger level to 100mA for 1A range.
SENS:PCUR:SYNC:DEL 500-3         ' Set trigger delay to 500msec.
SENS:FUNC "PCUR"                 ' Select pulse current function.
SENS:PCUR:MODE LOW               ' Configure to measure low pulse (trigger on
                                 ' falling edge).
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:RANG 5                     ' Select 5A range.
SOUR2:VOLT 15                    ' Set output voltage to 15V.
SOUR2:CURR 0.75                  ' Set current limit to 750mA.
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 100mA.
SENS2:PCUR:SYNC:DEL 50e-3        ' Set trigger delay to 50msec.
SENS2:FUNC "PCUR"                ' Select pulse current function.
SENS:PCUR:MODE LOW               ' Configure to measure low pulse (trigger on
                                   falling edge).
READ2:ARR?                       ' Trigger and return 3600 readings after sync-
                                   ing to the falling edge for the 1st reading
                                   only.
```

Pulse current STEP method (battery channel only)

Sample step method

The following command sequence measures pulses similar to the one shown in Figure 3-6. The step duration is 50ms with a pulse period of 2 seconds.

```
DISP:CHAN 1                        ' Set active channel - battery.
SENS:FUNC 'PCUR'                   ' Select PCUR function.
SENS:PCUR:STEP ON                  ' Enable step.
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 400µsec
                                   ' of step duration.
SENS:PCUR:STEP:RANGE 0.75          ' Specify 1 amp step range.
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:TLEV1 900e-3        ' Step 5 tlev value.
SENS:PCUR:STEP:TLEV2 900e-3        ' Step 6 tlev value.
SENS:PCUR:STEP:TLEV3 600e-3        ' Step 7 tlev value.
SENS:PCUR:STEP:TLEV4 400e-3        ' Step 8 tlev value.
SENS:PCUR:STEP:TLEV4 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" on page 3-26.)*

One-shot pulse

The following command sequence measures pulses similar to the one shown in Figure 3-7 with a one-shot pulse measurement. The step duration is 600μsec with 4msec between steps.

```
DISP:CHAN 1                     ' Set active channel - battery.
SENS:FUNC 'PCUR'                ' Select PCUR function.
SENS:PCUR:STEP ON               ' Enable step.
SENS:PCUR:STEP:UP 6             ' Specify 6 up steps.
SENS:PCUR:STEP:DOWN 0           ' Specify 0 down steps (remember the default
                                ' is 1). See "Pulse sequences - rising and
                                ' falling" on page 3-19 for more information.
SENS:PCUR:STEP:RANGE .75        ' Specify 1 amp 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 2306 for pulse step mea-
                                ' surement and wait between 3 to 5 seconds be
                                ' fore generating the one shot pulse to guar-
                                ' antee the Model 2306 is waiting for
                                ' detection of first step.
    ' Using the same step trigger level for all steps is contained in the
    ' following sample. Table 3-4 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

The following command sequence measures pulses similar to the one shown in Figure 3-8 in a continuous pulse train. The step duration is 600μsec with a step period of 2 seconds.

```
DISP:CHAN 1                    ' Set active channel - battery.
SENS:FUNC 'PCUR'               ' Select PCUR function.
SENS:PCUR:STEP ON              ' Enable step.
SENS:PCUR:STEP:UP 4            ' Specify 4 up steps.
SENS:PCUR:STEP:DOWN 0          ' Specify 0 down steps.
SENS:PCUR:STEP:RANGE .75       ' Specify 1 amp range.
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 600mA, 300mA, and 100mA steps, but not
                               ' so short it misses the 450mA step (600μsec x
                               ' 3 = 1.8 msec). Using 3msec 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.
```

4
Long Integration Measurements

- **Overview** — Provides an overview of the long integration measurement process.
- **Measurement configuration** — Explains how to configure the instrument for long integration measurements.
- **Long integration measurement procedure** — Provides the step-by-step procedure to perform long integration measurements from the front panel.
- **SCPI programming** — Documents the commands used to program the instrument for long integration measurements including FAST, SEARch and DETect usage.
- **Programming examples** — Include programming examples to perform long integration measurements.

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

Overview

Long integration is an average current measurement of one or more pulses that can be performed on either the battery channel or the charger channel. 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 (16.67ms for 60Hz) 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 16.67ms for 60 Hz and 20ms for a 50 Hz line frequency. A long integration reading, R_I, is the average of a series of current measurements, m_i, defined by:

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

where n is an integer given by:

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

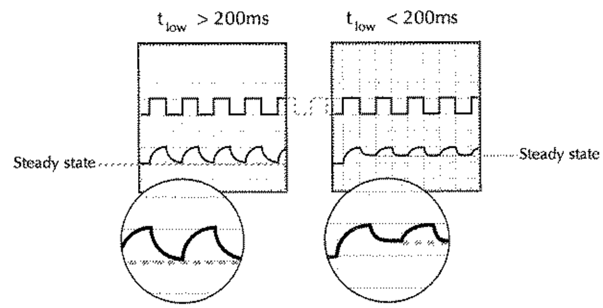
where:
$1PLC$ = one power line cycle
I_t = integration time

Here the integration time specified by the user and denominator represents the integration time of 1 PLC (16.67 msec for 60Hz or 20 ms for 50Hz) 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 833ms. 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 200ms, 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 200ms, 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 200ms (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 200ms.

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 60Hz power line frequency, the minimum integration time setting is 850msec. For 50Hz power line frequency, the minimum integration setting is 840msec.

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 (see "Trigger level" on page 4-4). 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 2A, pulses that are ≥2A will be detected. Current pulses <2A are ignored.

The charger channel has only one trigger level range: 0–5A. The battery channel has three trigger level range settings: 5A, 1A, or 100mA trigger level ranges. For 5A, the level may be set from 0 to 5A. For the 1A range, the trigger level may be set from 0 to 1A. Likewise, the level may be set from 0 to 100mA for the 100mA trigger level range. These ranges affect trigger level resolution and not the current range since long integration readings are always performed on the 5A current range. The trigger level range option on battery channel allows the user to set a trigger level with greater resolution.

Trigger level range

This setting affects long integration trigger level and has no affect on current range setting since long integration measurements are always performed on the 5A current range. Three settings (battery channel only) are available: 5A, 1A, or 100mA. Use the range that provides adequate trigger level resolution (a 100mA range provides a greater available resolution for trigger level than does the 1A range).

Pulse timeout

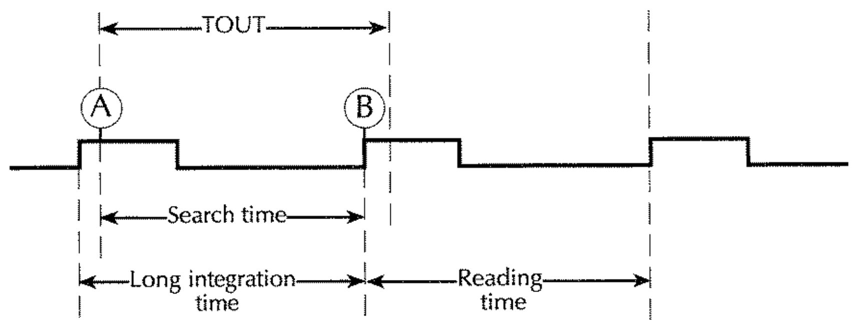
TOUT (timeout) specifies the timeout length for the pulse. When the TOUT value is reached, NO PULSE is displayed (top line of the front panel display). Set the value for TOUT as follows:

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.

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



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.

NOTES
- *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.

NOTES *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. *also see "Using FAST, SEARch, and DETect" on page 4-13.*

Measurement configuration

NOTE *Current range is selected from the CURRENT RANGE #1/#2 item of the menu. Integration time, trigger edge, trigger level range, 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 range, 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

For long integration measurements, the AUTO range selection is functionally a no-op (no operation). The instrument will not autorange with the long integration measurement function selected. Long integration measurements are always performed on the 5A range. Therefore, selecting long integration with the 5mA range active will cause the supply to first switch to the 5A range.

NOTE *To get better trigger level resolution, make sure the trigger level range is set appropriately for the expected measurement (set from* `TRIG LEVEL RANGE` *under* `LONG INTEGRAT #1` *menu).*

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" (in Section 2) 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 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 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 850msec to 60 sec (1 ms step value). For 50Hz power line frequency, integration time can be set from 840msec 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 autotime does not use the user setting for trigger edge, the user setting will be used for trigger commands (e.g., READ?, MEASure?, etc.).

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 while LONG INTEGRAT #2 refers to the charger channel.)

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, trigger level, and trigger level range

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

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" on page 4-4).

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.

Battery Channel (#1) — The trigger level can be set for either the 5A, 1A, or 100mA range. For the 5A range, the trigger level can be set from 0 to 5A in 5mA steps. For the 1A range, the trigger level can be set from 0 to 1A in 1mA steps. For the 100mA range, the trigger level can be set from 0 to 100mA in 0.1mA steps.

The three trigger level ranges are displayed as follows:

5A Range:	*LINT TRIG LEVEL #1* *A (5.0) 0.000A*
1A Range:	*LINT TRIG LEVEL #1* *A (1.0) 0.000A*
100mA Range:	*LINT TRIG LEVEL #1* *mA (100) 0.0000 A*

To toggle the range for the trigger level, place the blinking cursor on the "A" at the far right end of line two of the display, and press the ▲ and ▼ key. 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 5A in 5mA steps.

Trigger level range

TRIGGER LEVEL RANGE is a battery channel (#1) setting only. Use to specify the trigger level range. Possible ranges are:

5A FULL SCALE	(0–5A)
1A FULL SCALE	(0–1A)
100mA FULL SCALE	(0–100mA)

Long integration display mode

Long integration measurements are displayed with the long integration display mode selected. This display mode is selected as follows:

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).*

1. Press the DISPLAY key to access the display menu.
2. If the desired active display is not selected, use the ◀ and ▶ keys to toggle the active display. The top line of the display will show which display is active as either *DISPLAY TYPE #1* or *DISPLAY TYPE #2*.
3. Scroll through the DISPLAY menu ▲ or ▼ key until "LONG INTEGRATION" is displayed and press ENTER.

NOTE *For details on display modes, see "Display modes" in Section 1.*

Long integration measurement procedure

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

1. Set the output voltage and current limit, and 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.*

2. When using the battery channel, select the desired trigger level range (5A, 1A, or 100mA) from the TRIG LEVEL RANGE item of the LONG INTEGRAT #1 menu. For both channels, long integration measurements are automatically performed on the 5A current range.
3. 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 while LONG INTEGRAT #2 refers to the charger channel.) If using the battery channel (#1), make sure to set the trigger level for the trigger level 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.*

4. Press the DISPLAY key and select the LONG INTEGRATION display type for the desired channel.
5. 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 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 on page 4-10 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 ▼ key 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 ▼ key. 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. Select the long integration display type. 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 (access the main menu in step 3, 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 and LONG INTEGRAT #2 for the charger channel.)
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. Use the MENU key to back out of the menu structure and display long integration current measurements.

NOTE *For the battery channel, make sure the trigger level 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 TLEV ranges have been set and a trigger has not been detected. Refer to Table 4-1 for message preconditions.

See step 2 of the "Long integration measurement procedure" on page 4-9 for information on setting the trigger level range. For the charger channel #2, the trigger level range setting is not user selectable.

Table 4-1
TRIG NOT DETECTED message

TLEV setting	TLEV range	TRIG NOT DETECTED Message displayed?
100mA	1A	No (not checked because TLEV setting does not match TLEV range)
1A	1A	May appear
100mA	5A	Yes (TLEV setting too low)
1.1A	5A	No (valid setting)
3A	5A	Yes (TLEV too high)

NOTE *Setting the trigger level and/or the trigger 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" on page 4-17 demonstrate how to use these commands.

Table 4-2
SCPI commands — long integration measurements

Command	Description	Default
:SENSe[1]	SENSe subystem for channel #1 (battery channel):	
: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 trigger level (in amps) for 5A range: 0–5 (5mA resolution).	0.0
:ONE <NRf>	Set trigger level (in amps) for 1A trigger level range: 0–1 (1mA resolution).	0.0
:MILLiamp <NRf>	Set trigger level (in amps) for 100mA range: 0–0.1 (0.1mA resolution).	0.0

Table 4-2
SCPI commands — long integration measurements (cont.)

Command	Description	Default
:SENSe[1]		
:LINTegration		
:TLEVel <NRf>		
:RANGe <NRf>	Set trigger level range (100mA, 1A, or 5A). The parameter <NRf> sent with this command causes the trigger to be set with the trigger level setting of MILL, ONE, or AMP. Queries receive responses of 0.1, 1.0, or 5.0 accordingly. In other words, if a value of 2.0A is sent with the command, a value of 5A will be returned as a response to a query.	5A
: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 channel #2 (charger channel):	
: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
: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)

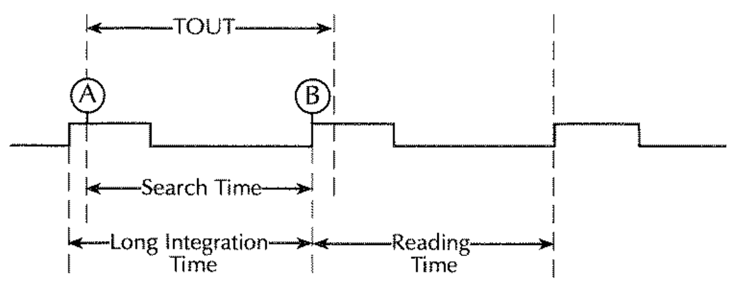
After sending a trigger reading command to perform long integration measurements, do not address the power supply to talk until all readings are completed. Details on READ? and the other signal oriented measurement commands are provided in Section 9.

Using FAST, SEARch, and DETect

Use 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 on page 4-14 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" on page 4-4.

Figure 4-3
TOUT and search time



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.*
- *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	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".
ON	ON	OFF	
ON	OFF	ON	
ON	OFF	OFF	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.)

Shaded cells designate command with precedence in each mode.

Table 4-3
FAST, SEARch, and DETect command reference (cont.)

FAST	SEARch	DETect	Description
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.)
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.

Shaded cells designate command with precedence in each mode.

Table 4-3
FAST, SEARch, and DETect command reference (cont.)

FAST	SEARch	DETect	Description
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

The following command sequence will trigger and return one long integration measurement:

Battery channel (#1)

```
DISP:CHAN 1                   ' Sets display to battery channel.
SENS:RANG 5                   ' Select 5A range.
VOLT 15                       ' Set output voltage to 15V.
CURR 0.75                     ' Set current limit to 750mA.
OUTP ON                       ' Turn output on.
SENS:LINT:TLEV:RANG 0.5       ' Select 1A trigger level range.
SENS:LINT:TEDG RISING         ' Select rising trigger edge to initiate
                                measurement.
SENS:LINT:TLEV:ONE 0.1        ' Set trigger level to 100mA for 1A trigger
                                level range.
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:RANG 5                  ' Select 5A range.
SOUR2:VOLT 15                 ' Set output voltage to 15V.
SOUR2:CURR 0.75               ' Set current limit to 750mA.
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 100mA.
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
```

5
Relay Control

- **Overview** — Summarizes how the power supply can be used to control an external relay.
- **Connections** — Explains how to connect an external relay circuit to the power supply.
- **Controlling relays** — Explains how to control the external relay circuit.

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

Overview

The power supply can be used to control up to four external relays. The control circuit is made up of four peripheral drivers, a +5VDC source (250mADC 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 (100mADC 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, 100mA per channel

  Internal source:

  1) 5VDC, 250mA maximum total current from all channels combined.

  2) 100mA per channel maximum (not to exceed the 250mA maximum total current).
- **Connect and disconnect relay drive circuits with the power supply power OFF.**

Figure 5-1
External source relay control

CAUTION **For external source relay control:**
-Do not exceed 100mA DC per channel
-Do not exceed +24V DC

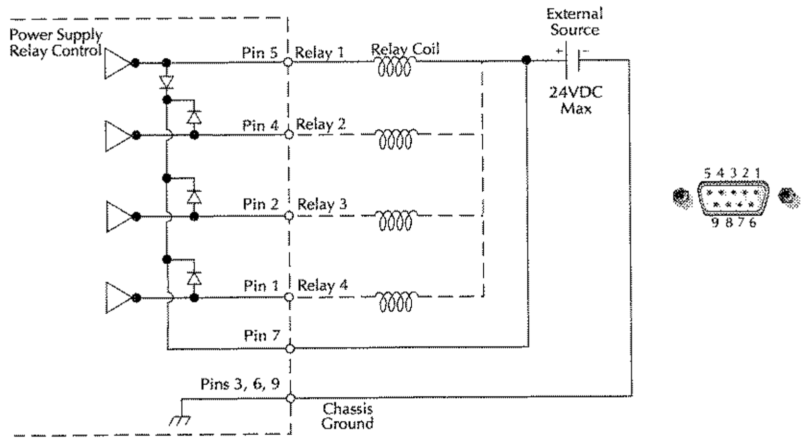
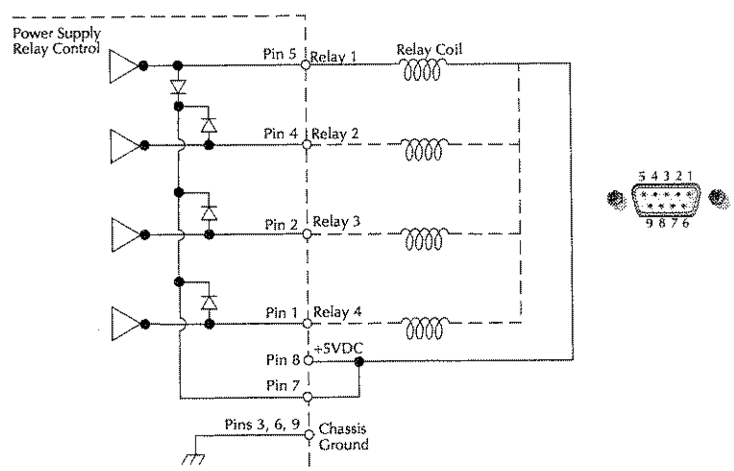


Figure 5-2
Internal source relay control

CAUTION **For internal source relay control:**
-Do not exceed 100mA DC per channel
-Do not exceed 250mA DC total



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)

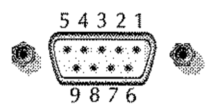


Table 5-1
Relay pinouts (for Figure 5-3)

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's 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 while 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. From the main menu, select OUTPUT RELAYS.

2. Use the ◀ and ▶ arrow 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, while 0 opens the circuit to de-energize the relay.

3. Use the ▲ and ▼ arrow keys to toggle the blinking cursor's value between 1 (close) or zero (open).

4. Repeat steps 2 and 3 to set the relays as desired.

5. 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 cancelled 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
SCPI command — output relay control

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

6
GPIB Operation

- **Introduction** — Describes the IEEE-488 (GPIB) standards used by the power supply.
- **GPIB bus connections** — Shows how to connect the power supply to the GPIB.
- **Primary address** — Explains how to check and/or change the primary address for the bus.
- **Setting the GPIB timeout for responses** — Documents general bus commands to set the GPIB timeout.
- **General bus commands** — Documents general bus commands that pertain to all GPIB instruments.
- **Front panel aspects of GPIB operation** — Describes aspects of the front panel and remote panel.
- **Programming syntax** — Provides syntax information for sending command and SCPI commands over the bus.

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

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. The power supply 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.

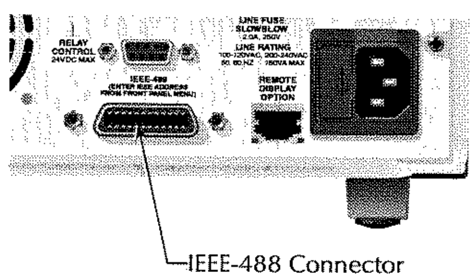


Figure 6-1
IEEE-488 connector

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

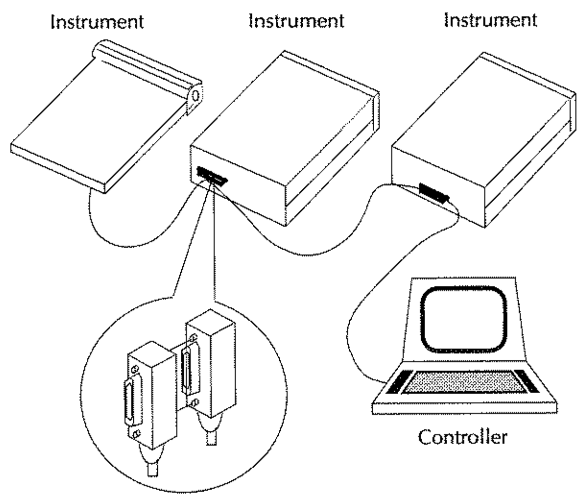
For a multi-unit test system, you can daisy-chain the instruments to the controller by connecting an IEEE cable from one unit to another. Figure 6-2 shows a typical multi-unit connecting scheme daisy chaining. Although any number of connectors could be stacked on one instrument's GPIB port, avoid possible 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

The power supply 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 *Table 1-3 shows 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 Model 2306 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 (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" > 15000. Setting the "GPIB timeout for responses" greater than the integration time ensures that a GPIB timeout does not occur while the Model 2306 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. Since the integration period is 25 seconds, set the "GPIB timeout for responses" > 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 (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 remote, 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 B 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 0.01 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.

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.

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

7
Status Structure

- **Overview** — Provides an operational overview of the status structure for the power supply.
- **Clearing registers and queues** — Covers the actions that clear (reset) registers and queues.
- **Programming and reading registers** — Explains how to program enable registers and read any register in the status structure.
- **Status byte and service request (SRQ)** — Explains how to program the status byte to generate service requests (SRQs). Shows how to use the serial poll sequence to detect SRQs.
- **Status register sets** — Provides bit identification and command information for the four status register sets; standard event status, operation event status, measurement event status and questionable event status.
- **Queues** — Provides details and command information on the output queue and error queue.

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

Overview

The power supply 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

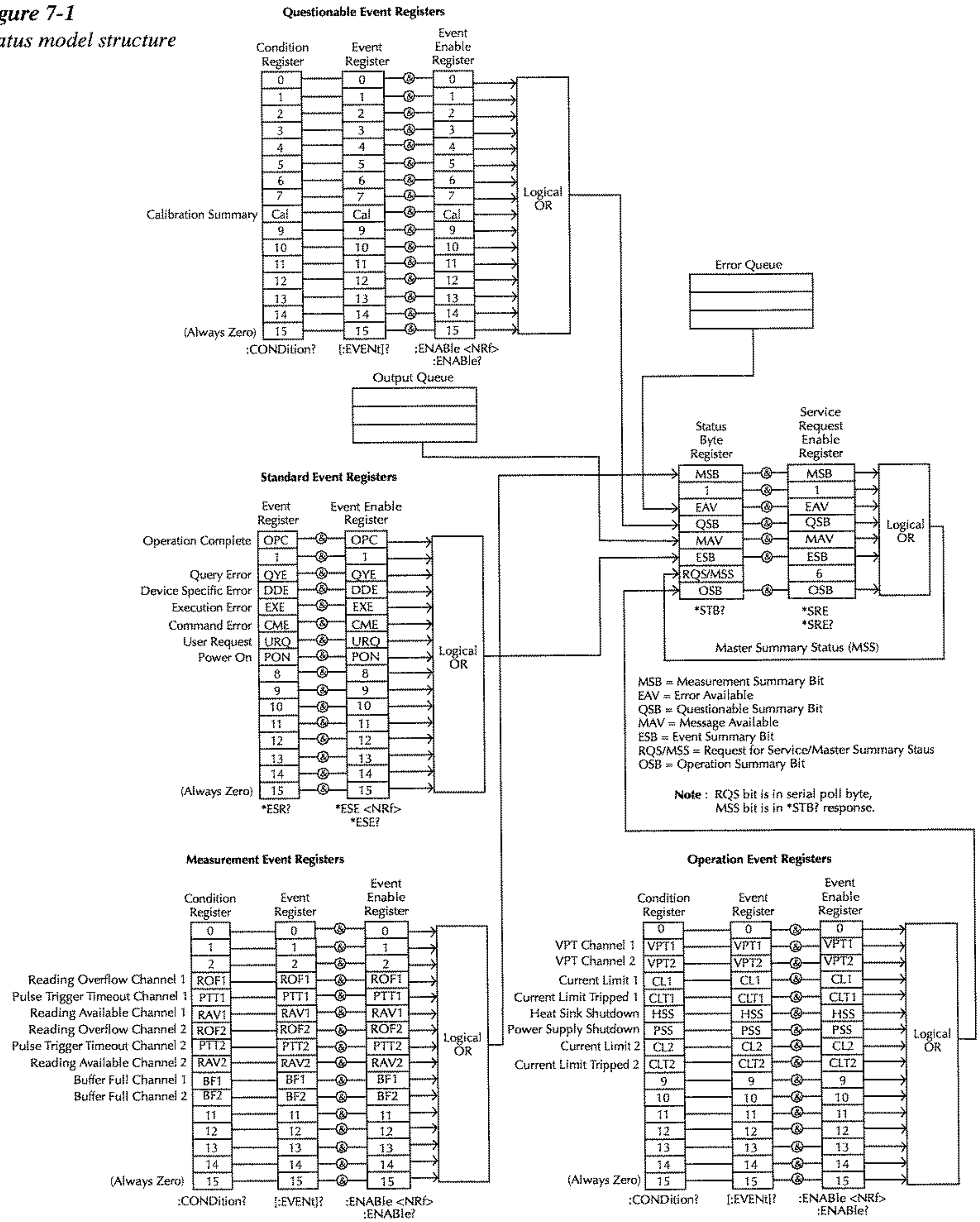
A typical status register set is made up of a condition register, an event register and an event enable register. A condition register is a read-only register that constantly updates to reflect the present operating conditions of the instrument.

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

The power supply 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" on page 7-19 for details on the error queue.*

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

Commands	Description	Ref
To reset registers:	Reset all bits of the following event registers to 0:	
*CLS	Standard event register	
	Operation event register	
	Measurement event register	
	Questionable event register	
STATus	STATus subsystem:	
:PRESet	Reset all bits of the following enable registers to 0:	Note 1
	Operation event enable register	
	Measurement event enable register	
	Questionable event enable register	
To clear error queue:		
*CLS	Clear all messages from error queue	Note 2
STATus	STATus subsystem:	
:QUEue	Error queue:	
{:NEXT}?	Read and clear the oldest error/status message.	
:CLEar	Clear all messages from error queue.	Note 3
SYSTem	SYSTem subsystem:	
:ERRor?	Read and clear the oldest error/status message.	
:CLEar	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" on page 7-9 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 7-5).

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 (Figure 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 Figure 7-2 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).

Figure 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

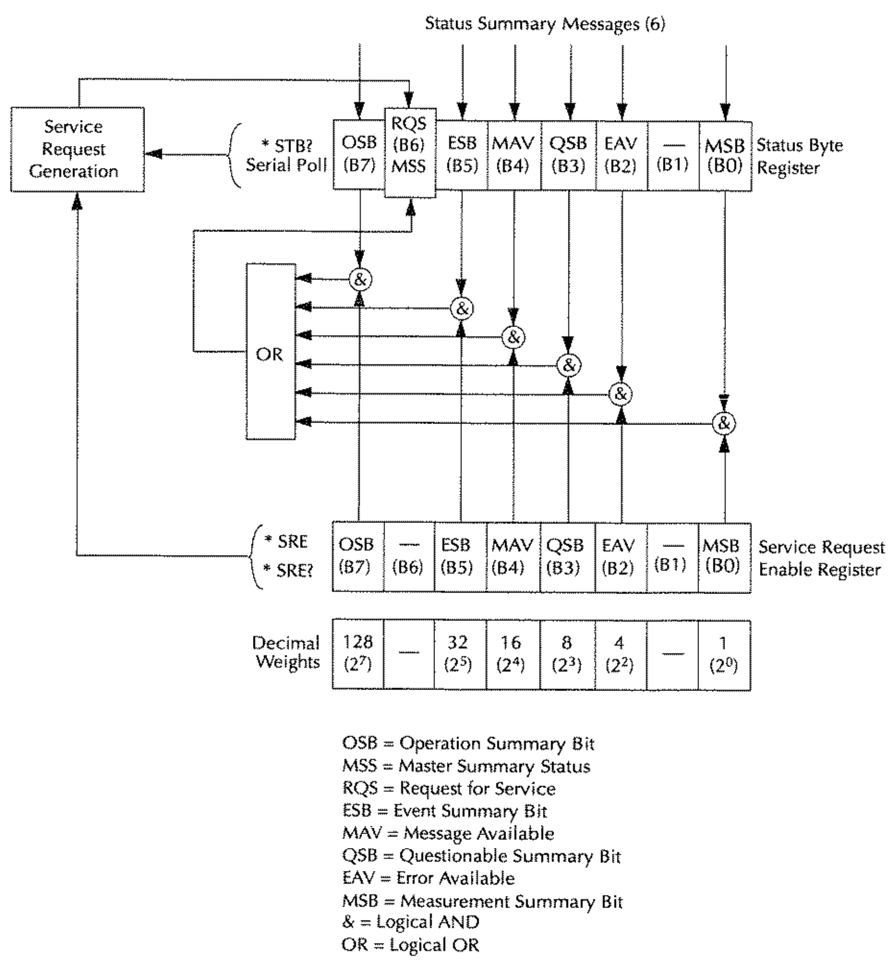
Any register in the status structure can be read by using the appropriate query (?) command. The specific query commands are covered later in this section (refer to Table 7-2 through Table 7-5).

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 7-3 shows the structure of these registers.

Figure 7-3
Status byte and service request



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" for details on using the serial poll sequence.
- When using the *STB? command (see "Status byte and service request commands" on page 7-9) 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 7-3, 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 7-2.

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 7-2. For details on programming and reading registers, see "Programming enable registers" and "Reading registers" on page 7-5.

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 7-2
Command commands — status byte and service request enable registers

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

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.

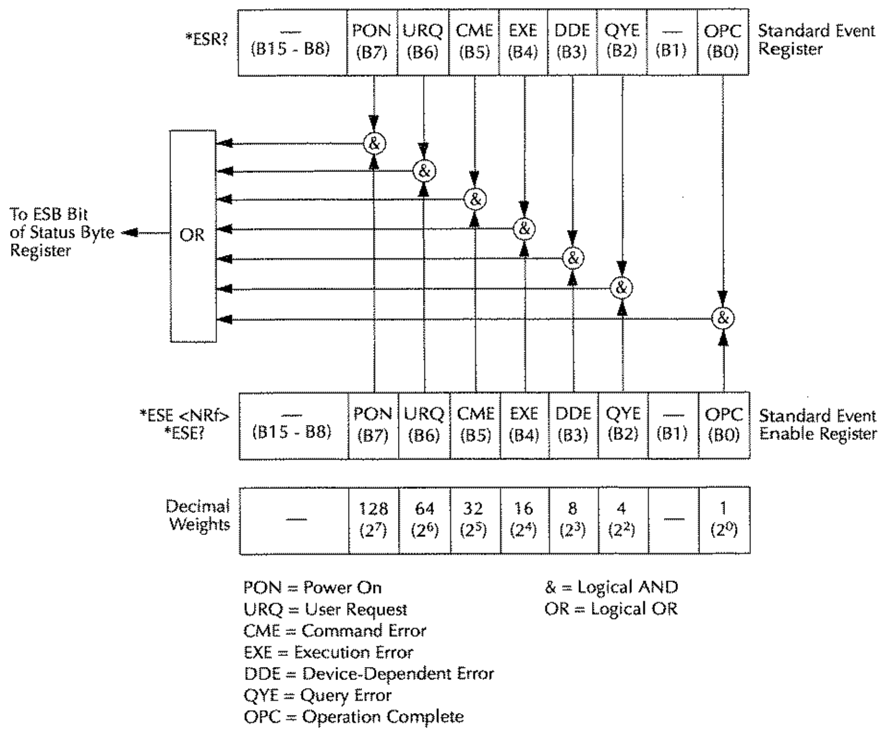
Register bit descriptions

Standard event status

The used bits of the standard event register (shown in Figure 7-4) 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:
  - → IEEE-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 7-4
Standard event status

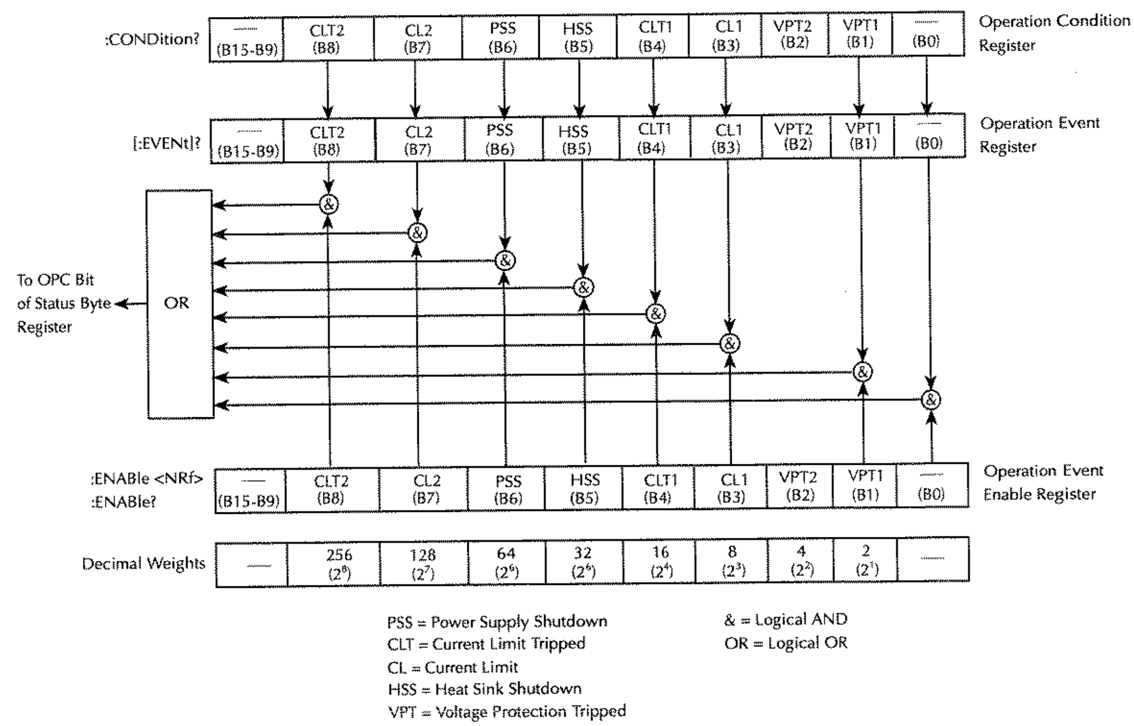


Operation event status

The used bits of the operation event register (shown in Figure 7-5) 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.)
- **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.)
- **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 7-5
Operation event status

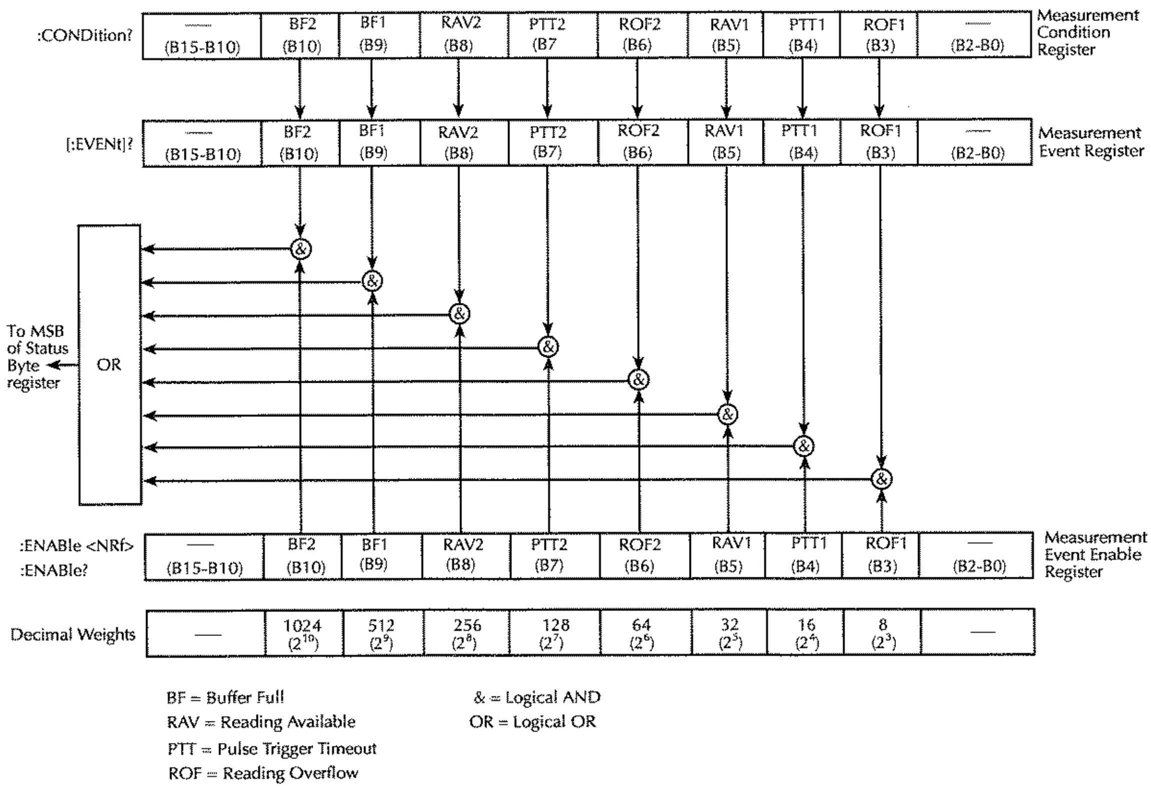


Measurement event status

The used bits of the measurement event register (shown in Figure 7-6) 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.)
- **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.)

Figure 7-6
Measurement event status

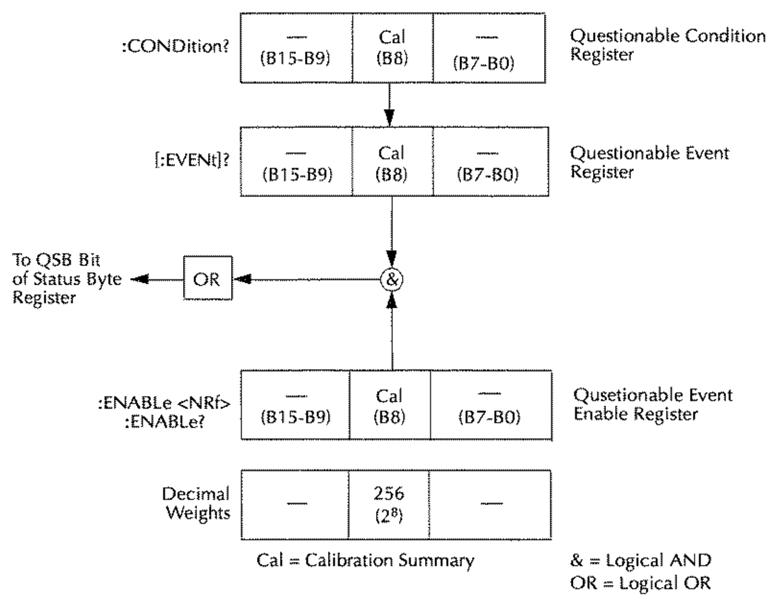


Questionable event status

The used bit of the questionable event register (shown in Figure 7-7) 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 7-7
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 7-3. For details on reading registers, See "Reading registers" on page 7-5.

Table 7-3
Common and SCPI commands — condition registers

Command	Description
STATus	STATus subsystem:
:OPERation:CONDition?	Read operation condition register.
:MEASurement:CONDition?	Read measurement condition register.
:QUEStionable:CONDition?	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 7-4. For details on reading registers, see "Reading registers" on page 7-5.

Table 7-4
Common and SCPI commands — event registers

Command	Description	Default
		(Note)
*ESR?	Read standard event status register.	
STATus	STATus subsystem:	
:OPERation:[:EVENt]?	Read operation event register.	
:MEASurement:[:EVENt]?	Read measurement event register.	
:QUEStionable:[:EVENt]?	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 7-5. For details on programming and reading registers, see "Programming enable registers" and "Reading registers" on page 7-5.

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 7-5
Common and SCPI commands — event enable registers

Command	Description	Default
		(Note)
*ESE <NRf>	Program standard event enable register (see "*Parameters*").	
*ESE?	Read standard event enable register.	
STATus	STATus subsystem:	
:OPERation	Operation event enable register:	
:ENABle <NRf>	Program enable register (see "*Parameters*").	
:ENABle?	Read enable register.	
:MEASurement	Measurement event enable register:	
:ENABle <NRf>	Program enable register (see "*Parameters*").	
:ENABle?	Read enable register.	
:QUEStionable	Questionable event enable register:	
:ENABle <NRf>	Program enable register (see "*Parameters*").	
:ENABle?	Read enable register:	
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,
                         ' you may talk the instrument for the data.
FETCh:ARR?               ' Request the buffer data from the 2306
Language specific        ' Talk the 2306 for the array (buffer) data.
```

This slows down the responsiveness of the Model 2306 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 2306 is talked too early for the buffer data, then a GPIB timeout may occur. (See “Setting the GPIB timeout for Responses” in Section 6.)

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 the 2306 for the array (buffer) data.
```

This method prevents the Model 2306 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” in Section 6.)

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:

```
*SRE16               ' 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 7-6. 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 Keithley defined messages. The messages are listed in Appendix B.

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 7-6, 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 7-6
SCPI commands — error queue

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

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 (dis-
                              able all SCPI defined messages).

STAT:QUE?                   ' Return oldest message.
```

8
Common Commands

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

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 (refer to Section 7)

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.

Command notes (IEEE-488.2 common commands and queries)

***IDN? — identification query** Reads identification code

The identification code includes the manufacturer, model number, serial number, and firmware revision levels.

KEITHLEY INSTRUMENTS INC., MODEL 2306, 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 — 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 on page 8-4 for examples). *OPC and *OPC? can be used in conjuction 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 (channel #1) while the second line applies to the charger channel (channel #2).

***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
4 = Memory location 4

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. Five 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 — 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).
2. Cancels all pending commands.
3. Cancels response to any previously received *OPC and *OPC? commands.

***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? — 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 — 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.

9
Signal Oriented Measurement Commands

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

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.
: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:ARRay[1][:<function>]?	Performs a READ:ARRay? on the specified battery channel (#1) function.
:MEASure2[:<function>]?	Performs a READ2? on the specified charger channel (#2) function.
:MEASure:ARRay2[:<function>]?	Performs a READ2:ARRay? on the specified charger channel (#2) function.

NOTE *For all array queries, make sure the computer's buffer is large enough to accomodate 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 Sections 2 and 3 for details.

NOTES 1. *FETCh? and FETCh:ARRay? readings are always sent in exponential form.*

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 Sections 2 and 3 for details.

NOTES 1. *READ? and READ:ARRay? readings are always sent in exponent form.*

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.*

: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
	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.*

10

DISPlay, FORMat, and SYSTem

- **DISPlay subsystem** — Covers the SCPI commands that are used to control the display.
- **FORMat subsystem** — Covers the SCPI commands to configure the format that readings are sent over the bus.
- **:SYSTem subsystem** — Covers miscellaneous SCPI commands.

NOTES *This manual covers Keithley Models 2302 and 2306 simulators (power supplies). Since the Model 2302 is a single channel battery simulator, functions related to the second channel (i.e., the charger channel) are not available for the Model 2302. Therefore:*

- *battery and charger channel features contained in this manual apply for the Model 2306*
- *only battery channel features contained in this manual apply for the Model 2302*

Refer to Appendix F for specific Model 2302 information.

Information contained in this section applies to all power supply channels (unless otherwise noted). In this manual, channel 1 refers to the battery channel while channel 2 refers to the charger channel (2306 feature only).

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
: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.

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 Model 2304-DISP remote module is connected (the Model 2304-DISP has an LCD display). Dependent on the revision level of the Model 2304-DISP 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 follow:

```
FULL BRIGHTNESS
BRIGHTNESS OFF
1/4 BRIGHTNESS
1/2 BRIGHTNESS
3/4 BRIGHTNESS
```

NOTE *Setting this option when a remote is connected (Model 2304-DISP) via remote or through the bus will be ignored. No error message will be generated.*

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 ◀ and ▶ keys will toggle the active display channel between channel #1 (battery channel) and channel #2 (charger channel). Note that changing active channels using this method (◀ and ▶ 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>	Specify data format; ASCii, SREal or DREal.	ASCii
:BORDer <name>	Specify byte order; NORMal or SWAPped.	SWAP

Command notes (SCPI commands — data format)

FORMat[:DATA] <type> Select data format

Parameters	<type>	= ASCii	ASCII format
		SREal	IEEE754 single precision format
		DREal	IEEE754 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 "Signal Oriented Measurement Commands" (Section 9) 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

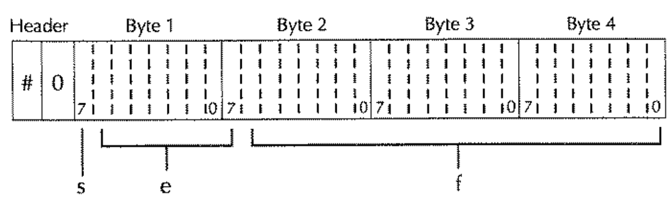
The ASCII data format is in a direct readable form for the operator. Most Basic languages easily convert ASCII mantissa and exponent to other formats. However, some speed is compromised to accommodate the conversion. The following shows the ASCII format for a reading of 10.058 volts.

+1.00580000 E+01

IEEE754 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



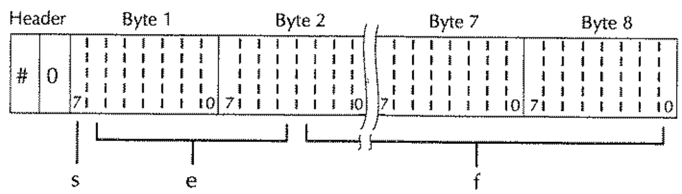
s = sign bit (0 = positive, 1 = negative)
e = exponent bits (8)
f = fraction bits (23)

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.

The ASCII data format can only be sent in the normal byte order. The SWAPped selection is ignored when the ASCII format is selected.

:SYSTem subsystem

The SYSTem subsystem contains miscellaneous commands (summarized in Table 10-3).

Table 10-3
SCPI commands — system

Command	Description	Default	Ref
SYSTem			
:LFRequency?	Read power line frequency.		Sec 1*
:POSetup <name>	Select power-on setup: RST or SAVx where: x = 0 to 4		
:VERSion?	Query SCPI revision level.		
:ERRor	Read and clear oldest message in error queue:	(see Note)	Sec 7
:CLEar	Clear messages from error queue.		Sec 7

* See "Line power connection" under "Power-up" in Section 1 for details.

Note: Clearing the error queue — Power-up and *CLS clears the error queue. *RST and STATus:PRESet have no effect on the error queue.

Command notes (SCPI commands — system)

SYSTem:POSetup <name> Program power-on defaults

Parameters	<name> =	RST	Power-up to *RST defaults
		SAV0	Power-up to setup stored in memory location 0
		SAV1	Power-up to setup stored in memory location 1
		SAV2	Power-up to setup stored in memory location 2
		SAV3	Power-up to setup stored in memory location 3
		SAV4	Power-up to setup stored in memory location 4

With RST selected, the power supply powers up to the *RST default conditions. Default conditions are listed in the SCPI tables.

With SAV0-4 specified, the power supply powers-on to the setup that is saved in the specified memory location using the *SAV command (Section 8). Note that the instrument will power up with the output OFF.