KEITHLEY

Model 6430 Sub-Femtoamp Remote SourceMeter

Instruction Manual

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4/01

Model 6430 Sub-Femtoamp Remote SourceMeter Instruction Manual

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Cleveland, Ohio, U.S.A.
Fourth Printing, June 2001
Document Number: 6430-901-01 Rev. D

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 6430-901-01) ..... May 1999
Addendum A (Document Number 6430-901-02) ..... June 1999
Revision B (Document Number 6430-901-01) ..... September 1999
Addendum B (Document Number 6430-901-02) ..... November 1999
Revision C (Document Number 6430-901-01) ..... January 2000
Revision D (Document Number 6430-901-01) ..... June 2001

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Safety Precautions

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

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read 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.

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

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.**

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.

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

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

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

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

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

When fuses are used in a product, replace with 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

- **General Information** — Covers general information that includes warranty information, contact information, safety symbols and terms, inspection, and available options and accessories.
- **Product Overview** — Summarizes the features of the Model 6430 Sub-Femtoamp Remote SourceMeter.
- **Mainframe and Remote PreAmp Familiarization** — Summarizes the controls and connectors on the mainframe and Remote PreAmp.
- **Power-up** — Covers line power connection, line voltage settings, fuse replacement, and the power-up sequence.
- **Display** — Provides information about the Model 6430 display.
- **Default Settings** — Covers factory default setups and saving and recalling user setups.
- **Menus** — Covers the main and configuration menus as well as rules to navigate menus.

General information

Warranty information

Warranty information is located at the front of this manual. Should your Model 6430 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

Worldwide phone numbers are listed at the front of this manual. If you have any questions, please contact your local Keithley representative or call one of our Application Engineers at 1-800-348-3735 (U.S. and Canada only).

Manual 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.

Safety symbols and terms

The following symbols and terms may be found on the instrument or used in this manual.

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

The symbol on the 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 this 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 this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Inspection

The SourceMeter 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. (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 Model 6430 Sub-Femtoamp Remote SourceMeter order:

- SourceMeter mainframe with line cord.
- SourceMeter Remote PreAmp with cable to mainframe.
- 8-inch triax-to-alligator clip cable (part number: 6430-322-1A).
- 5-inch input/output low-to-chassis ground cable (part number: CA-186-1A).
- Safety high voltage dual test leads (Model 8607).
- Accessories as ordered.
- Certificate of calibration.
- Instruction Manual.
- Support Software Disk including TestPoint instrument library for GPIB and LabVIEW for Windows driver.
- Manual addenda, containing any improvements or changes to the instrument or manual.

If an additional manual is required, order the appropriate manual package (for example, 6430-901-00). The manual packages include a manual and any pertinent addenda.

Options and accessories

The following options and accessories are available from Keithley for use with the Model 6430.

Triax cables and adapters (for Remote PreAmp)

Model 6430-322-1A — This low-noise 8-inch cable is terminated with a 3-slot male triax connector on one end, and three booted alligator clips on the other end.

Model 7078-TRX-1 — This low-noise 12-inch triax cable is terminated at both ends with 3-slot male triax connectors.

Model 237-TRX-BAR Barrel Adapter — This is a barrel adapter that allows you to connect two triax cables together. Both ends of the adapter are terminated with 3-lug female triax connectors.

CS-1053 Barrel Adapter — This barrel adapter is terminated at both ends with 3-slot male triax connectors.

Model 237-BNC-TRX Adapter — This is a male BNC to 3-lug female triax adapter (guard disconnected). It is used to terminate a triax cable with a BNC plug.

Model 237-TRX-T Adapter — This is a 3-slot male to dual 3-lug female triax tee adapter for use with triax cables.

Model 7078-TRX-BNC Adapter — This is a 3-slot male triax to female BNC adapter. This adapter lets you connect a BNC cable to the triax input of the Model 6430.

Model 237-TRX-TBC Connector — This is a 3-lug female triax bulkhead connector with cap for assembly of custom panels and interface connections.

General purpose probes

Model 8605 high performance modular test leads — Consists of two high voltage (1600V) test probes and leads. The test leads are terminated with a banana plug that has a retractable sheath on each end.

Model 8606 high performance probe tip kit — Consists of two spade lugs, two alligator clips, and two spring hook test probes. (The spade lugs and alligator clips are rated at 30V RMS, 42.4V peak; the test probes are rated at 1000V.) These components are for use with high performance test leads terminated with banana plugs, such as the Model 8605.

Model 8607 High Performance Banana Cables — Consists of two high voltage (1000V) banana cables. The cables are terminated with banana plugs that have retractable sheaths.

The following test leads and probes are rated at 30V RMS, 42.4V peak:

Models 5805 and 5805-12 Kelvin probes — Consists of two spring-loaded Kelvin test probes with banana plug termination. Designed for instruments that measure four-terminal resistance. The Model 5805 is 0.9m long; the Model 5805-12 is 3.6m long.

Model 5806 Kelvin clip lead set — Includes two Kelvin clip test leads (0.9m) with banana plug termination. Designed for instruments that measure four-terminal resistance. A set of replacement rubber bands is available (Keithley P/N GA-22).

Model 8604 SMD probe set — Consists of two test leads (0.9m), each terminated with a surface mount device “grabber clip” on one end and a banana plug with a retractable sheath on the other end.

Low thermal probes

Model 8610 low thermal shorting plug — Consists of four banana plugs mounted to a 1-inch square circuit board, interconnected to provide a short circuit among all plugs.

Model 8611 low thermal patch leads — Consists of two test leads (0.9m), each with a banana plug that has a retractable sheath at each end. These leads minimize the thermally-induced offsets that can be created by test leads.

Model 8612 low thermal spade leads — Consists of two test leads (0.9m), each terminated with a spade lug on one end and a banana plug that has a retractable sheath on the other end. These leads minimize the thermally-induced offsets that can be created by test leads.

Cables and adapters

CA-176-1D Preamp Cable — Connects the REMOTE Preamp to the Model 6430 mainframe.

Models 7007-1 and 7007-2 shielded GPIB cables — Connect the SourceMeter to the GPIB bus using shielded cables and connectors to reduce Electromagnetic Interference (EMI). The Model 7007-1 is 1m long; the Model 7007-2 is 2m long.

Models 8501-1 and 8501-2 trigger link cables — Connect the SourceMeter to other instruments with Trigger Link connectors (e.g., Model 7001 Switch System). The Model 8501-1 is 1m long; the Model 8501-2 is 2m long.

Model 8502 trigger link adapter — Lets you connect any of the six Trigger Link lines of the SourceMeter to instruments that use the standard BNC trigger connectors.

Model 8503 DIN to BNC trigger cable — Lets you connect Trigger Link lines one (Voltmeter Complete) and two (External Trigger) of the SourceMeter to instruments that use BNC trigger connectors. The Model 8503 is 1m long.

Rack mount kits

Model 4288-1 single fixed rack mount kit — Mounts a single SourceMeter in a standard 19-inch rack.

Model 4288-2 side-by-side rack mount kit — Mounts two instruments (Models 182, 428, 486, 487, 2000, 2001, 2002, 2010, 2015, 2400, 2410, 2420, 2430, 6430, 6517, 7001) side-by-side in a standard 19-inch rack.

Model 4288-3 side-by-side rack mount kit — Mounts a SourceMeter and a Model 199 side-by-side in a standard 19-inch rack.

Model 4288-4 side-by-side rack mount kit — Mounts a SourceMeter and a 5.25-inch instrument (Models 195A, 196, 220, 224, 230, 263, 595, 614, 617, 705, 740, 775, etc.) side-by-side in a standard 19-inch rack.

Model 4288-5 dual fixed rack mounting kit — Mounts a SourceMeter and another 3½-inch high instrument (Model 182, 428, 486, 487, 2000, 2010, 2400, 2410, 2420, 2430, or 7001) side-by-side in a standard 19-inch rack.

Calibration standards

Model 5156 Electrometer Calibration Standard Set — This calibration fixture contains standardized resistors and capacitors needed to calibrate the Model 6430.

Carrying case

Model 1050 padded carrying case — A carrying case for a SourceMeter. Includes handles and a shoulder strap.

Product overview

The SourceMeter combines a precise, low-noise, highly stable DC power supply with a low-noise, highly repeatable, high-impedance multimeter and a remote preamplifier for ultra low current measurements. It has 0.012% basic accuracy with 5½-digit resolution. At 5½ digits, the SourceMeter delivers 520 readings/second over the IEEE-488 bus. At 4½ digits, it can read up to 2000 readings/second into its internal buffer. The unit has broad source and measurement ranges:

- Source voltage from 5µV to 210V; measure voltage from 1µV to 211V.
- Source current from 0.5fA to 105mA; measure current from 10aA to 105.5mA.
- Measure resistance from 100µΩ (<100µΩ in manual ohms) to 21.1TΩ.
- Maximum source power is 2.2W.

NOTE *The Model 6430 is Y2K compliant.*

Some additional capabilities of the SourceMeter include:

- Perform measurements at the DUT using the small Remote PreAmp.
- Concurrent measurements of all three functions over the remote interface.
- Source-measure sweep capabilities (linear and logarithmic staircase sweeps, source sweep list of up to 1000 points, memory sweep of up to 100 instrument setups).
- 6-wire ohms measurement with programmable I-source or V-source with V or I clamp.
- 2.2W, 4-quadrant source and sink operation.
- Up to 11 stages of limit testing with a built-in comparator for pass/fail testing.
- Digital I/O for stand-alone binning operations or interface to component handler.
- Programming language and remote interfaces — The SourceMeter uses the SCPI programming language and two remote interface ports (IEEE-488/GPIB and RS-232C).
- Trigger-Link interface to Keithley Series 7000 switching hardware.
- Math expressions — 5 built-in, up to 5 user-defined (bus only).
- Reading and setup storage — Up to 2500 readings and seven setups (five user defaults, factory default, *RST default) can be stored and recalled.
- Closed-cover calibration — The instrument can be calibrated either from the front panel or remote interface.

Mainframe and Remote PreAmp familiarization

The following information should be reviewed before operating the instrument and is organized as follows:

- Mainframe front panel summary — Provides an overview of front panel controls and the display.
- Mainframe rear panel summary — Provides an overview of rear panel connectors.
- Remote PreAmp summary — Covers the Remote PreAmp connectors.

Mainframe front panel summary

The front panel of the Model 6430 is shown in Figure 1-1.

Figure 1-1
Front panel

Measurement (MEAS) function keys:

V	Measure volts.
I	Measure amps.
Ω	Measure ohms.
FCTN	Perform math functions.

SOURCE function keys:

V	Source voltage (V-Source).
I	Source current (I-Source).
▲	Increase source or compliance value.
▼	Decrease source or compliance value.

Operation keys:

EDIT	Select source or compliance reading for editing.
TOGGLE	Toggle display positions of source and measure readings, or display V and I measurements.
LOCAL	Cancel remote operation.
REL	Enable/disable relative reading on present function.
FILTER	Display digital filter status for present function and toggle filter on/off.
LIMIT	Perform configured limit tests.
TRIG	Trigger a measurement from the front panel.
SWEEP	Start configured sweep.
◀ and ▶	Move through parameter values or selections within functions and operations.
DIGITS	Change number of digits of display resolution.
SPEED	Change measurement speed by selecting accuracy or specifying NPLC.
STORE	Set buffer size and enable reading storage.
RECALL	Display stored readings and timestamp.
CONFIG	Press CONFIG and then appropriate key to configure function or operation.
MENU	Access and configure Main Menu selections. When entering numeric data, use to clear reading to minimum absolute value.
EXIT	Cancels selection. Use to back out of menu structures.
ENTER	Accepts selection.

RANGE keys:

▲	Moves to next higher range, increments digit, moves to next selection.
▼	Moves to next lower range, decrements digit, moves to previous selection.
AUTO	Enables or disables measurement auto range.

Annunciators:

EDIT	Instrument in edit mode.
ERR	Questionable reading, invalid cal step.
REM	Instrument in GPIB remote mode.
TALK	Instrument addressed to talk over GPIB.
LSTN	Instrument addressed to listen over GPIB.
SRQ	Service request over GPIB.
REAR	On = Remote Preamp not connected. Off = Remote Preamp connected.
REL	Relative measure reading displayed.
FILT	Digital filter enabled.
MATH	Math function enabled.
4W	Remote sensing enabled.
AUTO	Autoranging enabled.
ARM	Source-measure operations being performed.
TRIG	External trigger source selected.
*	Reading being stored.

Source control:

ON/OFF	Turns the source on or off.

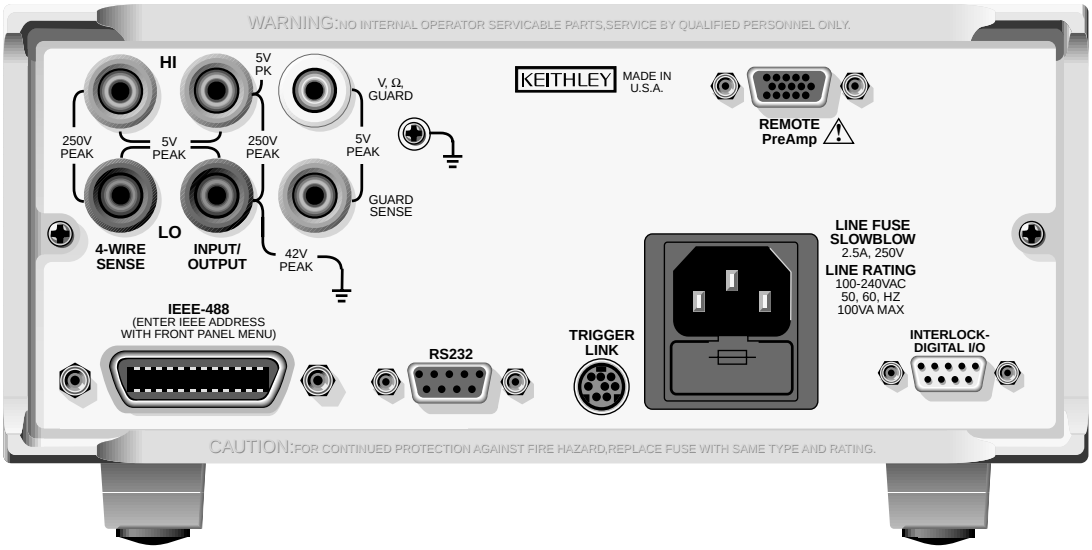
Handle:

Pull out and rotate to desired position.

Mainframe rear panel summary

The rear panel of the Model 6430 is shown in Figure 1-2.

Figure 1-2
Model 6430 rear panel



Source-measure connectors:

CAUTION **When using the Remote PreAmp, DO NOT use the INPUT/OUTPUT HI and 4-WIRE SENSE HI banana jacks. Using these source-measure banana jacks will result in errors and/or noise, and possible damage to the Remote PreAmp. Use the input/output HI and sense HI terminals on the Remote PreAmp.**

INPUT/OUTPUT HI and LO	Use to source-measure volts, amps, and ohms.
4-WIRE SENSE HI and LO	Use for 4-wire remote sensing.
V, Ω GUARD	Driven guard for guarded measurements.
GUARD SENSE	Use to correct for IR drops in Guard Output lead.
⏚	Earth (chassis) ground screw.

WARNING **INPUT/OUTPUT LO is not internally connected to the chassis and can float up to 42V peak above chassis ground.**

The maximum allowable voltage differentials between the various terminals are provided on the rear panel of the mainframe (see Figure 1-2):

Low voltage differentials — The maximum low voltage differentials are 5V peak. However, to achieve rated accuracy, do not exceed 1V peak on the 100µA through 100mA ranges. For the lower current ranges (1pA through 10µA), do not exceed the maximum allowable resistance. The maximum resistance for each of these current ranges are provided in Section 2 (see *Connections to DUT, 4-wire sensing specification clarifications).*

High voltage differentials — Exceeding the high voltage differentials (42V peak and 250V peak) could damage the instrument and create a shock hazard.

Remote PreAmp connector:

REMOTE PREAMP	Connect the Remote PreAmp to the mainframe using the supplied preamp cable (CA-176-1D).

Interlock and digital input/output port:

INTERLOCK — DIGITAL I/O	Male DB-9 connector for digital output lines, interlock, and component handler signals.

Power module:

Contains the AC line receptacle and the power line fuse.

Trigger link connector:

TRIGGER LINK	8-pin micro-DIN connector for sending and receiving trigger pulses. Use a trigger link cable or adapter, such as Models 8501-1, 8501-2, 8502, 8504.

RS-232 connector:

RS-232	Connector for RS-232 remote operation. Use a straight through (not null modem) DB-9 cable such as Keithley Model 7009-5.

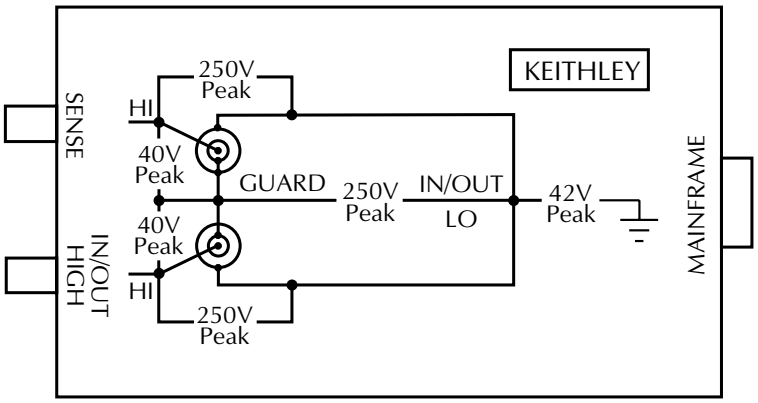
GPIB connector:

IEEE-488 INTERFACE	Connector for GPIB remote operation. Use a shielded cable (Model 7007-1 or 7007-2).

Remote PreAmp summary

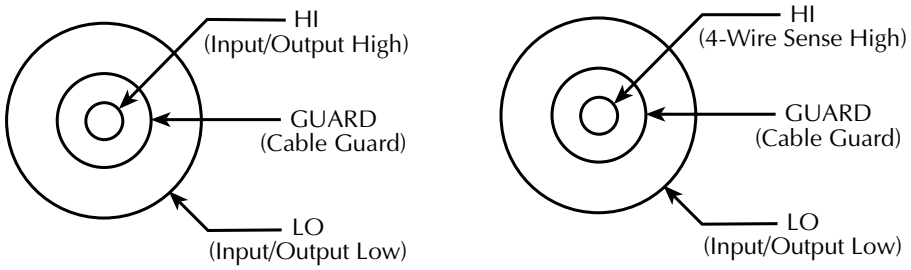
The Remote PreAmp is shown in Figure 1-3 and terminal identification for the IN/OUT HIGH and SENSE triax connectors is provided in Figure 1-4.

Figure 1-3
Remote preamp



REMOTE Preamp

Figure 1-4 *Triax connectors*



IN/OUT HIGH Triax Connector SENSE Triax Connector

Preamp connector:

MAINFRAME Connect the Remote PreAmp to the mainframe using the supplied preamp cable.

Triax connectors:

CAUTION **When using the Remote PreAmp, DO NOT use the INPUT/OUTPUT HI and 4-WIRE SENSE HI banana jacks on the mainframe. Using these source-measure banana jacks will result in errors and/or noise, and possible damage to the Remote PreAmp.**

IN/OUT HIGH	HI	Center conductor – Input/Output HI
	Guard	Inner shell – Driven cable guard for guarded measurements
	LO	Outer shell – Input/Output LO
SENSE	HI	Center conductor – 4-wire Sense HI
	Guard	Inner shell – Driven cable guard for guarded measurements
	LO	Outer shell – Input/Output LO

NOTE *Cable guard is always available on the Guard terminals of IN/OUT HIGH and SENSE regardless of the guard mode setting. Ohms guard can only be accessed at the V, Ω GUARD banana jack on the mainframe.*

The diagram on the Remote PreAmp (Figure 1-3) shows the maximum allowable voltage differentials between the various terminals. Exceeding the voltage differentials could damage the SourceMeter and create a shock hazard.

CAUTION **Instrument damage caused by excessive voltage differentials is not covered by the warranty.**

Power-up

WARNING **To prevent electric shock, power must be off when connecting the Remote PreAmp to the mainframe. If you wish to connect the Remote PreAmp at this time, proceed to Section 2, *Connecting Remote PreAmp to the mainframe*. Important safety precautions are included with the connection procedure.**

WARNING **During the power-up, voltage spikes may appear on the terminals of the SourceMeter. These voltage spikes could be at hazardous levels (>42.4V peak) and could damage sensitive DUTs. Never touch external circuitry or the test leads when powering up the SourceMeter. It is good practice to always disconnect DUTs from the SourceMeter before powering up the unit.**

WARNING **To prevent electric shock, test connections must be configured such that the user cannot come in contact with conductors or any DUT that is in contact with the conductors. Safe installation requires proper shields, barriers, and grounding to prevent contact with conductors. Operator protection and safety are the responsibility of the person installing the product.**

Line power connection

The SourceMeter operates from a line voltage in the range of 85 to 250V at a frequency of 50 or 60Hz. The SourceMeter will also operate at 400Hz; accuracy specifications are not guaranteed however. Line voltage and line frequency are automatically sensed. Therefore, there are no switches to set. Check to be sure the operating voltage in your area is compatible.

CAUTION **Operating the instrument on an incorrect line voltage may cause damage, possibly voiding the warranty.**

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

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.

WARNING **The power cord supplied with the SourceMeter 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.**

3. Turn on the instrument by pressing the front panel power switch to the on (1) position.

Power-up sequence

On power-up, the SourceMeter performs self-tests on its EPROM and RAM and momentarily lights all segments and annunciators. If a failure is detected, the instrument momentarily displays an error message, and the ERR annunciator turns on. Error messages are listed in Appendix B.

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 firmware revision levels are displayed. For example:

REV A01 A02

where: A01 is the main board ROM revision.
A02 is the display board ROM revision.

Also displayed is the line frequency (50, 60, or 400Hz). (If the wrong frequency is displayed, it can be manually set as covered below). The communication interface status is briefly displayed. If the IEEE-488 bus is the presently selected interface, the identification message will include the primary address. For example, if the primary address is 24 (factory default), the "IEEE Addr=24" message is displayed. If the RS-232 interface is selected, the "RS-232" message is displayed.

After the power-up sequence, the instrument goes to its normal display state with the output off (red OUTPUT indicator light off). With the output off, the "OFF" message is displayed, and dashes replace the reading. The "OFF" message indicates that the NORMAL output-off state is selected. See Section 12, *Output configuration* for details.

System identification

To obtain the serial number and revision information, use the MENU/GENERAL/SERIAL # selection or the *IDN? query via remote.

Line frequency setting

At the factory, the SourceMeter is configured to sense the power line frequency and automatically select the frequency setting. If, however, the line power source is noisy, the SourceMeter may select the wrong setting on power-up. If this situation occurs, noisy measurement readings will result, and accuracy may be affected. You can manually set the line frequency from the front panel or via remote as covered below.

Front panel line frequency

Set the line frequency from the front panel as follows:

1. Press the MENU key to display MAIN MENU.

2. Using the right arrow key, select AD-CTRL then press ENTER to display A/D CONTROLS.
3. Select LINE-FREQ, then press ENTER to display LINE FREQUENCY.
4. Place the cursor on 50Hz, 60Hz, or AUTO, and press ENTER. (Use 50Hz for 400Hz operation.)
5. Press EXIT to return to normal display.

Remote command line frequency

Table 1-1 summarizes remote commands used to control line frequency. See Section 17 for additional information on using these commands.

Programming examples

50 or 400Hz operation:

:SYST:LFR 50

Auto frequency operation:

:SYST:LFR:AUTO ON

Table 1-1
Line frequency remote commands

Commands	Description
:SYSTem:LFRequency <freq> :SYSTem:LFRequency:AUTO <state>	Select line frequency (freq = 50 or 60). Enable/disable auto frequency (state = ON or OFF).

Fuse replacement

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

1. The fuse is located in a drawer above the AC receptacle. See Figure 1-2. At the bottom of the fuse drawer is a small tab. At this location, use a small bladed screwdriver to pry the fuse drawer open.
2. 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.

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

3. Snap the fuse out of the drawer and replace it with the same type (250V, 2.5A, 5 × 20mm). The Keithley part number is FU-72.
4. Push the fuse drawer back into the power module.

Display

Display format

The SourceMeter display is used primarily to program source and compliance values and display measured readings. Annunciators, which are located along the top of the reading/ message display, indicate various states of operation, as covered previously in Front panel summary.

On power-up, the top (primary) display is used for measurements when the output is on (with the output off, “OFF” or “ZER” is displayed). The bottom-left display is used for the programmed source value (Vsrc or Isrc), and the bottom-right display is used for the programmed compliance (Cmpl) limit.

Reading information can be displayed using either engineering units or scientific notation in either fixed- or floating-point format. Use the GENERAL/NUMBERS selection of the main MENU to select the display format, as discussed under Menus later in this section.

Engineering units example: 1.23456µA

Scientific notation example: 1.23456e -6

EDIT key

The SourceMeter must be in the edit mode to set source and compliance values. The edit mode is selected by pressing the EDIT key (EDIT annunciator on). The editing cursor (flashing digit) appears for the source or compliance reading. If a value is not edited within six seconds, the edit mode is cancelled. While in the edit mode, the EDIT key toggles between the source value and compliance value. See Section 3 for details on setting source and compliance values.

TOGGLE key

The TOGGLE key manipulates readings on the top display and on the bottom-left display. It has no effect on the compliance reading (Cmpl), which is located on the bottom right. Each press of the TOGGLE key sequences through the display options.

With the voltage (V) or current (I) measurement function selected, the TOGGLE key lets you display both the current and voltage measurements at the same time. It also allows you to toggle display positions of the source and measure readings.

With the ohms (Ω) measurement function selected, the ohms measurement is always displayed on the top display. The TOGGLE key lets you display either the programmed source value, the current measurement, or the voltage measurement on the bottom-left display.

The TOGGLE key is also used to display statistical data on readings stored in the data store. This function is performed from the data store RECALL mode.

NOTE *If FCTN, REL, or Limits is enabled, the TOGGLE key is disabled.*

Status and error messages

Status and error messages are displayed momentarily. During SourceMeter operation and programming, you will encounter a number of front panel messages. Typical messages are either status or error in nature and are listed in Appendix B.

Remote display programming

The display can also be controlled by various SCPI :DISPlay subsystem commands. Table 1-2 summarizes basic commands. See *:DISPlay subsystem* in Section 17 for more information on using these commands and also *Disabling front panel display* later in this section.

Table 1-2
Basic display commands

Command	Description
:DISPlay:ENABle <state>	Enable/disable display (state = ON or OFF).
:DISPlay:CNDisplay	Return to source-measure display.
:DISPlay:DIGits <n>	Set display resolution (n = 4 to 7).

Front panel tests

Use the TEST/DISPLAY TESTS selection of the main MENU to test various aspects of the front panel. Test selections include:

- KEYS — Front panel keys are tested. Pressing a key displays a message that identifies that key. Pressing EXIT twice cancels this test.
- DISPLAY PATTERNS — Use this selection to turn on all display pixels and annunciators. Subsequent key presses cycle through tests that turn off annunciators and corner pixels of each digit, turn on the rows of the top-left display digit, and turn on all annunciators and pixels of each digit in a sequential manner. Press EXIT to cancel this test.
- CHAR SET — This test displays special characters. Press EXIT to cancel the test.

See *Menus* later in this section for more menu information.

Disabling front panel display

Front panel display circuitry can be disabled to allow the instrument to operate at a higher speed. While disabled, the display is frozen with the following message:

FRONT PANEL DISABLED
Press LOCAL to resume.

As reported by the message, all front panel controls (except LOCAL, TRIG, and OUTPUT ON/OFF) are disabled.

Front panel control

Front panel display circuitry is controlled from the DISABLE DISPLAY configuration menu, which is accessed by pressing CONFIG and then EDIT (or TOGGLE). To select an option (NOW, NEVER, SWEEP, or STORE), use the ◄ and ► keys to place the cursor on the desired option, then press ENTER.

The options for DISABLE DISPLAY are explained as follows:

NOW — Select this option to disable the display now.

NEVER — Select this option if you do not want the display to disable.

SWEEP — Select this option if you want the display to disable while performing a sweep. The display will disable as soon as sweep is started. The display will automatically re-enable after the sweep is completed.

STORE — Select this option if you want the display to disable when storing source-measure readings in the buffer. The display will disable as soon as the buffer is enabled. The display will automatically re-enable after the storage process is completed. Note that with this option, the display will disable while performing a sweep. Sweep readings are automatically stored in the buffer.

Remote command programming

Use the following SCPI commands to enable or disable the front panel display circuitry:

:DISPlay:ENABLe OFF	Disable the display
:DISPlay:ENABLe ON	Enable the display

Default settings

By using appropriate menu selections, you can save and recall various instrument setups, define the power-on configuration, or restore factory defaults as outlined below.

Saving and restoring user setups

You can save and restore up to five of your own user setups using the following procedures.

Saving setups

1. Select the various instrument operating modes you wish to save.
2. Press the MENU key, select SAVESETUP, then press ENTER.
3. From the SAVESETUP menu, select GLOBAL, then press ENTER.
4. From the GLOBAL SETUP MENU, select SAVE, then press ENTER.
5. Select the setup position (0-4) to save, then press ENTER to complete the process.

Restoring setups

1. Press the MENU key, select SAVESETUP, then press ENTER.
2. From the SAVESETUP menu, select GLOBAL, then press ENTER.
3. From the GLOBAL SETUP MENU, select RESTORE, then press ENTER.
4. Select the setup position (0-4) to restore, then press ENTER to complete the process.

Power-on configuration

You can also define which of the stored setups (factory default or user) the instrument assumes as the power-on configuration as follows:

1. Press the MENU key, select SAVESETUP, then press ENTER.
2. From the SAVESETUP menu, select GLOBAL, then press ENTER.
3. From the GLOBAL SETUP MENU, select POWERON, then press ENTER.
4. From the SET POWER-ON DEFAULT menu, choose the power-on configuration: BENCH or GPIB (see below), or USER-SETUP-NUMBER.
5. If you chose to use a user setup as the power-on configuration, select the user setup number, then press ENTER.

Factory default settings

As summarized in Table 1-3, there are two sets of factory defaults, BENCH (front panel) and GPIB (remote). You can restore either of these default conditions as follows:

1. Press the MENU key, select SAVESETUP, then press ENTER.
2. From the SAVESETUP menu, select GLOBAL, then press ENTER.
3. From the GLOBAL SETUP MENU, select RESET, then press ENTER.
4. Select BENCH or GPIB defaults as desired, then press ENTER to complete the process.

Table 1-3
Factory default settings

Setting	BENCH default	GPIB default
A/D Controls:		
Auto-zero	On	On
Line frequency	No effect	No effect
Beeper	On	On
Data Store	No effect	No effect
Digital output*	15 or 7	15 or 7
Digits	5.5	5.5
FCTN	Power (off)	Power (off)
Filter:	On	On
Auto filter	On	On
Moving filter count**	1	1
Advanced filter	Off (5% noise tol)	Off (5% noise tol)
Median filter rank**	0	0
Repeat filter count**	1	1
GPIB address	No effect	No effect
Guard	Cable	Cable
Limit tests:		
DigOut:		
Size	4-bit	4-bit
Mode:	Grading	Grading
Binning control	Immediate	Immediate
Auto clear:	Disabled	Disabled
Delay	0.00001 sec	0.00001 sec
Clear pattern*	15 or 7	15 or 7
H/W limits:		
Control	Disabled	Disabled
Fail mode:	In compliance	In compliance
Cmpl pattern*	15 or 7	15 or 7
S/W limits:		
Lim 2, 3, 5-12:		
Control	Disabled	Disabled
Low limit:	-1.0	-1.0
Low pattern*	15 or 7	15 or 7
High limit:	+1.0	+1.0
High pattern*	15 or 7	15 or 7
Pass (all tests):		
Pass pattern*	15 or 7	15 or 7
Source memory location	Next	Next
EOT mode	EOT	EOT
Numbers	No effect	No effect
Ohms source mode	Manual	Manual
Offset compensated ohms	Off	Off
Output	Off	Off
Interlock	Disabled	Disabled
Off state	Normal	Normal
Auto-off	Disabled	Disabled

* 15 if digout size is 4-bit, 7 if digout size is 3-bit.

** Changes with range when auto filter is enabled.

Table 1-3 (cont.)
Factory default settings

Setting	BENCH default	GPIB default
Power-on default	No effect	No effect
Ranging (measure):		
Auto range	Enabled	Enabled
Rel	Off	Off
Value	0.0	0.0
RS-232	No effect	No effect
Source delay	3ms	3ms
Auto-delay	Disabled	Disabled
Speed	Hi accuracy (10 PLC)	Hi accuracy (10 PLC)
Sweep	Linear staircase	Linear staircase
Start	0V or 0A	0V or 0A
Stop	0V or 0A	0V or 0A
Step	0V or 0A	0V or 0A
Sweep count	1	1
Sweep Pts	2500	2500
Source ranging	Best fixed	Best fixed
Voltage protection	NONE	NONE
Triggered source:		
Control	Disabled	Disabled
Scale factor	+1.0	+1.0
Triggering:		
Arm layer:		
Event	Immediate	Immediate
Count	1	1
Output trigger	Line #2, Off	Line #2, Off
Trigger layer:		
Event	Immediate	Immediate
Count	1	1
Output triggers	Line #2, All off	Line #2, All off
Delay	0.0 sec	0.0 sec

Remote setups

You can also save and recall setups via remote using the following SCPI commands:

- Save and recall user setups using *SAV and *RCL (Section 15).
- Restore GPIB defaults using *RST (Section 15).
- Restore bench defaults using :SYSTem:PRESet (Section 17).
- Save the power-on configuration using :SYSTem:POSetup (Section 17).

Menus

The following paragraphs discuss the main menu, configuration menus, and rules to navigate menus.

Main menu

Use the MENU key to access the Main Menu to select, configure, and/or perform various instrument operations. These include default setup conditions, communications (GPIB or RS-232), calibration, front panel tests, digital output states, auto zero and NPLC caching, timestamp, numeric display format, and the beeper.

The Main Menu structure is summarized in Table 1-4. Use the *Rules to navigate menus* to check and/or change menu options. Figure 1-5 shows the main menu tree.

Table 1-4
Main menu

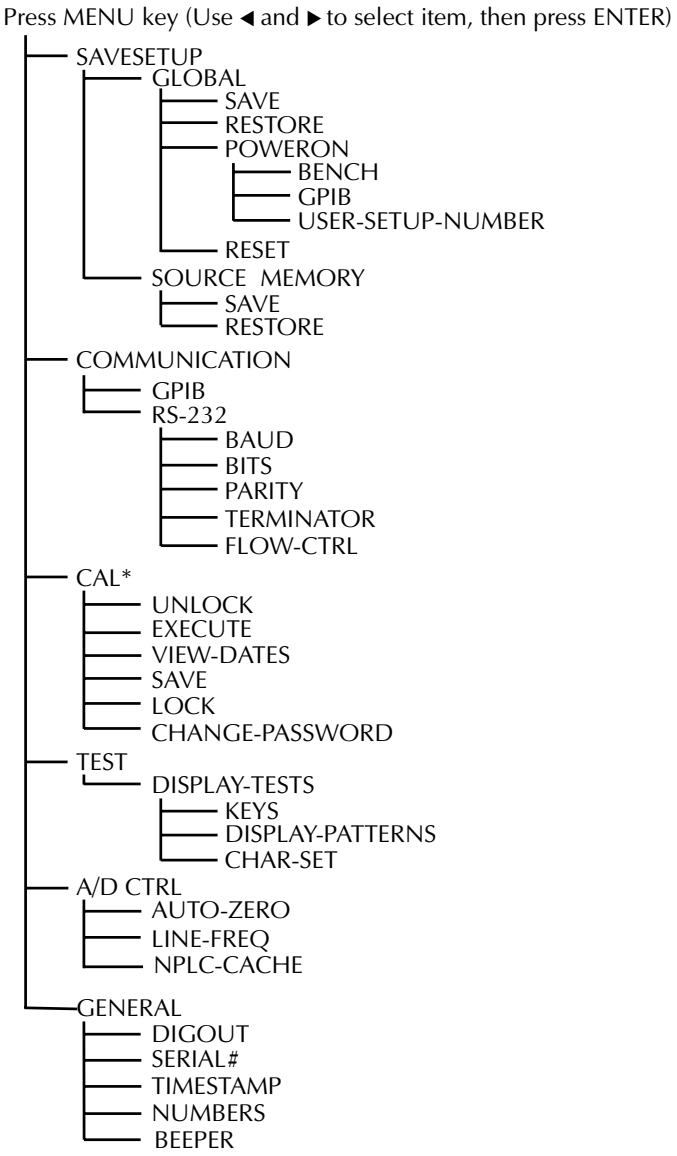
Menu item[1]	**Description**	**Parameters**
SAVESETUP	Configure setup conditions.	
GLOBAL	Control instrument settings.	
SAVE	Save present SourceMeter setup to memory location.	0 to 4
RESTORE	Return the SourceMeter to setup saved in memory.	0 to 4
POWERON	Select the power-on default setup.	
BENCH	Powers-on to BENCH defaults.	See Table 1-3.
GPIB	Powers-on to GPIB defaults.	See Table 1-3.
USER SETUP NUMBER	Powers-on to user setup.	0 to 4
RESET	Returns unit to BENCH or GPIB defaults.	See Table 1-3.
SOURCE MEMORY	Control memory sweep source setup configurations.	
SAVE	Save present setup configuration to memory location.	1 to 100
RESTORE	Return to configuration saved in memory location.	1 to 100
COMMUNICATION[2]	Select and configure remote interface.	
GPIB	Select GPIB (IEEE-488 Bus), set primary address, GPIB protocol (see Appendix G).	0 to 30 (Default: 24)
RS-232		
BAUD	Select the RS-232 interface, set parameters. Select baud rate.	57600, 38400, 19200, 9600, 4800, 2400, 1200, 600, 300
BITS		7 or 8
PARITY	Select number of data bits. Select parity.	NONE, ODD, EVEN
TERMINATOR	Select terminator.	CR, CR+LF, LF, or LF+CR
FLOW CTRL	Select flow control.	NONE or XON/XOFF

Table 1-4 (cont.)
Main menu

Menu item[1]	Description	Parameters
CAL[3]	Calibrate SourceMeter. (See Section 19.)	
TEST	Perform tests on SourceMeter.	
DISPLAY TESTS[4]	Test front panel keys and display digits.	
KEYS	Test front panel keys.	
DISPLAY PATTERNS	Test display pixels and annunciators.	
CHAR SET	Test special display characters.	
A/D CTRL	Control auto zero, line frequency, and NPLC caching.	
AUTO ZERO[5]	Control auto zero.	
DISABLE	Disable auto zero.	
ENABLE	Enable auto zero.	
ONCE	Force auto zero immediate update.	
LINE FREQ	Set the line frequency.	50 or 60Hz, or AUTO
NPLC CACHE	Control NPLC caching.	
DISABLE	Disable NPLC caching.	
ENABLE	Enable NPLC caching.	
REFRESH	Update all NPLC values in cache immediately.	
RESET	Clear NPLC cache of all NPLC values.	
GENERAL	Select general operations.	
DIGOUT	Set Digital I/O port bit pattern.	0-15
SERIAL#	Display serial number, firmware revision, SCPI version.	YES or NO
TIMESTAMP	Reset timestamp.	
NUMBERS	Select engineering units or scientific notation display format.	ENGR, SCIENTIFIC
BEEPER	Enable or disable beeper.	

NOTES
1. Top level menu choices indicated in bold. Indentation identifies each lower submenu level.
2. When the remote operation interface selection (GPIB or RS-232) is changed, the SourceMeter performs a power-on reset. To check or change options of the selected interface, you must re-enter the menu structure.
3. Password is required to unlock calibration. (See Section 19.)
4. Press EXIT key to cancel test.
5. Disabling auto zero will reduce measurement accuracy.

Figure 1-5
Main menu tree



* Without PreAmp connected

Rules to navigate menus

Many source-measure functions and operations are configured from the front panel menus. Use the following rules to navigate through these configuration menus:

NOTE *Rules to edit source and compliance values are found in Section 3, "Basic source-measure procedure."*

- A menu item is selected by placing the cursor on it and pressing ENTER. Cursor position is denoted by the blinking menu item or option. The left and right arrow keys control cursor position.
- A displayed arrow on the bottom line indicates there are one or more additional items (or messages) to select from. Use the appropriate cursor key to display them.
- A source or parameter value range is changed by placing the cursor on the range designator (i.e., k, M, G, etc.) and using the SOURCE ▲ or ▼ or RANGE ▲ or ▼ keys. Note that when the next higher or lower source range is selected, the reading increases or decreases by a decade.
- A parameter value is keyed in by placing the cursor on the digit to be changed and using one of the following methods:

NOTE *You can clear a parameter value by pressing the MENU key.*

  - Use the SOURCE ▲ or ▼ or RANGE ▲ or ▼ keys to increment or decrement the digit.
  - Use the number keys (0 through 9) to key in the value at the selected digit.
  - Use the ± key to change source value polarity, regardless of cursor position.
- Boolean selections (such as ON/OFF and HIGH/LOW) are toggled by placing the cursor on the selection and pressing a SOURCE or RANGE up or down arrow key.
- A change is only executed when ENTER is pressed. Entering an invalid parameter generates an error, and the entry is ignored. However, entering an out-of-range value (too small or too large) selects the lower or upper limit, respectively.
- The EXIT key is used to back out of the menu structure. Any change that is not entered is cancelled when EXIT is pressed.

Editing source and compliance values

Use the following keys to edit source and compliance values:

- EDIT: selects the source or compliance display field for editing. A blinking cursor will appear in the field to be edited. If no key is pressed within a few seconds, the edit mode will be cancelled automatically.
- EDIT ◄ and ►: places the display cursor on the display digit to be changed.
- SOURCE ▲ or ▼: increments or decrements the source or compliance value. Note that pressing either of these keys will automatically enable the source edit mode.
- RANGE ▲ or ▼: selects the source or compliance range.
- Numeric keys (0-9): allow you to directly enter source or compliance values.
- EXIT: exits the edit mode without waiting for the time-out period.

The basic procedure for editing source and compliance values is outlined below. See *Basic source-measure procedure* in Section 3 for more details.

1. Press the EDIT key until the blinking cursor is in either the source or compliance display field to be edited.
2. If desired, use the RANGE ▲ and ▼ keys to select the desired source or compliance range.
3. To simply increment or decrement the display value, use the EDIT ◄ and ► keys to place the blinking cursor on the digit to be changed, then increment or decrement the value with the SOURCE ▲ and ▼ keys. Note that the source or compliance value will be updated immediately; you need not press ENTER to complete the process.
4. To enter the source or compliance value directly, simply key in the desired value with the numeric keys while the cursor is blinking. Again, the source or compliance value will be updated immediately.

Toggling the source and measure display fields

Normally the measured reading value will appear in the upper, main display line, while the source and compliance values will appear in the left and right fields respectively of the lower display line. You can toggle the source and measure display fields by pressing the TOGGLE key to place the source and measure values in the desired positions.

Configuration menus

There are a number of configuration menus that can be accessed by pressing the CONFIG key followed by the appropriate function or mode key. For example, you can configure the voltage source by pressing CONFIG then SOURCE V. Configuration menus, which are summarized in Table 1-5 through Table 1-10, are available for the following operating modes:

- Measure functions (Ω, FCTN): Table 1-5.
- SOURCE V, SOURCE I, and RANGE: Table 1-6.
- REL, FILTER, and LIMIT: Table 1-7.
- TRIG: Table 1-8.
- SWEEP, DIGITS, SPEED, and STORE: Table 1-9.
- ON/OFF OUTPUT and Display (EDIT or TOGGLE): Table 1-10.

These various configuration menus are covered in detail in the pertinent sections of this manual.

Table 1-5
Measurement configuration menus

Configuration menu item	**Description**
CONFIG MEAS Ω	Configure ohms measure.
CONFIG OHMS	
SOURCE	Select manual or auto source for ohms.
MANUAL	
AUTO	
GUARD	Select ohms or cable guard.
OHMS	
CABLE	
SRC RDBK	Enable/disable source readback.
DISABLE	
ENABLE	
OFFSET COMPENSATION	Enable/disable offset compensation.
DISABLE	
ENABLE	
CONFIG FCTN	Configure functions.
CONFIGURE FUNCTION	
POWER	Enable power function.
OFF COMP OHMS	Enable offset-compensated ohms, program parameters.
VOLT-COEFF	Enable voltage coefficient, program parameters.
VAR ALPHA	Enable varistor alpha, program parameters.
%DEV	Enable percent deviation, program parameters.

Table 1-6
Source and range configuration menus

Configuration menu item	Description
CONFIG SOURCE V	Configure V source.
CONFIGURE V SOURCE	
PROTECTION	Select voltage protection.
DELAY	Program delay between source and measure.
AUTO DELAY	Enable/disable auto delay.
DISABLE	
ENABLE	
GUARD	Select ohms or cable guarding.
OHMS	
CABLE	
TRIG	Control triggered source.
CONTROL	Enable/disable triggered source.
DISABLE	
ENABLE	
SCALE FACTOR	Program scale factor.
CONFIG SOURCE I	Configure I source
CONFIGURE I SOURCE	
GUARD	Select ohms or cable guarding.
OHMS	
CABLE	
DELAY	Program delay between source and measure.
AUTO DELAY	Enable/disable auto delay.
DISABLE	
ENABLE	
TRIG	Control triggered source.
CONTROL	Enable/disable triggered source.
DISABLE	
ENABLE	
SCALE FACTOR	Program scale factor.
CONFIG ▲ RANGE	Program upper range limit.
CONFIG ▼ RANGE	Program lower range limit.
CONFIG AUTO RANGE	
AUTO RANGE TYPE	Select auto range type.
SINGLE SRC MTR	Select single SourceMeter operation.
MULTIPLE	Select multiple SourceMeter, program soak time.

Table 1-7
Rel, filter, and limit configuration menus

Configuration menu item	Description
CONFIG REL	Program REL value.
CONFIG FILTER	Configure filter.
AUTO FILTER	Enable/disable auto filter.
DISABLE	
ENABLE	
CONFIG LIMIT	Configure limit tests.
CONFIGURE LIMITS MENU	
DIGOUT	Program Digital I/O bit patterns for pass/fail.
SIZE	Select I/O number of bits.
3-BIT	3-bit size
4-BIT	4-bit size
16-BIT	16-bit size (2499-DIGIO option only).
MODE	Select Digital I/O mode.
GRADING	Pass if within HI/LO limits.
IMMEDIATE	Stop test after first failure.
END	Stop test at end of sweep.
SORTING	Fail if outside limits, program fail pattern.
AUTO CLEAR	Enable/disable auto clear.
DISABLE	Disable auto clear.
ENABLE	Enable auto clear, program pass/fail pattern.
H/W LIMITS	Control and set fail mode for Limit 1 (compliance) test.
CONTROL	Control Limit 1 test.
DISABLE	Disable Limit 1 test.
ENABLE	Enable Limit 1 test.
FAIL MODE	Select Limit 1 fail mode.
IN	Fail when in compliance, program bit pattern.
OUT	Fail when out of compliance, program bit pattern.
S/W LIMITS	Control LIM2, 3, 5-12 tests limits and bit patterns.
CONTROL	Enable/disable limit tests.
DISABLE	Disable test.
ENABLE	Enable test.
LOLIM	Set low limit.
HILIM	Set high limit.
PASS	Set pass Digital I/O bit pattern.
PASS	Set limit test pass conditions.
DIGIO PATTERN	Set pass conditions Digital I/O bit pattern.
SRC MEM LOC	Set pass conditions next source memory location.
NEXT	Use next location.
LOCATION#	Specify location number.
EOT MODE	Set Digital I/O line 4 to act as EOT or BUSY signal.
BUSY	Set line 4 HI while unit is busy (3-bit mode).
/BUSY	Set line 4 LO while unit is busy (3-bit mode).
EOT	Output line 4 HI pulse at end of test (3-bit mode).
/EOT	Output line 4 LO pulse at end of test (3-bit mode).

Table 1-8
Trigger configuration menu

Configuration menu item	Description
CONFIG TRIG	Configure triggering.
CONFIGURE TRIGGER	
ARM LAYER	Configure trigger model arm layer.
ARM IN	Select arm layer detection event.
IMMEDIATE	Immediate event detection.
GPIB	GPIB GET or *TRG.
TIMER	After timer interval elapses, enter interval.
MANUAL	Front panel TRIG key.
TLINK	Enter TLINK line and state.
ONCE	Bypass event detection once.
NEVER	Never bypass event detection.
↓STEST	When Digital I/O SOT line is pulsed low.
ONCE	Bypass event detection once.
NEVER	Never bypass event detection.
↑STEST	When Digital I/O SOT is pulsed high.
ONCE	Bypass event detection once.
NEVER	Never bypass event detection.
↑↓STEST	When Digital I/O SOT line is pulsed high or low.
ONCE	Bypass event detection once.
NEVER	Never bypass event detection.
ARM OUT	Configure arm layer output trigger.
LINE	Select trigger link output line (1-4).
EVENTS	Enable/disable events.
TRIG LAYER EXIT	Enable (ON) or disable (OFF) on exiting trigger layer.
TL ENTER	Enable (ON) or disable (OFF) on entering trigger layer.
COUNT	Specify arm count.
FINITE	Programmable count.
INFINITE	Never ending count.
TRIG LAYER	Configure trigger layer of trigger model.
TRIGGER IN	Select trigger layer detection event.
IMMEDIATE	Trigger event occurs immediately.
TRIGGER LINK	Select trigger link line as event (1-4).
TRIGGER OUT	Configure trigger layer output trigger.
LINE	Select trigger link line (1-4).
EVENTS	Enable (ON) or disable (OFF) for SOURCE, DELAY, and MEAS.
DELAY	Program trigger delay time.
COUNT	Program trigger count.
HALT	Return unit to idle state.

Table 1-9
Sweep, digits, speed, and data store configuration menus

Configuration menu item	Description
CONFIG SWEEP	**Configure sweeps.**
CONFIGURE SWEEPS	
TYPE	Select sweep type.
STAIR	Staircase sweep, program START, STOP, STEP.
LOG	Log sweep, program START, STOP, # POINTS.
CUSTOM	Custom sweep, program parameters.
# POINTS	Program number of sweep points.
ADJUST POINTS	Set individual point values.
INIT	Set first point value.
SRC MEMORY	Source memory sweep, set parameters.
START	Set first point value.
# POINTS	Set number of points.
SWEEP COUNT	Set sweep count.
FINITE	Program sweep count value.
INFINITE	Never-ending sweep.
SOURCE RANGING	Set sweep ranging mode.
BEST FIXED	Best fixed range based on maximum value.
AUTO RANGE	Auto range during sweep.
FIXED	Set fixed source range.
CONFIG DIGITS	Set display number of digits.
DISPLAY DIGITS	Select 3.5, 4.5, 5.5, or 6.5.
CONFIG SPEED	Set measurement speed.
SPEED ACCURACY MENU	
FAST	Fast speed.
MED	Medium speed.
NORMAL	Normal.
HI ACCURACY	Maximum accuracy.
OTHER	Program NPLCs (number power line cycles).
CONFIG STORE	Configure data store timestamp.
STORE TIMESTAMP	
ABSOLUTE	Absolute timestamp.
DELTA	Delta timestamp.

Table 1-10
Output and display configuration menus

Configuration menu item	Description
CONFIG ON/OFF OUTPUT	Configure output.
CONFIGURE OUTPUT	
OFF STATE	Set up output off state.
NORMAL	Normal off state.
ZERO	Zero off state.
GUARD	Guard mode off state.
AUTO OFF	Enable disable auto off mode.
DISABLE	Keep output on.
ENABLE	Turn output off after each measurement.
INTERLOCK	Enable/disable interlock.
DISABLE	Disable interlock.
ENABLE	Enable interlock.
CONFIG EDIT or TOGGLE	Enable/disable display.
DISABLE DISPLAY	
NOW	Disable display immediately.
NEVER	Never disable display.
SWEEP	Turn display off during sweep.
STORE	Turn display off during buffer store.

2
Connections

- **Connection Overview** — Explains how to connect the Remote PreAmp to the mainframe, provides basic information on the input/output connectors, and discusses using a test fixture interlock.
- **Connections to DUT** — Covers various methods for making connections to the DUT, including 4-wire remote sensing, 2-wire local sensing, cable and ohms guard, as well as guard selection.
- **Guarding Methods** — Discusses different guarding methods including cable guard, ohms guard, and guard selection.

Connection overview

WARNING **To prevent electric shock, test connections must be configured such that the user cannot come in contact with conductors or any DUT that is in contact with the conductors. Safe installation requires proper shields, barriers, and grounding to prevent contact with conductors. Operator protection and safety are the responsibility of the person installing the product.**

WARNING **During power-up, voltage spikes may appear on the terminals of the SourceMeter. These voltage spikes could be at hazardous levels (>42.4V peak) and could damage sensitive DUTs. Never touch external circuitry or the test leads when powering up the SourceMeter. It is good practice to always disconnect DUTs from the SourceMeter before powering up the SourceMeter.**

WARNING **Up to 210V may be present on the output and guard terminals. To prevent electrical shock that could cause injury or death, NEVER make or break connections to the SourceMeter while it is on or is connected to an external source.**

Connecting Remote PreAmp to the mainframe

WARNING **Potentially hazardous source voltage is routed from the mainframe to the Remote PreAmp via the preamp cable. Adhere to the following safety precautions to prevent electric shock:**

- **The SourceMeter must be turned off before connecting (or disconnecting) the Remote PreAmp to the mainframe.**
- **When not using the Remote PreAmp, disconnect the preamp cable at the rear panel of the mainframe. DO NOT leave the preamp cable connected to the mainframe if the other end is not connected to the Remote PreAmp.**
- **ALWAYS re-install the plastic safety cover onto the mainframe preamp connector whenever the Remote PreAmp is not being used.**

Use the supplied preamp cable to connect the Remote PreAmp to the mainframe as follows:

1. From the front panel of the SourceMeter, turn the POWER off.
2. Connect the preamp cable to the Remote PreAmp. The preamp connector on the Remote PreAmp is labeled “MAINFRAME.”

3. At the rear panel of the mainframe, remove the plastic safety cover from the preamp connector. This connector is labeled “REMOTE PreAmp.” The plastic cover is secured to the connector with two screws. Hold on to the plastic cover and the retaining screws. Whenever the Remote PreAmp is not being used, the plastic safety cover must be re-installed on the mainframe preamp connector.
4. Connect the other end of the preamp cable to the mainframe.

Source-measure terminals

The SourceMeter can be used with or without the Remote PreAmp. However, when not using the Remote PreAmp, the lower current ranges and higher resistance ranges are not available. The small Remote PreAmp can be positioned near the DUT allowing the use of short triax cables. Short triax cables help minimize cable capacitance which could adversely affect the response time of low current measurements.

When not using the Remote PreAmp, all connections to the SourceMeter are made at the rear panel of the mainframe using cables terminated with banana plugs. These terminals are summarized in Section 1 (Figure 1-2). When using the Remote PreAmp, not all source-measure terminals are available at the preamp and must be accessed at the mainframe. Table 2-1 lists each mainframe terminal and the equivalent Remote PreAmp terminal.

Table 2-1
Terminal equivalency between mainframe and Remote PreAmp

Mainframe terminal	**Equivalent Remote PreAmp terminal**
INPUT/OUTPUT HI	IN/OUT HI
INPUT/OUTPUT LO	IN/OUT LO
4-WIRE SENSE HI	SENSE HI
4-WIRE SENSE LO	N/A
V, Ω GUARD	GUARD (cable guard only)
GUARD SENSE	N/A
Chassis ground (screw)	N/A

N/A = Not available at Remote PreAmp.

NOTE *Whenever the Remote PreAmp is connected to the mainframe, adhere to the following rules to achieve best performance:*

- *Do not use INPUT/OUTPUT HI and 4-WIRE SENSE HI on the mainframe. Access these terminals at the Remote PreAmp.*
- *Access input/output low at the Remote PreAmp or at the mainframe, but not both. Test circuit common should be tied to one point to avoid ground loops which could generate error currents.*
- *Do not use guard from the mainframe and the Remote PreAmp at the same time. Use one or the other.*

Remote PreAmp triax connectors

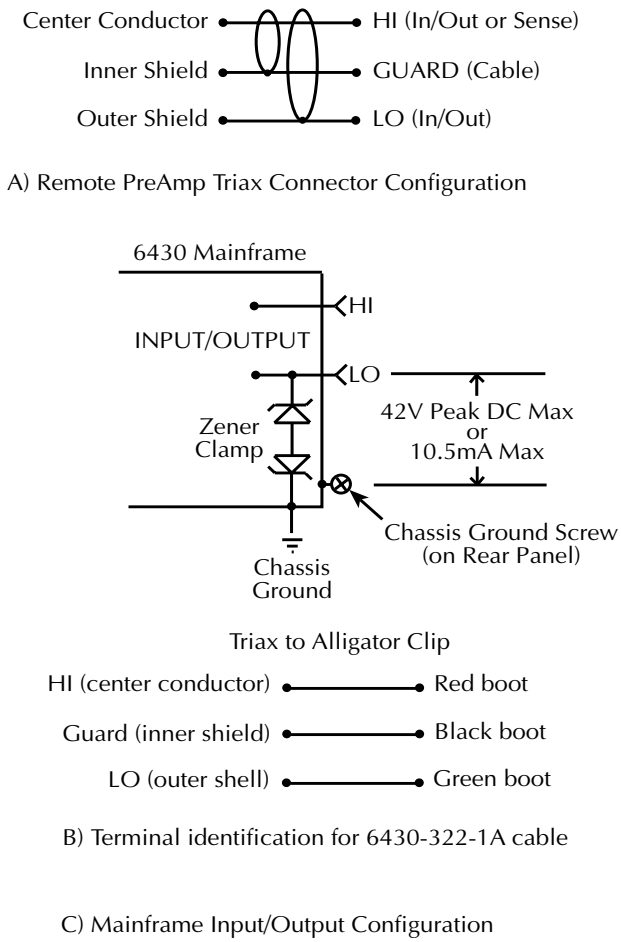
The electrical configuration of each triax connector is shown in Figure 2-1A. The center conductor of the connector (and triax cable) is HI (input/output or sense), and the inner shield is cable guard. The outer shield (shell) of each triax connector is input/output LO.

NOTE *The 6430-322-1A triax cable (which is a supplied accessory) is terminated with a triax connector on one end and booted alligator clips on the other end. (See Figure 2-1B.) When connected to the Remote PreAmp, the alligator clip with the red boot is HI, the one with the black boot is GUARD and the one with the green boot is LO.*

The outer shells of the triax connectors are connected to Input/Output LO. Therefore, for floating source-measure operations, a voltage potential will be present on the shells of the triax connectors. Even with the output of the SourceMeter off, voltage could be applied from the external test circuit. As a general rule, do not touch the triax cables while any power is present.

WARNING **To prevent injury from electric shock, DO NOT touch the triax cables of the Remote PreAmp while the SourceMeter is turned on or any external source is turned on.**

Figure 2-1
Basic input/output configurations



Input/output LO and chassis ground

Input/Output LO is not directly connected to chassis ground. For test circuits that require Input/Output LO connected to chassis ground, you can use the supplied chassis ground plug. Connect the lug end of the cable to the chassis ground screw on the rear panel of the mainframe, and plug the other end into the INPUT/OUTPUT LO banana jack.

With no Input/Output LO-to-chassis ground connection, floating source-measure operations (up to 42V peak) can be performed. Inside the mainframe, a zener clamp (Figure 2-1C) is used to isolate Input/Output LO from the chassis.

WARNING **Exceeding 42V between Input/Output LO and chassis ground creates a shock hazard and could cause damage to the SourceMeter that is not covered by the warranty.**

CAUTION **Do not connect any external sources between Input/Output LO and chassis ground. Current exceeding 10.5mA will damage the zener clamp (Figure 2-1C). Such damage is not covered by the warranty.**

Test fixture interlock

A test fixture interlock switch can be used with the SourceMeter to help protect the DUT. The SourceMeter output will turn off when the lid of the test fixture is opened. However, you must ALWAYS assume that power is present until you verify that the SourceMeter output is off.

WARNING **To prevent electric shock, test connections must be configured such that the user cannot come in contact with conductors or any DUT that is in contact with the conductors. Safe installation requires proper shields, barriers, and grounding to prevent contact with conductors. Operator protection and safety are the responsibility of the person installing the product.**

See Section 12 for complete details on using the interlock and output configuration information.

Connections to DUT

NOTE *Connection drawings in this manual are shown using the Remote PreAmp. If not using the Remote PreAmp, make connections to the equivalent banana jack terminals on the rear panel of the mainframe.*

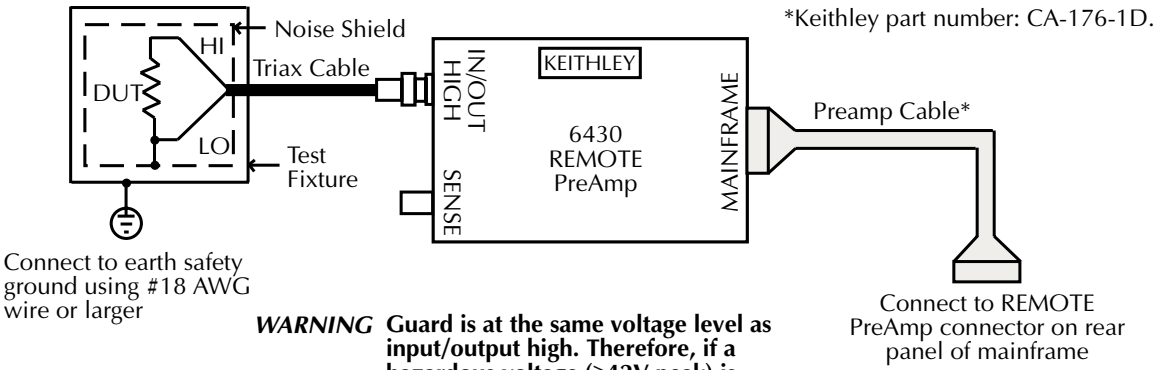
WARNING **To prevent injury from electric shock, DO NOT touch the triax cables of the Remote PreAmp while the SourceMeter is turned on or is connected to an external source that is turned on.**

CAUTION **When using the Remote PreAmp, DO NOT use the INPUT/OUTPUT HI and 4-WIRE SENSE HI banana jacks on the mainframe. Using these terminals while the Remote PreAmp is plugged in will result in errors and/or noise, and possible damage to the Remote Amplifier.**

Sensing methods

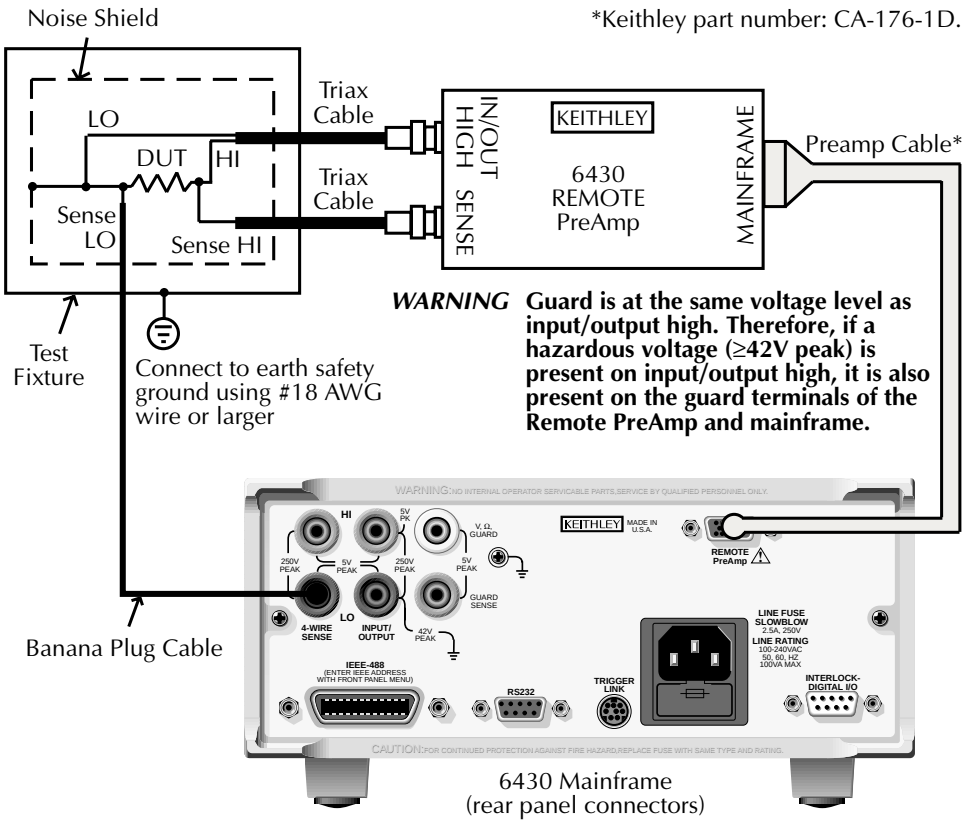
Basic source-measure operations are performed using either 2-wire sense connections (Figure 2-2) or 4-wire sense connections (Figure 2-3). See Section 4, *Ohms sensing* for additional information.

Figure 2-2 *Two-wire sense connections*



WARNING **Guard is at the same voltage level as input/output high. Therefore, if a hazardous voltage (≥42V peak) is present on input/output high, it is also present on the guard terminals of the Remote PreAmp and mainframe.**

Figure 2-3
Four-wire sense connections



WARNING **There is no direct internal connection between earth ground and the INPUT/OUTPUT LO terminal of the SourceMeter. Therefore, hazardous voltages (>30V rms) can appear on the LO terminal. Typically, this can occur when the SourceMeter is operating in any mode where the output changes rapidly, such as quick, pulsed waveforms that can be generated using the ZERO, AUTO-OFF output state, or fast pulse sweep operations.**

To eliminate the shock hazard, connect the INPUT/OUTPUT LO terminal to earth ground. You can connect the LO terminal to the chassis ground screw terminal on the rear panel using the supplied chassis ground plug, or connect it to a known safety earth ground.

WARNING **For floating source-measure operations, voltage will be present on the outer shell (IN/OUT LO) of the triax cable(s). If IN/OUT LO is connected to a noise shield as shown in Figures 2-2 and 2-3, the floating voltage will also be present on the shield. To prevent contact with the floating voltage, enclose the test circuit in a metal test fixture that is connected to safety earth ground (as shown in Figures 2-2 and 2-3), and do not touch the triax cable(s).**

2-wire sensing

When using 2-wire sensing to source and/or measure voltage, the error associated with IR drops in the test leads could be significant. The ratio between the test lead resistance and DUT resistance determines the error that is introduced. If the error introduced by the IR drop of the test leads is not acceptable, use 4-wire sensing.

For example, assume test lead resistance (R_L) is 1Ω and the DUT resistance (R_{DUT}) is 10kΩ. The error is calculated as follows:

Error = R_L / R_{DUT}
= 1Ω / 10kΩ
= 0.0001
= 0.01%

Notice that as the resistance of the DUT increases, the error decreases. For DUT above 1GΩ, guarding should also be used. See *Cable guard*.

Since current in a series circuit is the same at all points in the loop, remote sensing does not improve I-Source or I-Measure accuracy. Thus, if sourcing current and measuring current, you can use local sensing.

NOTE *For Measure Only (V or I) operation, 2-wire sensing must be used.*

4-wire sensing

Voltage source and measure accuracy are optimized by using 4-wire sense connections. When sourcing voltage, 4-wire sensing ensures that the programmed voltage is delivered to the DUT. When measuring voltage, only the voltage drop across the DUT is measured.

Use 4-wire sensing for the following source-measure conditions:

- The error contributed by test lead resistance for local sensing is not acceptable.
- Optimum Ohms, V-Source, and/or V-Measure accuracy are required.

4-wire sensing specification clarifications

- There is no hardware configurations needed to enable 4-wire sense. Simply hook up the sense wires; otherwise, the Model 6430 will sense the voltage locally through resistors.
- Specified accuracies for both source and measure are only achieved using 4-wire sensing.
- Sense wires must be no more than 10Ω per lead.

- The Model 6430 will perform to rated specification with up to 1V drop per source lead on the 100µA through 100mA ranges. On the 10µA range and below (when using the Remote PreAmp), the allowable voltage drop in each source lead is limited as follows:

Current range	Maximum allowable resistance per source lead
10µA	10Ω
1µA	50Ω
100nA	500Ω
10nA	5kΩ
1nA	50kΩ
100pA	1MΩ
10pA	50MΩ
1pA	1GΩ

Guarding methods

Cable guard

Use the high-impedance (cable) guard connection scheme shown in Figure 2-4 for the following source-measure condition:

- Test circuit impedance is >1GΩ.

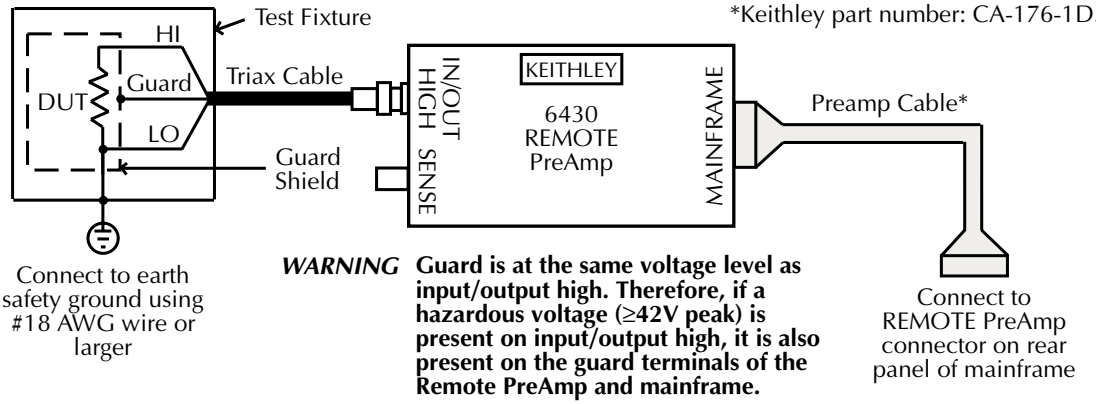


Figure 2-4
High-impedance guarding

Cable guard is always available at the Remote PreAmp. If not using the Remote PreAmp, use the V, Ω GUARD banana jack on the mainframe with CABLE guard selected. See *Guard selection* to select cable guard.

A test fixture is typically used when testing high-impedance devices. The test fixture reduces noise and protects the user from a potentially hazardous voltage on the guard shield (or plate). See *Section 5, Guard* for details on using guard.

Note that the test fixture chassis is connected to In/Out LO to reduce noise.

Ohms guard

Use ohms guard for the following source-measure operation:

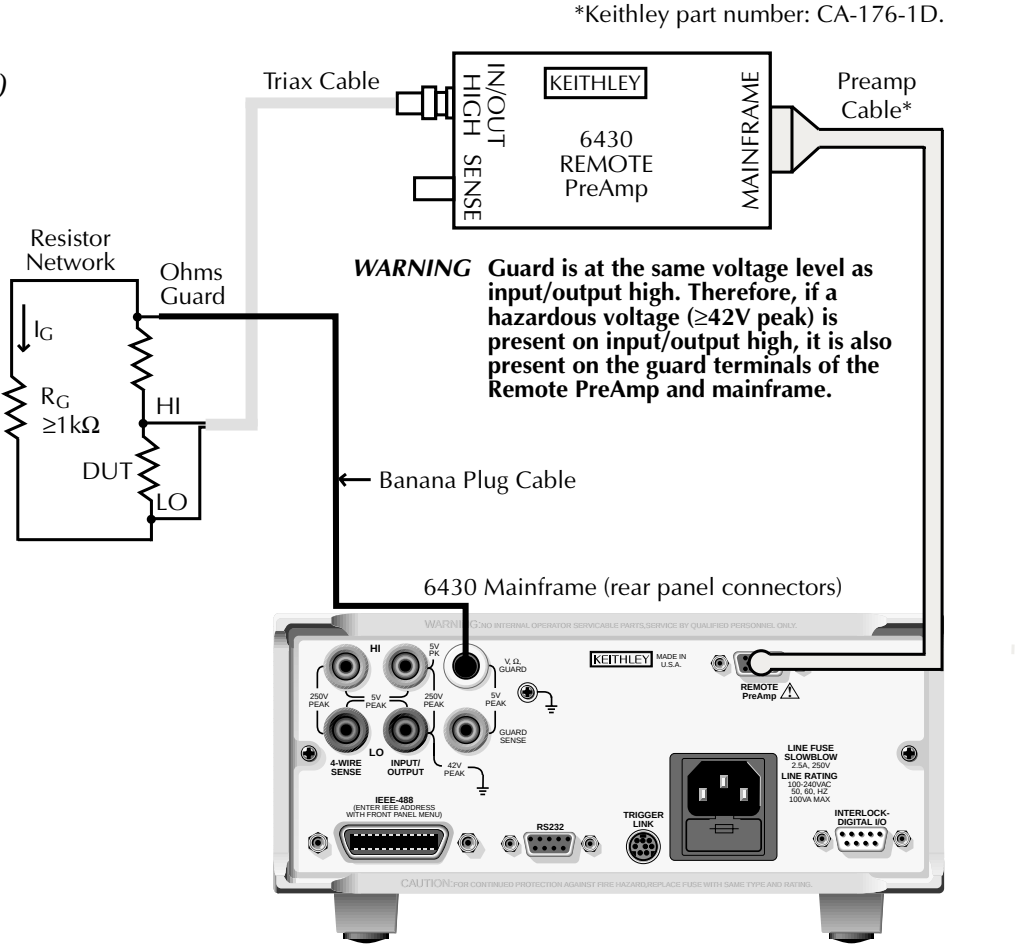
- In-circuit resistance measurements on the DUT where other parasitic leakage devices are present.

Note that ohms guard must be selected for this connection scheme. See *Guard selection* to select ohms guard.

NOTE *Ohms guard cannot be accessed from the Remote PreAmp. It is only available at the rear panel of the mainframe.*

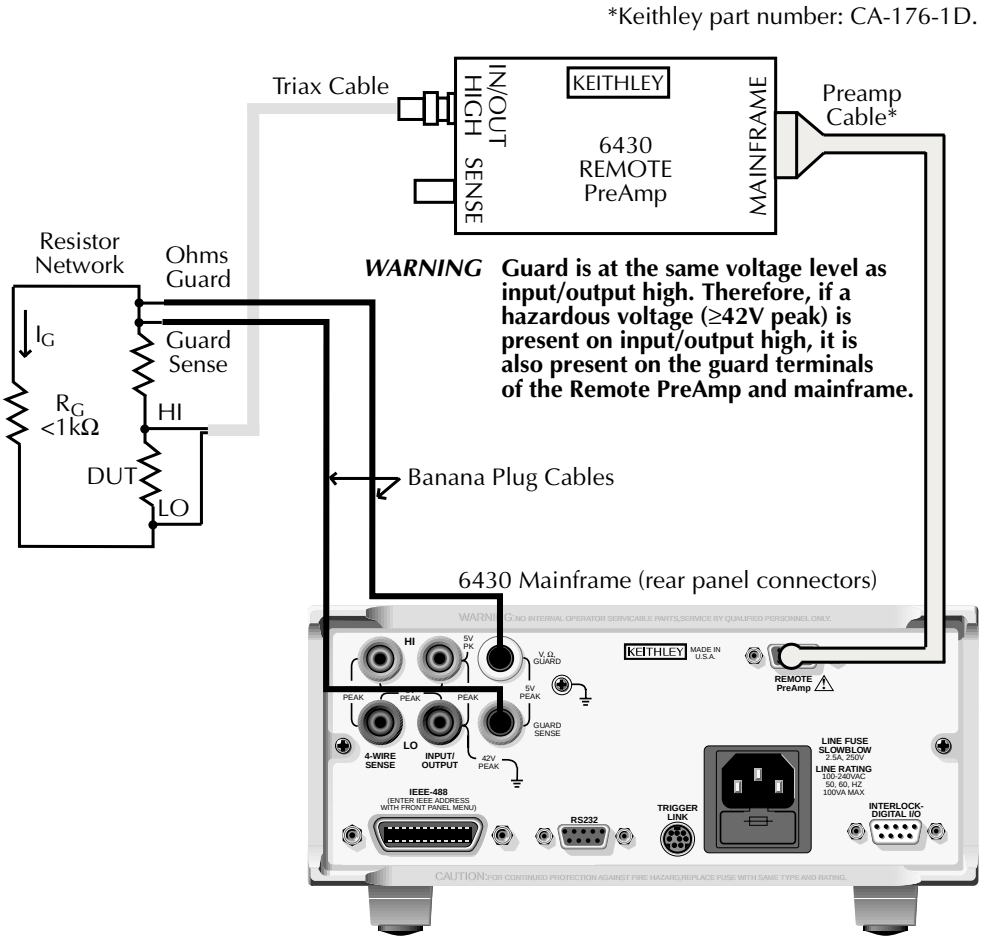
Figures 2-5, 2-6, and 2-7 show how to make connections to measure the resistance of a single resistor (DUT) in a resistor network. See Section 4, *6-wire ohms measurements* and Section 5, *Guard* for more information on guarded ohms measurements.

Figure 2-5
Guarded ohms connections (basic)



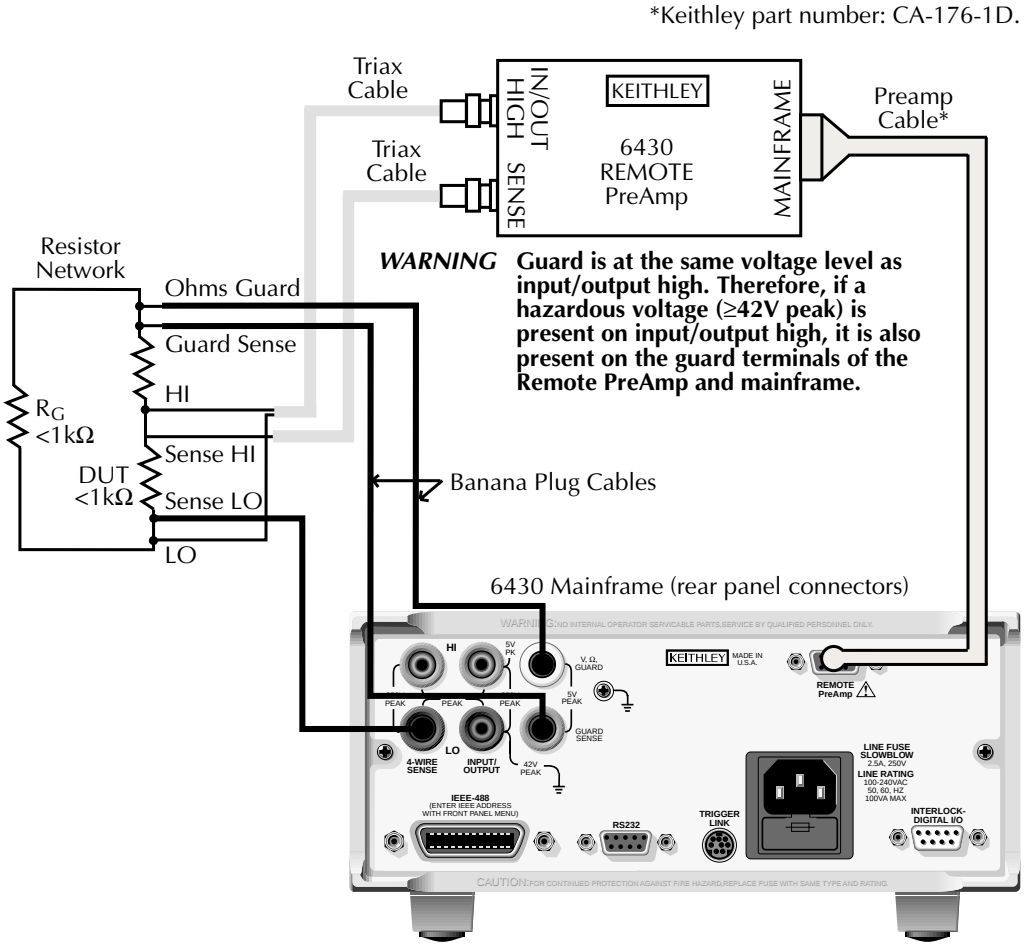
The basic connection scheme for guarded ohms measurements is shown in Figure 2-5. If the guard resistance path (R_G) is <1kΩ, IR drop in the GUARD test lead could be high enough that the guard voltage at the resistor network is significantly less than the output voltage at the DUT. This results in leakage current and will corrupt the measurement. To cancel the effect of IR drop in the GUARD test lead, connect GUARD SENSE to the resistor network as shown in Figure 2-6. Guard sense ensures that the guard voltage at the resistor network is the same as the output voltage at the DUT.

Figure 2-6
Guarded ohms connections (guard sense)



Note that if the DUT is <1kΩ, you should use the 4-wire measurement method (remote sensing) by connecting SENSE HI and LO to the DUT (Figure 2-7).

Figure 2-7
Guarded ohms connections (6-wire ohms)



NOTE *Guard current (I_G) must never exceed 50mA. If it does, guard voltage will become less than the output voltage and corrupt the measurement.*

Guard selection

Cable guard is used for high-impedance guarding for cables (i.e., coax and triax) and test fixtures. Ohms guard provides a high-current guard output, which allows in-circuit guarded ohms measurements.

The guard setting (cable or ohms) only applies to mainframe guard (V,Ω GUARD banana jack). Cable guard is always available at the Remote PreAmp, regardless of the guard setting. Ohms guard is only available at the mainframe. On power-up, the mainframe defaults to cable guard.

NOTE *When the guard selection is changed, the OUTPUT will turn OFF.*

Front panel guard selection

Perform the following steps to check or change the guard selection:

1. Press CONFIG and then the SOURCE V, SOURCE I, or Ω. Changing guard in one configuration menu changes it in all of the others.
2. Using the ◀ and ▶ keys, place the cursor (flashing menu item) on GUARD and press ENTER.

NOTE *Cursor position indicates the present guard selection (OHMS or CABLE). To retain the present selection, use the EXIT key to back out of the menu structure and skip the next two steps.*

3. To change the guard selection, place the cursor on the alternate selection and press ENTER.
4. Use the EXIT key to back out of the menu structure.

NOTE *Do not connect ohms guard using coaxial cabling, or oscillations may occur.*

Remote command guard selection

Use the :SYSTem:GUARd command in Section 17 to choose between cable and ohms guard mode via remote. For example, send the following command to enable ohms guard:

:SYST:GUAR OHMS

Conversely, send this command to enable cable guard:

:SYST:GUAR CABL

3
Basic Source-Measure Operation

- **Operation Overview** — Discusses source-measure capabilities, compliance limit, and fundamental source-measure configuration.
- **Operation Considerations** — Covers warm-up, auto zero, V-source protection, and source delay.
- **Basic Source-Measure Procedure** — Describes the basic procedure for setting up the SourceMeter for source-measure operations, including selecting the source function, output values, and compliance limits; choosing measurement range and function; and turning the output on and off.
- **Measure Only** — Covers how to use the SourceMeter for measurements only.
- **Sink Operation** — Describes sink operation.

CAUTION

Excessive heat could damage the SourceMeter and at the very least, degrade its performance. The SourceMeter must be operated in an environment where the ambient temperature does not exceed 50°C.

The SourceMeter uses a heat sink to dissipate heat. The left side of the case is cut out to expose the black, finned heat sink. To prevent damaging heat build-up and thus, ensure specified performance, adhere to the following precautions:

- **Keep the heat sink free of dust, dirt, and contaminates, since its ability to dissipate heat could become impaired.**
- **Keep the bottom cooling vents from becoming blocked. NEVER remove the plastic feet and place the SourceMeter directly on a flat surface. NEVER operate the SourceMeter when it is sitting on a conformable surface (such as a carpet). This could block the bottom cooling vents.**
- **Do not position any devices adjacent to the SourceMeter that force air (heated or unheated) into or onto its surfaces or cooling vents. This additional airflow could compromise accuracy performance.**
- **When rack mounting the SourceMeter, make sure there is adequate airflow around the bottom and sides to ensure proper cooling. Adequate airflow enables air temperatures within approximately one inch of the SourceMeter surfaces to remain within specified limits under all operating conditions.**
- **Rack mounting high power dissipation equipment adjacent to the SourceMeter could cause excessive heating to occur. The specified ambient temperatures must be maintained around the surfaces of the SourceMeter to specified accuracies.**
- **A good measure to ensure proper cooling in rack situations with convection cooling only is to place the hottest equipment (i.e., power supply) at the top of the rack. Precision equipment, such as the SourceMeter, should be placed as low as possible in the rack where temperatures are the coolest. Adding spacer panels below the SourceMeter will help ensure adequate airflow.**

Operation overview

Source-measure capabilities

From the front panel, the SourceMeter can be configured to perform the following operations:

- **Source voltage** — Display current and/or voltage measurement
- **Source current** — Display voltage and/or current measurement
- **Measure resistance** — Display voltage or current component of measurement
- **Measure only (V or I)** — Display voltage or current measurement

Voltage — The V-Source can output voltage from ±5µV to ±210V and limit current from 1fA to 105mA. The V-Meter can measure voltage from ±1µV to ±211V. The V-Source and V-Meter each have four ranges; 200mV, 2V, 20V, and 200V.

Current — With the Remote PreAmp, the I-Source can output current from ±0.5fA to ±105mA and limit voltage from 200µV to 210V. The I-Meter can measure current from ±10aA to ±105.5mA. The I-Source and I-Meter each have 12 ranges; 1pA, 10pA, 100pA, 1nA, 10nA, 100nA, 1µA, 10µA, 100µA, 1mA, 10mA, and 100mA.

Without the Remote PreAmp, the 1pA, 10pA, 100pA, 1nA, 10nA, and 100nA ranges are not available. Therefore, without the Remote PreAmp, the I-Source can output current from ±50pA to ±105mA and measure current from ±10pA to ±105.5mA.

Resistance — With the Remote PreAmp, the SourceMeter can make resistance measurements from <100µΩ to >20TΩ. When using the auto ohms measurement method, the following ohms ranges are available, 20Ω, 200Ω, 2kΩ, 20kΩ, 200kΩ, 2MΩ, 20MΩ, 200MΩ, 2GΩ, 20GΩ, 200GΩ, 2TΩ, and 20TΩ. When using the manual ohms measurement method, you cannot select ohms ranges. The ohms reading is the mathematical result of V/I.

Without the Remote PreAmp, the 200MΩ, 2GΩ, 20GΩ, 200GΩ, 2TΩ, and 20TΩ auto ohms ranges and, as previously pointed out, the six lowest current ranges are not available. Therefore, without the Remote PreAmp, the SourceMeter can measure resistance from <100µΩ to >20MΩ.

Measure only (V or I) — The SourceMeter can be used exclusively as a voltmeter (V-Meter) or an ammeter (I-Meter). When used as a V-Meter only, the I-Source is set to output 0A. When used as an I-Meter only, the V-Source is set to output 0V.

Range of operation — The maximum power output of the SourceMeter is 2.2W. At maximum source levels, you can output 210V at 10.5mA or 21V at 105mA. The full range of operation is explained in Section 5, *Operating boundaries*.

NOTE *Load regulation – The voltage specification for V-source mode load changes is 0.01% +100µV. This means that on the 200mV range, the load current can be changed from zero to full scale with less than 1.02mV of error. Calculation:*

error = (0.01% × 0.2V) + 100µV
= 0.02mV + 100µV
= 0.12mV

*Assuming a 0 to 100mA change in current, the output impedance equates to 1.2mΩ (0.12mV/100mA = 1.2m*W*). This level can only be achieved using 4-wire sensing.*

Compliance limit

When sourcing voltage, the SourceMeter can be set to limit current (from 1fA to 105mA). Conversely, when sourcing current, the SourceMeter can be set to limit voltage (from 200µV to 210V). The SourceMeter output will not exceed the compliance limit.

Table 3-1 summarizes compliance limits according to range. See Section 5 for more details on compliance limits.

Table 3-1
Compliance limits

Measurement range	Maximum compliance value
200mV	210mV
2V	2.1V
20V	21V
200V	210V
1pA*	1.05pA
10pA*	10.5pA
100pA*	105pA
1nA*	1.05nA
10nA*	10.5nA
100nA*	105nA
1µA	1.05µA
10µA	10.5µA
100µA	105µA
1mA	1.05mA
10mA	10.5mA
100mA	105mA

* Only available when using the Remote PreAmp.

Setting the compliance limit

Front panel compliance limit

Set the compliance limit from the front panel as follows:

1. Select the desired source and measure functions using the MEAS and SOURCE keys.
2. Press the EDIT key until the cursor flashes in the compliance (Compl:) display field.
3. Select the desired compliance range using the RANGE ▲ and ▼ keys.
4. To increment or decrement the compliance value, use the EDIT ◄ and ► keys to place the cursor over the digit to be changed, then press the SOURCE ▲ or ▼ key to increment or decrement the compliance value.
5. To change the compliance value directly, simply enter the value using the numeric keys while the cursor is flashing in the compliance display field.

Remote compliance limit

Table 3-2 summarizes basic commands to program the compliance limit. See Section 17, *Set compliance limit* for more details on these commands. To program the compliance, simply send the command using the desired parameter. For example, the following command sets the current compliance to 50mA:

:SENS:CURR:PROT 50E-3

Similarly, the following command sets the voltage compliance to 4V:

:SENS:VOLT:PROT 4

Table 3-2
Compliance commands

Command	**Description**
:SENSe:CURRent:PROTection <n>	Set current compliance (n = compliance).
:SENSe:VOLTage:PROTection <n>	Set voltage compliance (n = compliance).

Basic circuit configuration

The fundamental source-measure configuration for the SourceMeter (with Remote PreAmp) is shown in Figure 3-1, where the Source is either the V-Source or the I-Source. If not using the Remote PreAmp, Input/Output HI and LO is accessed at the rear panel of the mainframe.

NOTE *When using the Remote PreAmp, nothing should be connected to INPUT/OUTPUT HI banana jack on the mainframe. If using mainframe INPUT/OUTUT HI, the cable to the Remote PreAmp should be disconnected.*

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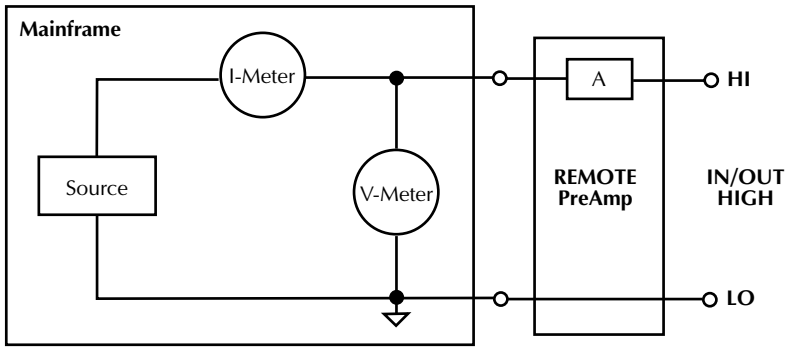


Operation considerations

The following paragraphs discuss warm-up period, auto zero, V-source protection, and source delay.

Warm-up

The SourceMeter must be turned on and allowed to warm up for at least one hour to achieve rated accuracies. See Appendix A for specifications.

Auto zero

Every A/D conversion (reading) is calculated from a series of zero, reference, and signal measurements. With auto zero enabled, all three of these measurements are performed for each reading to achieve rated accuracy. With auto-zero disabled, zero and reference are not measured. This increases measurement speed, but zero drift will eventually corrupt accuracy. With auto zero disabled, periodically change measurement speed.

Temperature changes across components within the instrument can cause the reference and zero values for the A/D converter to drift due to thermo-electric effects. Auto zero acts to negate the effects of drift in order to maintain measurement accuracy over time. Without auto zero enabled, measurements can drift and become erroneous.

Front panel auto zero

Set the auto zero from the front panel as follows:

1. Press the MENU key.
2. Select A/D CTRL from the main menu, then press ENTER.
3. Select AUTO ZERO, then press ENTER.
4. Select ENABLE or DISABLE as appropriate, then press ENTER.
5. Press EXIT as necessary to return to normal display.

Remote command auto zero

Use the :SYSTem:AZERo command to enable or disable auto zero via remote. For example, send the following command to disable auto zero:

```
:SYST:AZER ON
```

Conversely, send this command to disable auto-zero:

```
:SYST:AZER OFF
```

NPLC caching

NPLC caching speeds up source memory sweeps by caching A/D reference and zero values. When NPLC caching is enabled (using the NPLC-CACHE/ENABLE menu selection), the A/D reference and zero values will be saved for up to the 10 most recent voltage, current, and resistance measurement function settings. Whenever the integration rate is changed via the SPEED key, a recalled user setup (using the SAVESETUP/RESTORE menu selection), or during a source memory recall (either with the SOURCE-MEMORY/RESTORE menu or during a source memory sweep), NPLC caching will occur. If the integration rate is already stored in the cache, the stored reference and zero values are recalled and used. Otherwise, a reference and zero value are acquired and stored in the cache. If there are already 10 NPLC values stored, the oldest one will be overwritten by the newest one.

NOTE *Auto zero should be disabled for maximum source memory sweep speed; otherwise the cache is of little use. With auto zero enabled, new A/D reference and zero values are taken for every reading and saved into the cache, slowing down sweep operation. However, with auto zero disabled, measurements may drift and become erroneous. To minimize drift when using NPLC caching with auto zero disabled, periodically select AUTO-ZERO/ONCE in the A/D-CTRL menu to force an immediate auto zero update.*

NPLC cache setup

Follow the steps below to enable and use NPLC caching with a source memory sweep:

1. Press the MENU key, select A/D-CTRL, then press ENTER.
2. Select AUTO-ZERO, then press ENTER.
3. Choose DISABLE, then press ENTER to disable auto zero.
4. From the A/D CONTROLS menu, select NPLC-CACHE, then press ENTER.
5. Select ENABLE, then press ENTER to enable NPLC caching.
6. Use the EXIT key to back out of the main menu structure.
7. Set up the source memory parameters, and run the source memory sweep. (See *Source memory sweep* in Section 9.)

Typical NPLC cache test times

Typically, NPLC caching will decrease source memory sweep times by a factor of three. Table 3-3 shows typical averaged times for a test consisting of 10 sweeps of four source memory locations with NPLC values for successive memory locations set to 10, 1, 0.1, and 0.01 respectively.

Table 3-3
Typical NPLC cache test times

NPLC cache conditions	Time
Auto Zero OFF, Caching OFF	5.89s
Auto Zero ON, Caching OFF	5.89s
Auto Zero OFF, Caching ON	2.05s
Auto Zero ON, Caching ON	5.89s
Auto Zero OFF, Caching ON, Cache empty	2.5s

V-source protection

Use V-source protection to select the maximum voltage level the SourceMeter can output. Available limit values include 20V, 40V, 60V, 80V, 100V, 120V, 160V, and NONE (allows voltage >160V). These are absolute values with 5% tolerance. The power-on default is NONE.

WARNING **Even with the voltage protection limit set to the lowest value (20V), NEVER touch the triax cable(s) or anything connected to the terminals of the SourceMeter when it is on or connected to an external source. Always assume that a hazardous voltage (>30V rms) is present when the power is on.**

To prevent damage to DUT (devices under test) or external circuitry, DO NOT program the V-Source to levels that exceed the voltage protection limit.

Front panel V-source protection

To program V-source protection from the front panel:

1. Press CONFIG then SOURCE V.
2. Select PROTECTION from the displayed choices, then press ENTER.
3. Select the desired protection value, then press ENTER.
4. Press EXIT to return to normal display.

Remote command V-source protection

Use the :SOURce:VOLTage:PROTection command to program the V-source protection value via remote. See Section 17 for details. For example, the following command sets the protection value to 20V:

:SOUR:VOLT:PROT 20

Source delay

The source delay options are used to set the settling time for the source. This source delay is the delay phase of the Source-delay-measure cycle. See Section 5. The auto delay period is current range dependent (Table 3-4).

Table 3-4
Auto source delay

SourceMeter I-Range	Auto Delay
1pA	1sec
10pA	350msec
100pA	50msec
1nA	35msec
10nA	10msec
100nA	6msec
1µA	5msec
10µA	5msec
100µA	3msec
1mA	3msec
10mA	3msec
100mA	3msec

Manual delay can be set from 0000.00000 to 9999.99800 seconds. Manually setting the delay disables auto delay.

Front panel source delay

To set the manual source delay from the front panel:

1. Press CONFIG then SOURCE V (or SOURCE I).
2. Select DELAY from the displayed choices, then press ENTER.
3. Enter the desired DELAY value, then press ENTER.
4. Press EXIT to return to normal display.

To set the auto source delay state from the front panel:

1. Press CONFIG then SOURCE V (or SOURCE I).
2. Select AUTO DELAY from the displayed choices, then press ENTER.
3. Select ENABLE or DISABLE as desired, then press ENTER.
4. Press EXIT to return to normal display.

Remote command source delay

Use the :SOURce:DELay or :SOURce:DELay:AUTO commands to program the source delay via remote. See Section 17 for details. For example, the following command sets the source delay to 500ms:

:SOUR:DEL 0.5

Similarly, send the following command to enable auto delay:

:SOUR:DEL:AUTO ON

Basic source-measure procedure

Output control

Use the ON/OFF OUTPUT key to turn the SourceMeter output on or off for basic source-measure situations. With the output on, the red ON/OFF OUTPUT indicator light will be on. The indicator light turns off when the output is turned off.

You can also control the output off state (normal, zero, or guard) and program the instrument for auto output off operation. See Section 12 for complete details on these aspects.

WARNING **To prevent electric shock, do not make or break connections to the SourceMeter while it is on.**

Current measurements and capacitive loads

When measuring current in a test circuit that has high capacitance, ringing may occur. Ringing is the fluctuation of current readings that is initiated by a voltage step. This fluctuation eventually decays to a settled current reading. The higher the capacitance, the more ringing that will occur.

Table 3-5 lists the maximum capacitive loads that the Model 6430 can accommodate effectively. For the higher current ranges (1nA range and higher), the listed values represent the largest capacitance in which ringing created by a voltage step will decay in less than one power line cycle. For the lower current ranges (100pA and lower), the listed values represent the largest capacitance that causes ringing that will settle in a reasonable amount of time.

Current measurements can be performed for higher capacitive loads as long as the increased ringing can be tolerated. Ringing can be reduced by adding a resistor in a series with the load at the expense of longer settling times. See *Source capacitance* in Appendix F for more information.

Table 3-5
Maximum capacitive loads

Current range	Maximum Capacitive Load
100mA	0.2µF
10mA	0.2µF
1mA	0.2µF
100µA	0.04µF
10µA	3300pF
1µA	470pF
100nA	100pF
10nA	100pF
1nA	100pF
100pA	100pF
10pA	100pF
1pA	100pF

Front panel source-measure procedure

Refer to Section 4 to measure ohms.

NOTE The following procedure assumes that the SourceMeter is already connected to the DUT as explained in Section 2.

Step 1: Select source.

Press SOURCE V to select the V-Source or press SOURCE I to select the I-Source. The presently programmed source value (V_{SRC} or I_{SRC}) and compliance level (Cmpl) are displayed.

Step 2: Set source level and compliance limit.

The source level is the voltage or current setting of the selected source (V-Source or I-Source). A compliance limit is set to protect the DUT from damaging currents or voltages. When using the V-Source, a current compliance is set. When using the I-Source, a voltage compliance is set. Compliance defines the maximum absolute value the SourceMeter can output.

Note that compliance can also be determined by the measurement range. Depending on which value is lower, compliance occurs at the programmed value (real compliance) or at the maximum compliance value for the present fixed measurement range (range compliance). For example, with compliance set to 2V and the 200mV measurement range selected, compliance will occur at 210mV. On the 20V measurement range, compliance will occur at 2V. See Section 5, *Compliance limit* for details on real and range compliance.

NOTE The SourceMeter must be in the edit mode (EDIT annunciator ON) to set source and compliance values. The edit mode is selected by pressing the EDIT key. The flashing digit for the source or compliance reading indicates that the SourceMeter is in the edit mode. If no editing operation is performed within six seconds, the edit mode times out and is cancelled. To return to the edit mode, press EDIT again. While in the edit mode, the EDIT key toggles between the source value and the compliance value.

The SOURCE ▲ and ▼ and ◄ and ► keys also enable the edit mode. They choose the last selected field.

When editing the source value, the source is updated immediately, allowing you to adjust the source value while the output is on.

The source value cannot be changed while the SourceMeter is performing a sweep. This occurs with Output ON and either the SWEEP key is pressed, Offset Compensation is enabled under Ohms, or OFF-COMP-OHMS, VOLT-COEFF, or VAR-ALPHA functions are enabled.

When editing the compliance value, compliance is not updated until ENTER is pressed or the edit mode is allowed to time out.

EDIT always goes to the source field first, except while sweeping, in which case it goes into the compliance field.

Source and compliance values cannot be edited in AUTO OHMS mode.

Perform the following steps to edit the source and compliance values:

1. Press EDIT to enter the edit mode. The flashing digit indicates which reading (source or compliance) is presently selected for editing. If you wish to edit the other field, press EDIT again.
2. Use the RANGE ▲ and ▼ keys to select a range that will accommodate the value you want to set. For best accuracy, use the lowest possible source range.
3. Enter the desired source or compliance value. There are two methods to edit the value: value adjust and numeric entry.

NOTE *To clear the source value to 0V or 0A, press the MENU key while in the edit source field.*

- **Value adjust** — To adjust the value, use the EDIT cursor keys to place the cursor at the appropriate position, and use the SOURCE ▲ and ▼ keys to increment or decrement the value.
- **Numeric entry** — When the edit mode is entered, the cursor is located on the most significant digit of the value. From this position, you can key in the value using the number keys (0 through 9). After each number is keyed in, the cursor moves one position to the right. If desired, you can use the EDIT cursor keys to place the cursor on a digit to be changed, and press the appropriate number key. The cursor does not have to be on the polarity sign of the value to change polarity. If the MENU key is pressed, the Source Value will be clear to 0V or 0A.

4. To edit the other field, press EDIT to select it, and repeat steps 1 and 2.
5. When finished editing the source and compliance values, press ENTER or wait six seconds to exit from the edit mode.

NOTE *When a compliance limit value is entered, the SourceMeter automatically goes to the lowest (most sensitive) compliance range that will accommodate that value.*

The lowest compliance levels that can be set are 0.00100pA (1fA) and 000.200mV (200µV).

Step 3: Select measurement function and range.

Select the desired measurement function by pressing MEAS V (voltage) or MEAS I (current).

When measuring the source (i.e., Source V Measure V), you cannot select the range using the measurement RANGE keys. The selected source range determines the measurement range.

When not measuring the source (i.e., Source V Measure I), measurement range selection can be done manually or automatically. When using manual ranging, use the lowest possible range for best accuracy. In autorange, the SourceMeter automatically goes to the most sensitive range to make the measurement.

Measuring voltage — When sourcing current, you can use the RANGE ▲ and ▼ keys to manually select the voltage measurement range. You can also press AUTO to select autoranging. When sourcing voltage, the RANGE keys are inoperative.

Measuring current — When sourcing voltage, you can use the RANGE ▲ and ▼ keys to manually select the current measurement range. You can also press AUTO to select autoranging. When sourcing current, the RANGE keys are inoperative.

NOTE *With the 200V V-Source range selected, the highest current measurement range is 10mA. With the 100mA I-Source range selected, the highest voltage measurement range is 20V.*

Measurement range is also limited by the compliance setting. For example, if voltage compliance is 1V (2V compliance range), the highest voltage measurement range that can be selected is 2V.

Step 4: Turn output on.

Turn the output on by pressing the ON/OFF OUTPUT key. The OUTPUT indicator will turn on to indicate the output is on.

Step 5: Observe readings on the display.

The SourceMeter is in compliance if the “Cmpl” label or the units label (i.e. “mA”) for the displayed compliance setting is flashing. If the “Cmpl” label is flashing, real compliance has occurred. The output is clamped at the displayed compliance value. If the units label is flashing, range compliance has occurred. The output is clamped at the maximum compliance value for the present fixed measurement range. For example, if presently on the 2V measurement range, a flashing units label for the voltage compliance value indicates that the output is clamped at 2.1V.

The SourceMeter can be taken out of compliance by going into the edit mode and decreasing the source value or increasing the compliance value. Note that increasing the compliance limit may compromise protection for the DUT. If in range compliance, selecting a higher measurement range may take the SourceMeter out of compliance.

NOTE *See Section 5,“Compliance limit” for details on real and range compliance.*

Step 6: Turn output off.

When finished, turn the output off by pressing the ON/OFF OUTPUT key. The OUTPUT indicator light will turn off.

Remote command source-measure procedure

Basic source-measurement procedures can also be performed via remote by sending appropriate commands in the right sequence. The following paragraphs summarize the basic commands and give a simple programming example.

Basic source-measure commands

Table 3-6 summarizes basic source-measure commands. See Section 17 for more information on using these commands.

Table 3-6
Basic source-measure commands

Command	Description
:SOURce:FUNCtion <function>	Select source function (function = VOLTage or CURRent).
:SOURce:CURRent:MODE FIXed	Select fixed sourcing mode for I-source.
:SOURce:VOLTage:MODE FIXed	Select fixed sourcing mode for V-source.
:SOURce:CURRent:RANGe <n>	Select I-source range (n = range).
:SOURce:VOLTage:RANGe <n>	Select V-source range (n = range).
:SOURce:CURRent:LEVel <n>	Set I-source amplitude (n = amplitude in amps).
:SOURce:VOLTage:LEVel <n>	Set V-source amplitude (n = amplitude in volts).
:SENSe:FUNCtion <function>	Select measure function (function = “VOLTage” or “CURRent”).
:SENSe:CURRent:PROTection <n>	Set current compliance (n = compliance).
:SENSe:VOLTage:PROTection <n>	Set voltage compliance (n = compliance).
:SENSe:CURRent:RANGe <n>	Set current measure range (n = range).
:SENSe:VOLTage:RANGe <n>	Set voltage measure range (n = range).
:OUTPut <state>	Select output state (state = ON or OFF)
:READ?	Trigger and acquire reading.

Source-measure programming example

Table 3-7 summarizes the command sequence for a basic source-measure procedure. Note that the steps correspond to those listed previously in *Front panel source-measure procedure*. These commands set up the SourceMeter as follows:

- Source function: volts
- Source mode: fixed
- Source range: 20V
- Source output level: 10V
- Current compliance: 10mA
- Measure function: current
- Measure range: 10mA

Table 3-7
Basic source-measure command sequence

Step[1]	Action	Commands[2,3]	Comments
		*RST	Restore GPIB defaults.
1	Select source function, mode.	:SOUR:FUNC VOLT :SOUR:VOLT:MODE FIXED	Select voltage source. Fixed voltage source mode.
2	Set source range, level, compliance.	:SOUR:VOLT:RANG 20 :SOUR:VOLT:LEV 10 :SENS:CURR:PROT 10E-3	Select 20V source range. Source output = 10V. 10mA compliance.
3	Set measure function, range.	:SENS:FUNC “CURR” :SENS:CURR:RANG 10E-3	Current measure function. 10mA measure range.
4	Turn on output.	:OUTP ON	Output on before measuring.
5	Read data.	:READ?	Trigger, acquire reading.
6	Turn off output.	:OUTP OFF	

[1]Steps correspond to front panel steps listed previously in *Front panel source-measure procedure*.
[2]Commands must be sent in order given.
[3]Instrument must be addressed to talk after :READ? to acquire data.

Measure only

Front panel measure only

In addition to being used for conventional source-measure operations, the SourceMeter can also be used to measure only voltage or current. Perform the following steps to use the SourceMeter to measure voltage or current:

1. Select source-measure functions.

   Measure voltage only (voltmeter) — Press SOURCE I to select the I-Source, and press MEAS V to select the voltage measurement function.

   Measure current only (ammeter) — Press SOURCE V to select the V-Source, and press MEAS I to select the current measurement function.
2. Set source and compliance levels.

   Use the editing procedure provided in step 2 of *Basic source-measure procedure* to edit the source and compliance levels as follows:

   a. Select the lowest source range and set the source level to zero (0.00000pA or 000.000mV).

   b. Set compliance to a level that is higher than the expected measurement.

CAUTION **When using the SourceMeter as a voltmeter, V-Compliance must be set higher than the voltage that is being measured. Failure to do this could result in instrument damage due to excessive current that will flow into the SourceMeter.**

3. Select range.

   Use the RANGE ▲ and ▼ keys to select a fixed measurement range that will accommodate the expected reading. Use the lowest possible range for best accuracy.

   When measuring current, AUTO range can be used instead. The SourceMeter will automatically go to the most sensitive range. When measuring voltage, DO NOT use AUTO range. See the following CAUTION.

CAUTION **When using the SourceMeter as a voltmeter only, DO NOT use AUTO range and NEVER select a measurement range that is below the applied signal level. For these conditions, high current will be drawn from the external source. This high current could damage the external source or test circuit.**

4. Connect voltage or current to be measured. Connect the DUT to the SourceMeter using 2-wire connections. See Figure 2-2.
5. Turn output on. Press the ON/OFF key to turn the output on.
6. Take a reading from the display.
7. When finished, turn output off.

Remote command measure only

Table 3-8 summarizes the basic command sequence for measure only. The steps outlined correspond to those in the *Front panel measure only* sequence above. These commands set up the SourceMeter for measure only voltage measurements up to 20V as follows:

- Measure function: volts
- Source function: current
- Source mode: fixed
- Source range: minimum
- Source value: 0mA
- Measure range: 20V
- Compliance 25V

Table 3-8
Measure only programming example

Step[1]	Action	Commands[2,3]	Comments
		*RST	Restore GPIB defaults.
1	Select measure, source functions.	:SOUR:FUNC CURR	Current source function.
		:SOUR:CURR:MODE FIXED	Fixed current source mode.
		:SENS:FUNC “VOLT”	Volts measure function.
2	Set source and compliance.	:SOUR:CURR:RANG MIN	Lowest source range.
		:SOUR:CURR:LEV 0	0µA source level.
		:SENS:VOLT:PROT 25	25V compliance.
3	Select volts measure range.	:SENS:VOLT:RANG 20	20V range.
5	Turn on output.	:OUTP ON	Output on before measuring.
6	Read data.	:READ?	Trigger, acquire reading.
7	Turn off output.	:OUTP OFF	Output off after measuring.

[1]Steps correspond to front panel steps listed previously in *Front panel measure only*. DUT should be connected to SourceMeter before running program.

[2]Commands must be sent in order given.

[3]Instrument must be addressed to talk after :READ? to acquire data.

Sink operation

Overview

When operating as a sink (V and I have opposite polarity), the SourceMeter is dissipating power rather than sourcing it. An external source (i.e., battery) or an energy storage device (i.e., capacitor) can force operation into the sink region.

For example, if a 12V battery is connected to the V-Source (In/Out HI to battery high) that is programmed for +10V, sink operation will occur in the second quadrant (Source +V and measure -I).

CAUTION **When using the I-Source as a sink, ALWAYS set V-Compliance to a level that is higher than the external voltage level. Failure to do so could damage the instrument due to excessive current that will flow into the SourceMeter.**

NOTE *The sink operating limits are shown in Section 5, "Operating boundaries."*

Sink programming example

Table 3-9 lists a command sequence to program the SourceMeter for sink operation. These commands set up the unit as follows:

- Source function: volts
- Measure function: current
- Source voltage: 0V
- Measure range: auto
- Compliance (discharge current): 100mA

Table 3-9
Sink programming example

Command	Description
*RST	Restore GPIB defaults.
:SOUR:FUNC VOLT	V-source function.
:SOUR:VOLT:MODE FIXED	Fixed source mode.
:SENS:FUNC "CURR"	Current measure function.
:SENS:CURR:RANG:AUTO ON	Auto measure range.
:SENS:CURR:PROT 100E-3	100mA compliance (discharge current).
:OUTP ON	Turn on output.
:READ?	Trigger and acquire reading.

4
Ohms Measurements

- **Ohms Configuration Menu** — Outlines the ohms configuration menu that allows you to set up various ohms measurement aspects.
- **Ohms Measurement Methods** — Discusses auto and manual ohms measurement methods and how to select them.
- **Ohms Sensing** — Covers 2-wire and 4-wire ohms sensing.
- **Offset-compensated ohms** — Describes offset-compensated ohms, which can be used to overcome the effects of offsets when making low-resistance measurements.
- **Ohms Source Readback** — Covers enabling and disabling ohms source readback.
- **6-wire Ohms Measurements** — Describes the basic procedure for setting up the SourceMeter for 6-wire ohms measurement, which can be used for measuring resistor networks and hybrid circuits.
- **Remote Ohms Programming** — Summarizes the basic remote commands required to program the SourceMeter for ohms measurements and gives several typical programming examples.

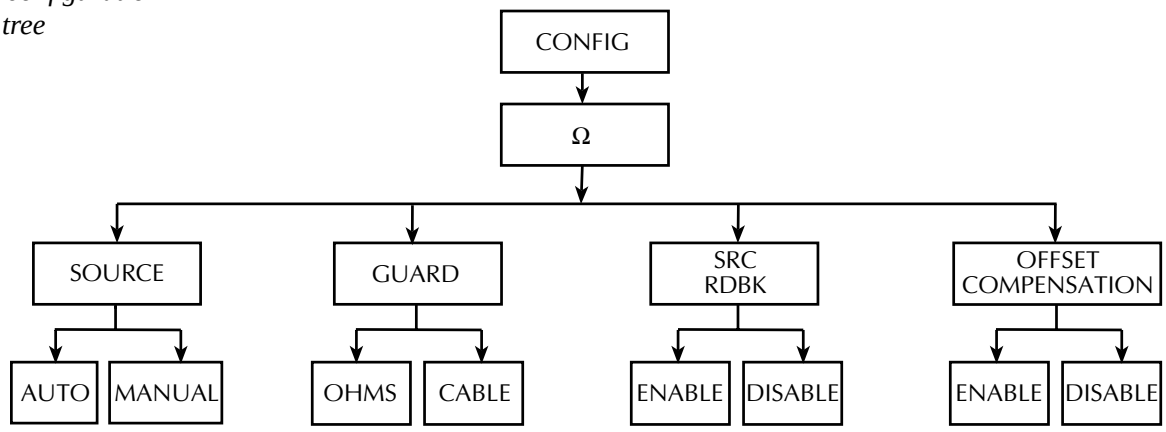
Ohms configuration menu

Press CONFIG then Ω to access the ohms configuration menu. Use the *Rules to navigate menus* in Section 1 to select the various items in the menu tree, which is shown in Figure 4-1. Menu items include:

- **SOURCE** — Select AUTO or MANUAL source mode.
- **GUARD** — Choose OHMS or CABLE guard.
- **SRC RDBK** — Enable or disable source readback mode.
- **OFFSET COMPENSATION** — Enable or disable offset-compensated ohms.

The following paragraphs discuss each of these aspects in detail.

Figure 4-1
Ohms configuration menu tree



Ohms measurement methods

There are two methods to measure ohms: auto ohms and manual ohms. When using auto ohms, the SourceMeter operates as a conventional constant current source ohmmeter. To use this method, simply select an ohms measurement range (or use autorange), and take the reading from the display. When using auto ohms, the default test current varies with the ohms range, as summarized in Table 4-1.

NOTE *You cannot change the test current in the auto ohms mode. If you attempt to change the source current in auto ohms, the SourceMeter will display an error message.*

With the manual ohms mode you can select either source V or source I to make ohms measurements, and the unit will automatically compute the resistance reading using the V/I measurement method. After configuring the desired source and selecting a voltage or current measuring range, select the Ω measurement method to display the calculated V/I ohms reading.

NOTE *To achieve optimum accuracy, the SourceMeter measures both V and I and uses these values in ohms calculations (with source readback enabled). The measured source value is more accurate than the programmed source value. For remote operation, the user specifies the functions to measure. See the resistance measurement accuracy specifications in Appendix A for more information.*

Table 4-1
Auto ohms default test currents

Auto ohms range*	Default test current
20Ω	100mA
200Ω	10mA
2kΩ	1mA
20kΩ	100mA
200kΩ	10mA
2MΩ	1mA
20MΩ	1mA
200MΩ	100nA
2GΩ	10nA
20GΩ	1nA
200GΩ	100pA
2TΩ	10pA
20TΩ	1pA

*200MΩ maximum without PreAmp

Selecting ohms measurement method

On power-up, auto ohms is the default method for the ohms function. Perform the following steps to check and/or change the ohms measurement method:

1. Press CONFIG and then Ω to display the ohms configuration menu.
2. Using left and right arrow EDIT keys, place the cursor (flashing menu item) on SOURCE and press ENTER.

NOTE *Cursor position indicates the presently selected ohms measurement method. To retain this selection, use the EXIT key to back out of the menu structure and skip the next two steps.*

3. To change the measurement method, place the cursor on the alternate selection (AUTO or MANUAL), and press ENTER.
4. Press EXIT to exit from the menu structure.

Auto ohms measurements

Perform the following steps to perform auto ohms measurements.

NOTE *The following procedure assumes that the SourceMeter is already connected to the DUT as explained in Section 2.*

WARNING **To prevent electric shock, do not make or break connections to the SourceMeter with the output on. If on, press the ON/OFF OUTPUT key to turn the output off.**

1. Select ohms measurement function.
   Press MEAS Ω to select the ohms measurement function.
2. Select auto ohms measurement method.
   - Press CONFIG then Ω.
   - Select SOURCE, then press ENTER.
   - Select AUTO, then press ENTER.
   - Press EXIT to return to normal display.

   Note that the SourceMeter will be configured to Source I and Measure V. Also, the I-Source level and V-Compliance limit are based on the measurement range and cannot be edited.

NOTE *Use the manual ohms mode and the V-source method when high-speed settling is required.*

3. Select measurement range.

   Use the RANGE ▲ and ▼ keys to select a range appropriate for the expected ohms reading, or use autorange by pressing AUTO. When using manual ranging, selecting the most sensitive (lowest) range provides the best accuracy. Autorange automatically goes to the most sensitive range.
4. Turn output on.

   Turn the output on by pressing the ON/OFF OUTPUT key. The OUTPUT indicator will turn on to indicate the output is on.
5. Observe reading on display.

   The SourceMeter will go into compliance if you exceed the maximum ohms measurement range.
6. Turn output off.

   When finished, turn the output off by pressing the ON/OFF OUTPUT key. The OUTPUT indicator light will turn off.

Manual ohms measurements

Perform the following steps to perform manual ohms measurements.

NOTE *The following procedure assumes that the SourceMeter is already connected to the DUT as explained in Section 2.*

WARNING **To prevent electric shock, do not make or break connections to the SourceMeter with the output on. If on, press the ON/OFF OUTPUT key to turn the output off.**

1. Select ohms measurement function.

   Press MEAS Ω to select the ohms measurement function.
2. Select manual ohms measurement method.
   - Press CONFIG then Ω.
   - Select SOURCE, then press ENTER.
   - Select MANUAL, then press ENTER.
   - Press EXIT to return to normal display.
3. Configure source.

   For manual ohms, you can Source I or Source V at the user-programmed output level. The lowest allowable compliance limit is based on the load and the source value. For example, if sourcing 1V to a 1kΩ resistor, the lowest allowable current compliance is 1mA (1V/1kΩ = 1mA). Setting a limit lower than 1mA will place the source in compliance. Refer to steps 1 and 2 of Section 3, *Basic source-measure procedure* to configure the source.

NOTE *Use the V-Source for manual ohms measurements when high-speed settling is required (i.e., production testing).*

4. Select measurement range.

   Using the RANGE ▲ and ▼ keys, select the lowest possible fixed range or use AUTO range. Note that if sourcing current, you will be setting the voltage measurement range. Conversely, if sourcing voltage, you will be setting the current measurement range. The most sensitive measurement range provides the best accuracy.

NOTE *Measurement range is limited by the compliance setting. For example, if the voltage compliance is 1V, (2V compliance range), the highest voltage measurement range that can be selected is 2V.*

5. Turn output on.

   Turn the output on by pressing the ON/OFF OUTPUT key. The OUTPUT indicator will turn on to indicate the output is on.

6. Observe reading on display.

   The SourceMeter is in compliance if the Cmpl label or the units label (i.e. “mA”) for the displayed compliance setting is flashing. If the Cmpl label is flashing, real compliance has occurred. The output is clamped at the displayed compliance value. If the units label is flashing, range compliance has occurred. The output is clamped at the maximum compliance value for the present fixed measurement range. For example, if presently on the 2V measurement range, a flashing units label for the voltage compliance reading indicates that the output is clamped at 2.1V.

   The SourceMeter can be taken out of compliance (real or range) by going into the edit mode and decreasing the source value or increasing the compliance value. Note that increasing the compliance limit may compromise protection for the DUT. If in range compliance, selecting a higher measurement range may take the SourceMeter out of compliance.

NOTE *See Section 5, “Compliance limit” for details on real and range compliance.*

7. Turn output off.

   When finished, turn the output off by pressing the ON/OFF OUTPUT key. The OUTPUT indicator light will turn off.

Ohms sensing

Ohms measurements can be made using either 2-wire or 4-wire sensing. See Section 2 for details on sensing. Note that resistance measurement accuracy specifications are based on using 4-wire sensing.

Offset-compensated ohms

The presence of thermal EMFs (V_{EMF}) can adversely affect low-resistance measurement accuracy. To overcome these unwanted offset voltages, use the offset-compensated ohms measurement method.

In general, this method measures resistance (V/I) at a specific source level and then subtracts a resistance measurement made with the source set to zero. With the source set to zero, the source level is V_{EMF}. Thus, the resistance contributed by the presence of V_{EMF} is eliminated.

This two-point measurement method is mathematically expressed as:

Offset-Compensated $\Omega = \Delta V / \Delta I$ where $\Delta V = V2 - V1$ and $\Delta I = I2 - I1$.
V1 is the voltage measurement with the source set to a specific level.
V2 is the voltage measurement with the source set to zero.
I1 is the current measurement with the source set to a specific level.
I2 is the current measurement with the source set to zero.

For auto ohms, the SourceMeter will select the appropriate current source level and voltage measurement range. For manual ohms, first select the appropriate source (V or I) value while the output is off. When the source is turned on, the output will cycle between the programmed value and zero (0A or 0V) to derive the offset-compensated ohms measurement.

NOTE *Manual offset-compensated ohms is also available as a math (FCTN) operation. This math function allows you to specify both source values. For details, see Section 7, "Offset-compensated Ω."*

Measuring high resistance devices

When using offset-compensated ohms to measure high resistance values, an appropriate source delay must be used to provide settled readings. There is a rise time associated with high ohms measurements. For normal ohms measurements, you can watch the reading change on the display. When it stops changing, you know you have the final, settled reading. For offset-compensated ohms, this process is not as straight forward since the source is constantly changing between two values. If measurements are performed while the source is still rising (or falling), incorrect offset-compensated ohms readings will result. Therefore, it is imperative that an adequate source delay be used to make sure that measurements occur while the source is at its final, settled values.

Settling times are drastically different from one type of resistor to another. Another factor that affects settling time is the test setup (i.e., cabling, fixturing, and guarding). These variables make it necessary for the user to characterize his test system to assure that the source delay is adequate.

NOTE *Source delay is set from the source configuration menu (press CONFIG > select SOURCE I (or V) > select DELAY). See "Source delay" in Section 3 for details.*

Enabling/disabling offset-compensated ohms

Offset-compensated ohms is enabled or disabled from the OFFSET COMPENSATION option of the CONFIG OHMS menu as follows:

1. Press CONFIG and then Ω to display the ohms configuration menu.
2. Place the cursor on OFFSET COMPENSATION, and press ENTER.
3. Place the cursor over ON (to enable compensation) or OFF (to disable compensation), and press ENTER.
4. Use the EXIT key to exit the menu structure.

Offset-compensated ohms procedure

NOTE *The following procedure assumes that the desired ohms measurement method (auto or manual) is already selected and the SourceMeter is connected to the DUT as explained in Section 2. Refer to "Selecting ohms measurement method" to check or change the measurement method.*

1. Turn the output off and select the Ω measurement function.
2. If measuring high resistance, set an adequate source delay (see *Measuring high resistance devices*). Source delay is set from the source configuration menu (press CONFIG > select SOURCE I (or V) > select DELAY). See Section 3, *Source delay* for details.
3. Enable offset compensation as previously explained in *Enabling/disabling offset-compensated ohms*.

NOTE *If using the auto ohms measurement method, go to step 5.*

4. For manual ohms measurements, configure the desired source (V or I) to output the appropriate source level. Set compliance and select a measurement range (or use AUTO range). See steps 1, 2, and 3 of Section 3, *Basic source-measure procedure* for details.
5. Turn the output on, and observe the offset-compensated ohms reading on the display. Note that the source alternates between the programmed output value and zero.

NOTE *When the output is turned off, the displayed source value may be zero (0V or 0A). It will usually be the previously programmed value in Manual Ohms mode. However, the programmed source value is remembered and used when the output is turned back on. If a new source value is programmed, the SourceMeter uses the new source value when the output is turned back on. The source value cannot be changed while the output is on. If a global setup or source memory location is saved, the previously programmed source value will always be stored.*

6. When finished, turn the output off, and disable offset-compensated ohms.

Ohms source readback

With ohms source readback enabled, the instrument measures the actual source value used for ohms measurements and then uses that measured value for reading calculations. Normally, ohms source readback should be left enabled for optimum measurement accuracy. However, disabling source readback will allow you to make valid ohms measurements with the source in compliance. Use the following procedure to enable or disable ohms source readback:

1. Press CONFIG then Ω.
2. Select SRC RDBK, then press ENTER.
3. Select DISABLE or ENABLE as desired, then press ENTER.
4. Press EXIT to return to normal display.

NOTE *Readings in the compliance field will be invalid with source readback disabled.*

6-wire ohms measurements

The 6-wire ohms measurement configuration allows you to make accurate resistance measurements on resistor networks and hybrid devices in cases where internal resistance connection nodes are not accessible. The combination of 4-wire Kelvin connections and guarded ohms features eliminates the effects of internal parallel resistances that could degrade measurement accuracy and reduce measurement speed. The basic procedure for setting up the SourceMeter for 6-wire ohms measurements is covered below.

NOTE *See Figure 2-7 for 6-wire ohms connections. See also Section 2, "Ohms guard" and Section 5, "Guard" for more information. Keep in mind that ohms guard is only available at the rear panel of the mainframe.*

1. Press CONFIG then Ω to display the CONFIG OHMS menu.
2. Select GUARD, then press ENTER.
3. Select OHMS, then press ENTER.
4. Press EXIT to return to normal display.
5. Press MEAS then Ω to select the ohms measurement function.
6. Select the appropriate measurement range, or use autoranging if desired.
7. Turn on the output by pressing the ON/OFF OUTPUT key.
8. Take readings from the display.
9. Turn the output off when done by pressing the ON/OFF OUTPUT key.

Remote ohms programming

The following paragraphs summarize those basic command necessary for remote ohms programming and also give a programming example for a typical ohms measurement situation.

Remote ohms commands

Table 4-2 summarizes the remote commands for making basic ohms measurements. See Section 17 for more details on these commands.

Table 4-2
Remote commands for basic ohms measurements

Command	Description
:SENSe:FUNCtion “RESistance”	Select ohms function.
:SENSe:RESistance:RANGe <n>	Select ohms range (n = range).
:SENSe:RESistance:MODE <name>	Select ohms mode (name = MANual or AUTO).
:SENSe:RESistance:OCOMpensated <state>	Enable/disable offset compensation (state = ON or OFF).
:OUTPut <state>	Turn output on or off (state = ON or OFF).
:READ?	Trigger and acquire reading.

Ohms programming example

Table 4-3 summarizes the command sequence for a typical ohms measurement. These commands set up the SourceMeter as follows:

- Ohms mode and range: auto, 20kΩ
- Offset compensation: off

Table 4-3
Commands for ohms programming example

Command*	Description
*RST	Restore GPIB defaults.
FUNC “RES”	Select ohms measurement function.
RES:RANG 20E3	Choose 20kΩ range.
RES:MODE AUTO	Auto ohms mode.
:OUTP ON	Turn on output.
:READ?	Trigger and acquire reading.
:OUTP OFF	Turn off output.

* Send commands in order given. Instrument must be addressed to talk after :READ?

5
Source-Measure Concepts

- **Compliance Limit** — Discusses compliance limit including real and range compliances, maximum compliance values, and how to determine compliance limit.
- **Overheating Protection** — Explains how to keep the SourceMeter from overheating.
- **Source-Delay-Measure Cycle** — Describes the various phases of the source-delay-measure cycle as well as sweep waveforms.
- **Operating Boundaries** — Covers voltage and current operating boundaries for source and sink operation, I-source and V-source, and source-measure modes.
- **Basic Circuit Configurations** — Covers basic circuit configurations for source I, source V, and measure only operating modes.
- **Guard** — Covers cable guard, ohms guard, and guard sense.
- **Data Flow** — Describes measurement readings, math, rel, and limits operation, and how data is stored in the buffer.

Compliance limit

When sourcing voltage, the SourceMeter can be set to limit current (from 1fA to 105mA). Conversely, when sourcing current, the SourceMeter can be set to limit voltage (from 200µV to 210V). The SourceMeter output will not exceed the compliance limit.

NOTE *For the following discussion, "measurement range" refers to the measurement function that is the opposite of the source function. When sourcing voltage, the current measurement range is the point of discussion. Conversely, when sourcing current, the voltage measurement range is the point of discussion.*

Types of compliance

There are two types of compliance: "real" and "range." Depending upon which value is lower, the output will clamp at either the displayed compliance setting (real compliance) or at the maximum possible compliance value for the fixed measurement range (range compliance). This clamping action effectively limits the power that can be delivered to the device. When the SourceMeter is acting as a current source, the voltage is clamped at the compliance value; conversely, the current is clamped at the compliance value when the SourceMeter is acting as a voltage source. Note that range compliance cannot occur if the AUTO measurement range is selected. Thus, to avoid range compliance, use AUTO range.

When in real compliance, the source clamps at the displayed compliance value. For example, if the compliance voltage is set to 1V and the measurement range is 2V, output voltage will clamp at 1V. In this case, the "CMPL" annunciator will flash.

When in range compliance, the source output clamps at the maximum compliance value for the fixed measurement range (not the compliance value). For example, if compliance is set to 1V and the measurement range is 200mV, output voltage will clamp at 210mV. In this situation, the units in the compliance display field will flash. For example, with the following display: Vcmpl: 10mA, the "mA" units indication will flash.

Maximum compliance values

The maximum compliance values for the measurement ranges are summarized in Table 5-1.

Table 5-1
Maximum compliance values

Measurement range	Maximum compliance value
200mV	210mV
2V	2.1V
20V	21V
200V	210V
1pA*	1.05pA
10pA*	10.5pA
100pA*	105pA
1nA*	1.05nA
10nA*	10.5nA
100nA*	105nA
1µA	1.05µA
10µA	10.5µA
100µA	105µA
1mA	1.05mA
10mA	10.5mA
100mA	105mA

* Only available when using the Remote PreAmp.

Compliance examples

When the SourceMeter goes into real compliance, the “Cmpl” label for the compliance display will flash. When the SourceMeter goes into range compliance, the units label (“mA”) will instead flash. For the following examples, labels in boldface indicate that they are flashing.

Measurement Range:	100mA	
Compliance Setting:	**Cmpl**: 075.000 mA	Flashing “Cmpl” indicates that real compliance has occurred. The output is clamped at 75mA.
Measurement Range:	10mA	
Compliance Setting:	Cmpl: 075.000 **mA**	Flashing “mA” indicates that range compliance has occurred. The output is clamped at 10.5mA.

Compliance principles

Compliance acts as a clamp. If the output reaches the compliance value, the SourceMeter will attempt to prevent the output from exceeding that value. This action implies that the source will switch from a V-source to an I-source (or from an I-source to a V-source) when in compliance. The clamping value is determined either by a user-defined value (compliance setting) or the measurement range (range compliance) since the unit will not output more than it is configured to measure.

As an example, assume the following:

SourceMeter: V_{SRC} = 10V; I_{CMPL} = 10mA
DUT resistance: 1Ω

With a source voltage of 10V and a DUT resistance of 1Ω, the current through the DUT should be: 10V/1Ω = 10A. However, because the compliance is set to 10mA, the current will not exceed that value, and the voltage across the resistance is limited to 10mV. In effect, the 10V voltage source is transformed into a 10mA current source with a 10mV compliance value.

Determining compliance limit

The relationships to determine which compliance is in effect are summarized as follows:

- Compliance Setting < Measurement Range = Real Compliance
- Measurement Range < Compliance Setting = Range Compliance

The compliance that is in effect can be determined by comparing the displayed compliance setting to the present measurement range. Make sure the correct measurement function is displayed. If sourcing voltage, select the current measurement function. Conversely, if sourcing current, select the voltage measurement function.

If the compliance setting is lower than the maximum compliance value on the present fixed measurement range, then the compliance setting is the compliance limit. If the compliance setting is higher than the measurement range, then the maximum compliance value on that measurement range is the compliance limit.

Table 5-2 provides examples for determining the actual compliance limit. For the first three entries in the table, the compliance setting is 150V. On the 200V measurement range, the actual compliance is 150V (compliance setting < measure range = real compliance). On the 20V and 200mV measurement ranges, compliance is 21V and 210mV, respectively (measure range < compliance setting = range compliance). The same rules apply for the next three entries for current compliance.

Table 5-2
Compliance examples

Compliance setting		Measurement range		Actual compliance	
Display message	**Setting**	**Display message**	**Range**	**Value**	**Type**
Cmpl: 150.000 V	150V	---.---V	200V	150V	Real
Cmpl: 150.000 V	150V	--.----V	20V	21V	Range
Cmpl: 150.000 V	150V	---.---mV	200mV	210mV	Range
Cmpl: 075.000 mA	75mA	---.---mA	100mA	75mA	Real
Cmpl: 075.000 mA	75mA	--.---mA	10mA	10.5mA	Range
Cmpl: 075.000 mA	75mA	-.-----mA	1mA	1.05mA	Range

Over the bus, use the appropriate SCPI commands to determine the measurement range and the compliance setting. Once those parameters are known, compare them as previously explained to determine the compliance in effect.

When sourcing current, use the following commands to acquire the measurement range and the compliance setting:

VOLTage:RANGe?	Query voltage measurement range.
VOLTage:PROTection?	Query voltage compliance limit.

When sourcing voltage, use the following commands to acquire the measurement range and the compliance setting:

CURRent:RANGe?	Query current measurement range.
CURRent:PROTection?	Query current compliance limit.

Overheating protection

Proper ventilation is required to keep the SourceMeter from overheating. See the "CAUTION" located at the beginning of Section 3 for details on maintaining proper ventilation.

The SourceMeter has an over-temperature protection circuit that will turn the output off in the event that the instrument overheats. If the output trips due to overheating, a message indicating this condition will be displayed. You will not be able to turn the output back on until the instrument cools down.

Source-delay-measure cycle

In addition to static source and/or measure operation, SourceMeter operation can consist of a series of source-delay-measure (SDM) cycles (Figure 5-1). During each SDM cycle, the following occurs:

1. Set the source output level.
2. Wait for the delay.
3. Make the measurement.

Figure 5-1
Source-delay-measure (SDM) cycle

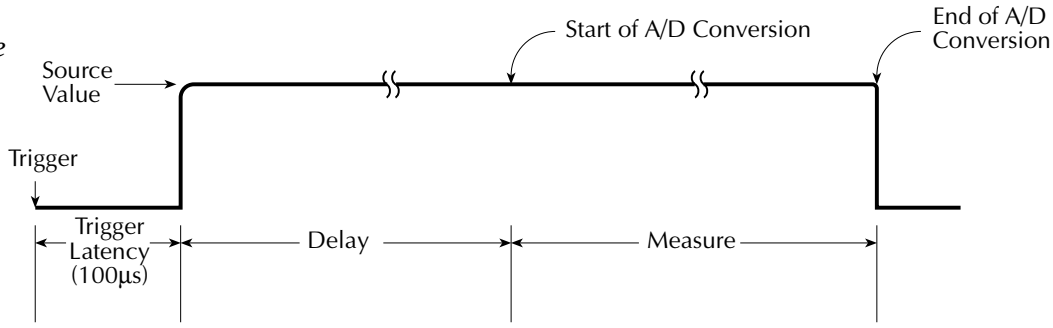


Figure 5-2 shows how the SDM cycle fits into the trigger model. See Section 10 for complete details on the trigger model. When the source is turned on (triggered), an approximate 100µsec trigger latency occurs before the programmed source level is output. As long as the source output stays on, trigger latency will not be included in subsequent SDM cycles. Trigger latency only occurs when the output makes the transition from off to on. See the specifications in Appendix A for definitions of trigger latency as well as other trigger specifications.

The delay phase of the SDM cycle allows the source to settle before the measurement is performed. The delay period depends on how the source delay is configured. The source delay can be manually set from 0000.00000 seconds to 9999.9990 seconds. If using auto delay, the delay depends on which source range is presently selected, as summarized in Table 3-4; see Section 3 for details.

The manually set delay (up to 9999.999 sec) is available to compensate for longer settling required by external circuitry. The more capacitance seen at the output, the more settling time is required for the source. The actual delay period needed can be calculated or determined by trial and error. For purely resistive loads and at higher current levels, the programmable delay can be set to 0msec.

The measure time depends on the selected measurement speed. For example, if speed is set at 0.01 PLC (power line cycles), the measure time would be 167µsec for 60Hz operation (0.01/60).

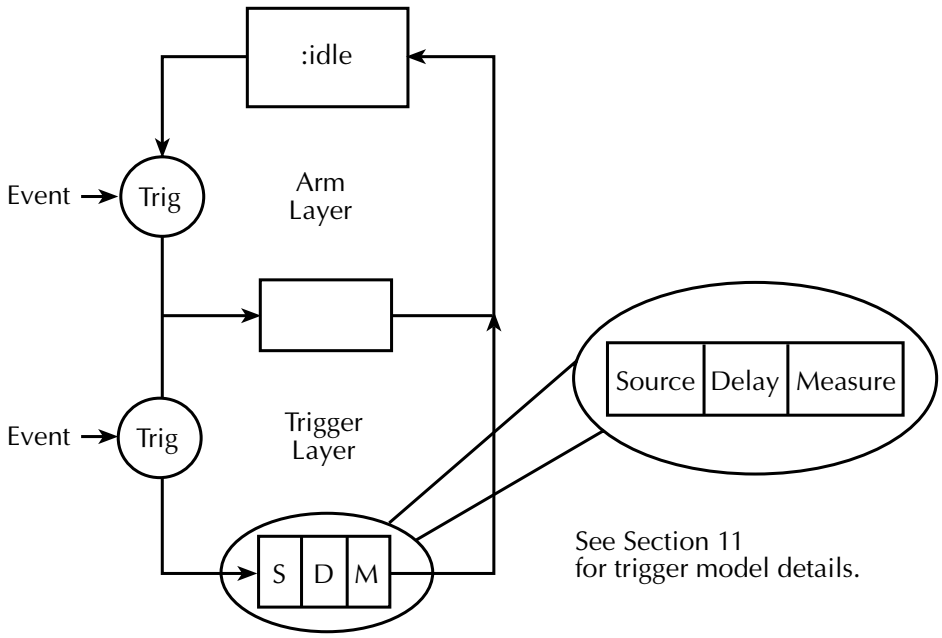
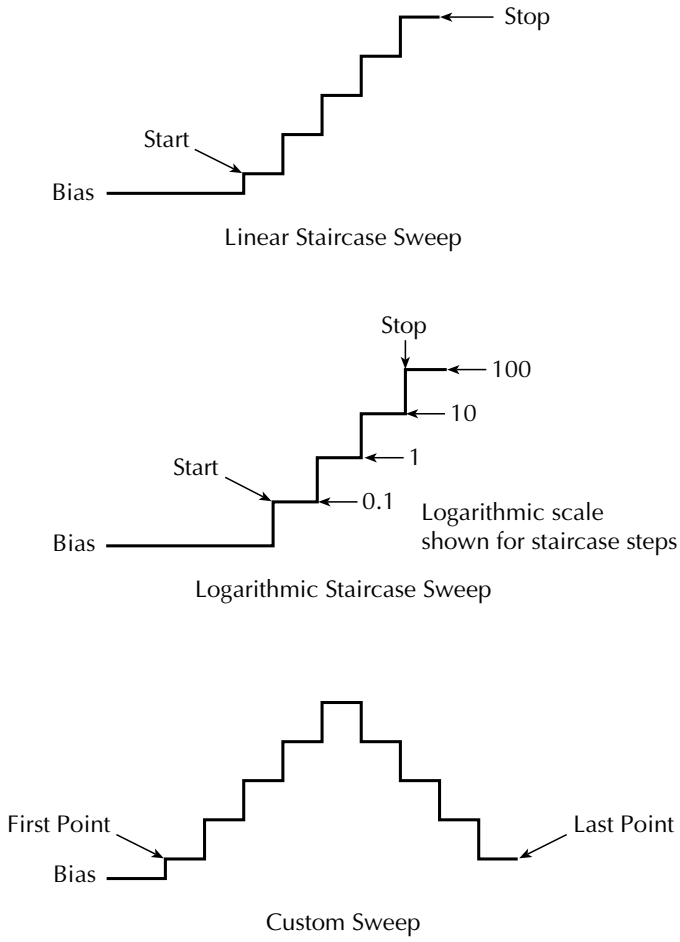


Figure 5-2
Simplified trigger model

Sweep waveforms

There are four basic sweep types to select from: linear staircase, logarithmic staircase, custom, and source memory. Three of the sweeps are shown in Figure 5-3. The linear staircase sweep goes from the start level to the stop level in equal linear steps. The logarithmic staircase sweep is similar except it is done on a log scale with a specified number of steps per decade. The custom sweep lets you construct your own sweep by specifying the number of measure points and the source level at each point. For a source memory sweep, up to 100 setup configurations can be saved in memory. When the sweep is performed, the setup at each memory point is recalled. See Section 9 for more details on sweep operation.

Figure 5-3
Three basic sweep waveform types



An SDM cycle is performed on each step (or point) of the sweep. Thus, one measurement will be performed at each step (level). The time spent at each step (level) depends on how the SDM cycle is configured (i.e., source delay, measure speed) and the trigger delay (if used).

Typical applications for staircase sweeps include: I-V curves for two- and three-terminal semiconductor devices, characterization of leakage versus voltage, and semiconductor breakdown. Pulse sweeps are used in applications where thermal response is measured or where sustained power levels can damage the external Device Under Test (DUT). Source memory sweeps are used in applications where multiple source-measure functions and/or math expressions are required.

The custom sweep can be used to configure a pulse sweep with a 50% duty cycle. For example, a 1V pulse sweep can be configured by programming the odd numbered points for 1V and the even numbered points for 0V. When the sweep is run, the output will alternate between 1V and 0V.

For a sweep that has a finite sweep count, the data will automatically be stored in the buffer. This data can be accessed from the front panel or sent to a computer (remote operation) for evaluation (plotting). Statistical information on readings stored in the buffer are also available from the front panel.

Operating boundaries

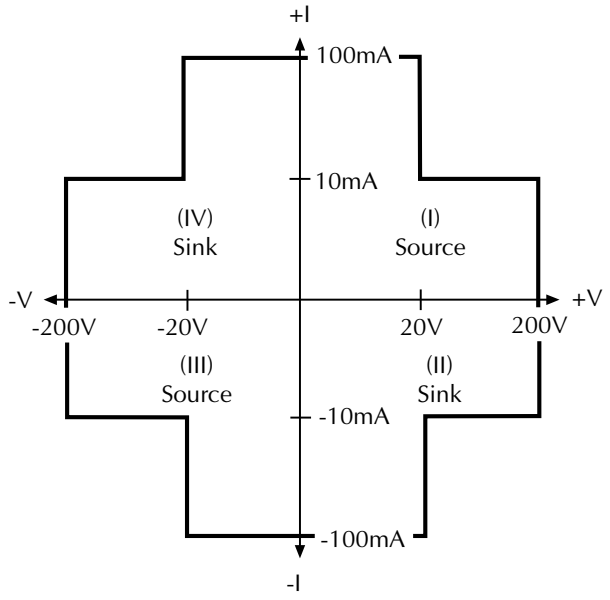
Source or sink

Depending on how it is programmed and what is connected to the output (load or source), the SourceMeter can operate in any of the four quadrants. The four quadrants of operation are shown in Figure 5-4. When operating in the first (I) or third (III) quadrant, the SourceMeter is operating as a source (V and I have the same polarity). As a source, the SourceMeter is delivering power to a load.

When operating in the second (II) or fourth (IV) quadrant, the SourceMeter is operating as a sink (V and I have opposite polarity). As a sink, it is dissipating power rather than sourcing it. An external source or an energy storage device, such as a capacitor or battery, can force operation in the sink region. See Section 3, *Sink operation* for more information.

The general operating boundaries for the SourceMeter are shown in Figure 5-4. In this drawing, the 100mA, 20V and 10mA, 200V magnitudes are nominal values. The actual maximum output magnitudes of the SourceMeter are 105mA, 21V and 10.5mA, 210V. Also note that the boundaries are not drawn to scale.

Figure 5-4
Operating boundaries



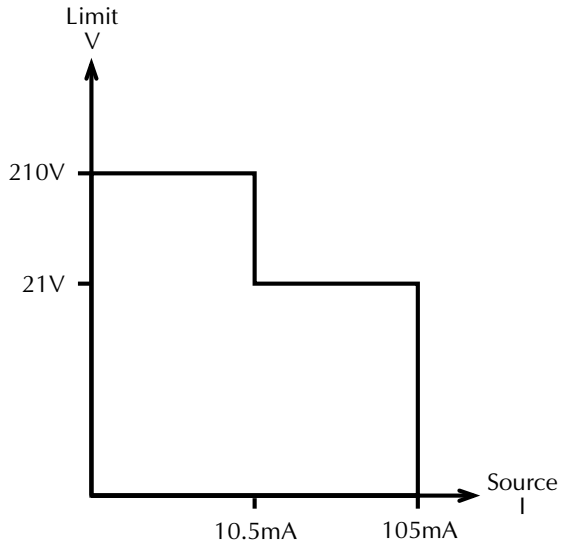
I -Source operating boundaries

Figure 5-5 shows the operating boundaries for the I-Source. Only the first quadrant of operation is covered. Operation in the other three quadrants is similar.

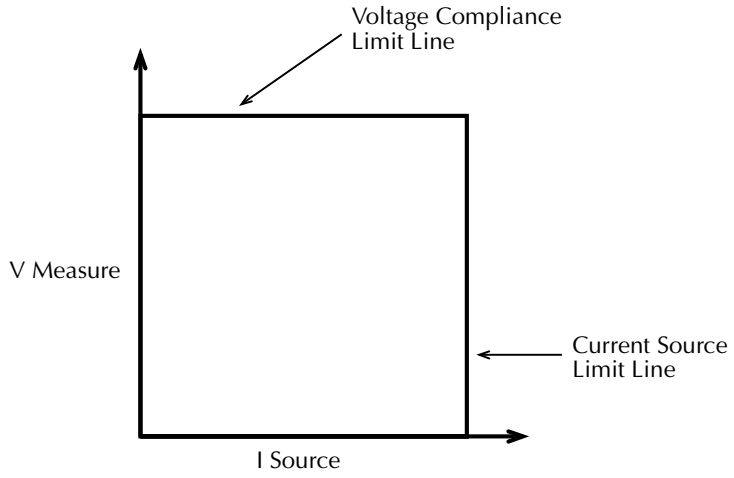
Figure 5-5A shows the output characteristics for the I-Source. As shown, the SourceMeter can output up to 10.5mA at 210V, or 105mA at 21V. Note that when sourcing more than10.5mA, voltage is limited to 21V.

Figure 5-5B shows the limit lines for the I-Source. The current source limit line represents the maximum source value possible for the presently selected current source range. For example, if on the 100mA current source range, the current source limit line is at 105mA. The voltage compliance limit line represents the actual compliance that is in effect. Remember that compliance can be real or range. See *Compliance limit.* These limit lines are boundaries that represent the operating limits of the SourceMeter for this quadrant of operation. The operating point can be anywhere inside (or on) these limit lines. The limit line boundaries for the other quadrants are similar.

Figure 5-5
I-Source boundaries



A) Output Characteristics



B) Limit Lines

Where within the boundaries the SourceMeter operates depends on the load (DUT) that is connected to its output. Figure 5-6 shows operation examples for resistive loads that are 50Ω and 200Ω, respectively. For these examples, the SourceMeter is programmed to source 100mA and limit 10V.

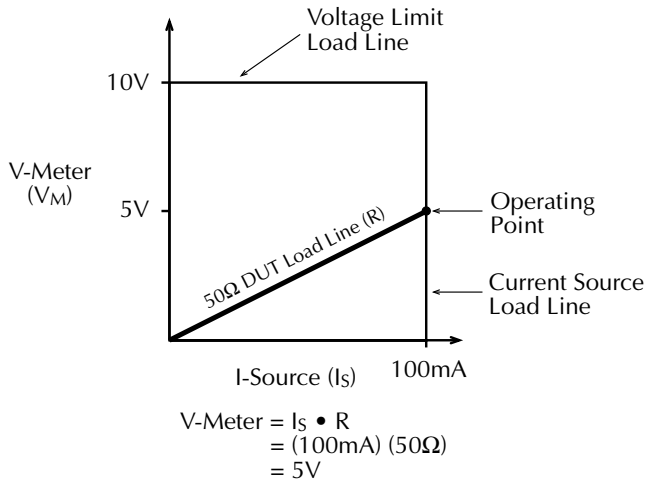
In Figure 5-6A, the SourceMeter is sourcing 100mA to the 50Ω load and subsequently measures 5V. As shown, the load line for 50Ω intersects the 100mA current source line at 5V.

Figure 5-6B shows what happens if the resistance of the load is increased to 200Ω. The DUT load line for 200Ω intersects the voltage compliance limit line placing the SourceMeter in compliance. In compliance, the SourceMeter will not be able to source its programmed current (100mA). For the 200Ω DUT, the SourceMeter will only output 50mA (at the 10V limit).

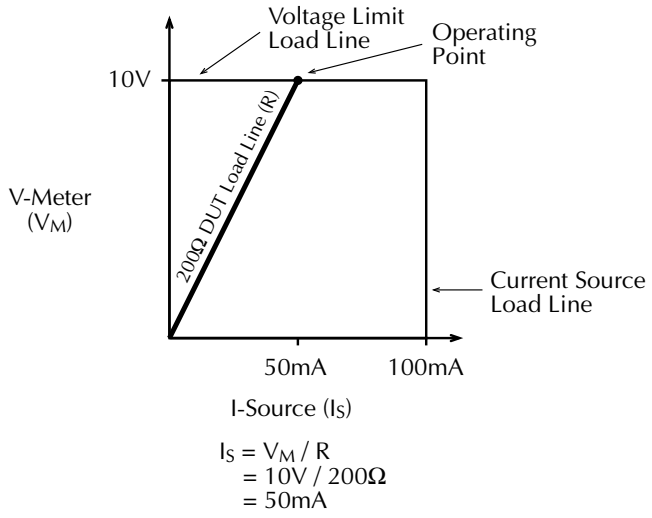
Notice that as resistance increases, the slope of the DUT load line increases. As resistance approaches infinity (open output), the SourceMeter will source virtually 0mA at 10V. Conversely, as resistance decreases, the slope of the DUT load line decreases. At zero resistance (shorted output), the SourceMeter will source 100mA at virtually 0V.

Regardless of the load, voltage will never exceed the programmed compliance of 10V.

Figure 5-6
I-Source operating boundaries



A) Normal I-source operation



B) I-source in compliance

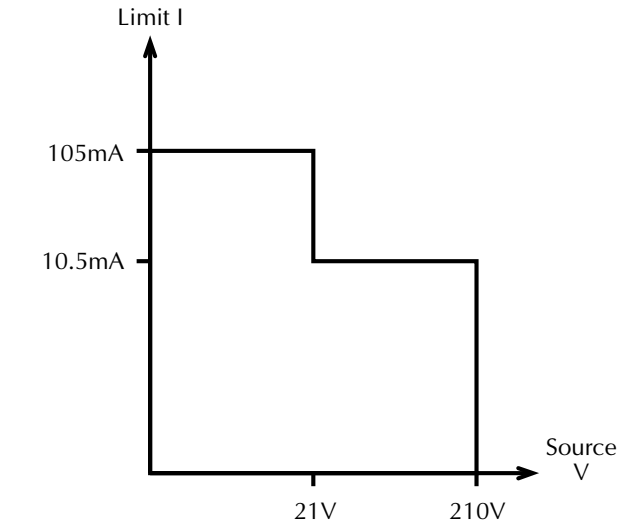
V-Source operating boundaries

Figure 5-7 shows the operating boundaries for the V-Source. Only the first quadrant of operation is covered. Operation in the other three quadrants is similar.

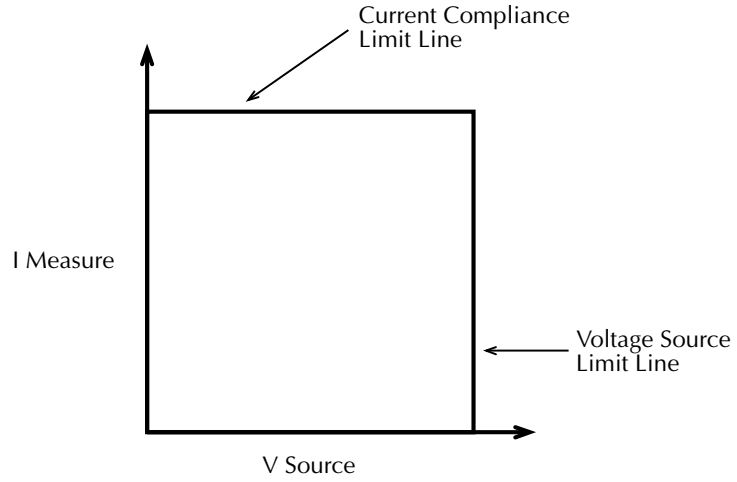
Figure 5-7A shows the output characteristics for the V-Source. As shown, the SourceMeter can output up to 21V at 105mA, or 210V at 10.5mA. Note that when sourcing more than 21V, current is limited to 10.5mA.

Figure 5-7B shows the limit lines for the V-Source. The voltage source limit line represents the maximum source value possible for the presently selected voltage source range. For example, if on the 20V source range, the voltage source limit line is at 21V. The current compliance limit line represents the actual compliance in effect. Remember that compliance can be real or range. See *Compliance limit*. These limit lines are boundaries that represent the operating limits of the SourceMeter for this quadrant of operation. The operating point can be anywhere inside (or on) these limit lines. The limit line boundaries for the other quadrants are similar.

Figure 5-7
V-Source boundaries



A) Output characteristics



B) Limit lines

Where within the boundaries the SourceMeter operates depends on the load (DUT) that is connected to the output. Figure 5-8 shows operation examples for resistive loads that are 2kΩ and 800Ω, respectively. For these examples, the SourceMeter is programmed to source 10V and limit 10mA.

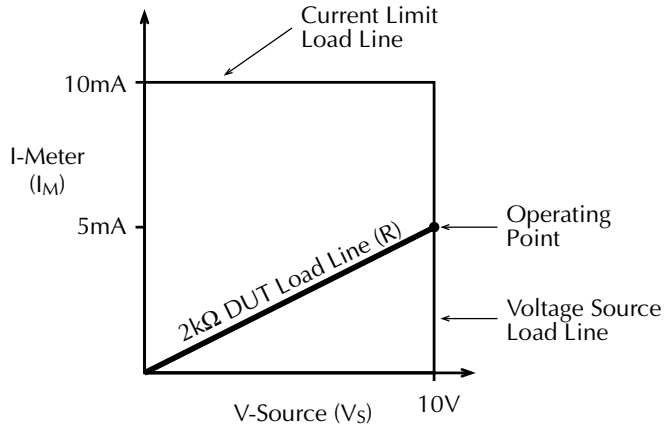
In Figure 5-8A, the SourceMeter is sourcing 10V to the 2kΩ load and subsequently measures 5mA. As shown, the load line for 2kΩ intersects the 10V voltage source line at 5mA.

Figure 5-8B shows what happens if the resistance of the load is decreased to 800Ω. The DUT load line for 800kΩ intersects the current compliance limit line placing the SourceMeter in compliance. In compliance, the SourceMeter will not be able to source its programmed voltage (10V). For the 800kΩ DUT, the SourceMeter will only output 8V (at the 10mA limit).

Notice that as resistance decreases, the slope of the DUT load line increases. As resistance approaches infinity (open output), the SourceMeter will source virtually 10V at 0mA. Conversely, as resistance increases, the slope of the DUT load line decreases. At zero resistance (shorted output), the SourceMeter will source virtually 0V at 10mA.

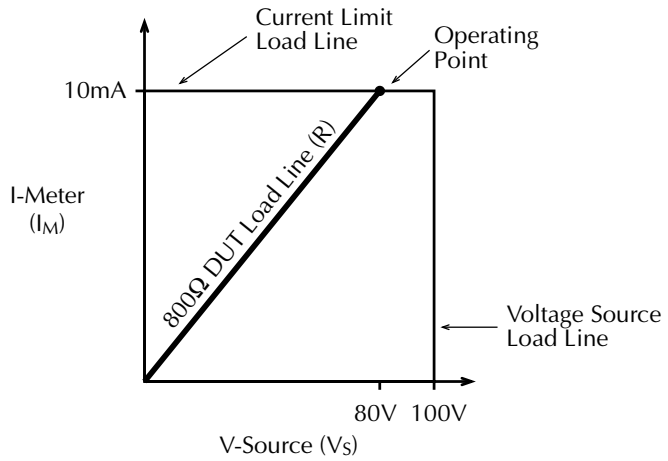
Regardless of the load, current will never exceed the programmed compliance of 10mA.

Figure 5-8
V-Source operating examples



$I_M = V_S / R$
$= 10V/2k\Omega$
$= 5mA$

A) Normal V-source operation



$V_S = I_M \bullet R$
$= (10mA)\ (800\Omega)$
$= 8V$

B) V-Source in compliance

Source I measure I and source V measure V

The SourceMeter can measure the function it is sourcing. When sourcing a voltage, you can measure voltage. Conversely, if you are sourcing current, you can measure the output current. For these measure source operations, the measure range is the same as the source range.

This feature is valuable when operating with the source in compliance. When in compliance, the programmed source value is not reached. Thus, measuring the source lets you measure the actual output voltage. With the use of the TOGGLE key, you can display the measurement of any two of the three functions (volts, amps, and ohms) concurrently. For remote operation, you can measure all three functions concurrently. See Sections 16 and 17.

Source readback accuracy

SourceMeter measurement accuracy is better than sourcing accuracy (see the source and measure specifications in Appendix A). For that reason, select the same measurement and source functions, then use the measured value instead of the programmed source value for optimum accuracy.

Basic circuit configurations

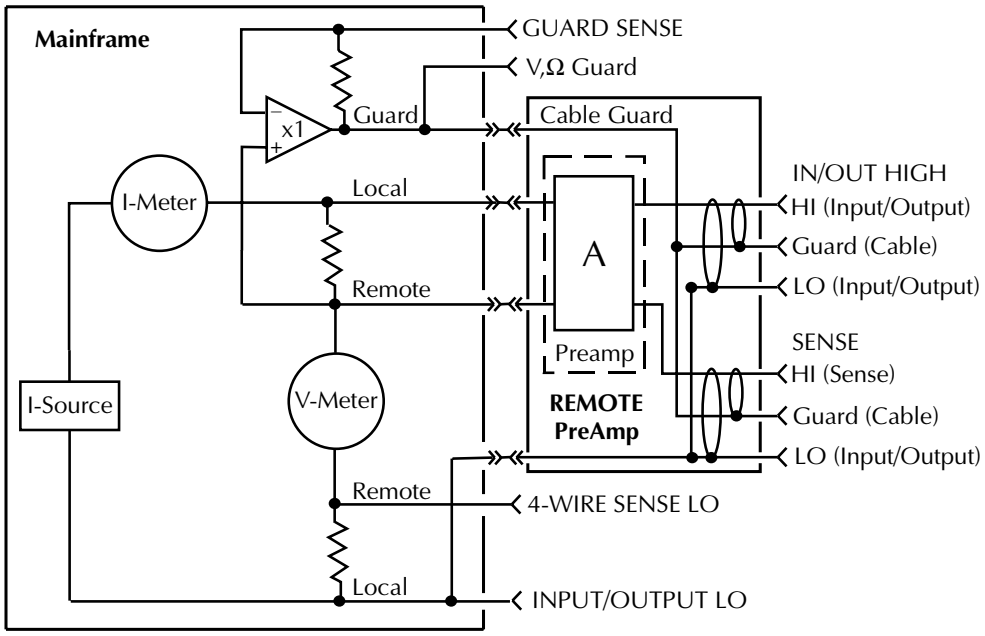
Source I

When configured to source current (I-Source) as shown in Figure 5-9, the SourceMeter functions as a high-impedance current source with voltage limit capability and can measure current (I-Meter) or voltage (V-Meter).

For 2-wire local sensing, voltage is measured at the Input/Output terminals of the SourceMeter. For 4-wire remote sensing, voltage is measured directly at the DUT using the sense terminals. This eliminates any voltage drops that may be in the test leads or connections between the SourceMeter and the DUT.

NOTE *The current source does not require or use the sense leads to enhance current source accuracy.*

Figure 5-9
Source I



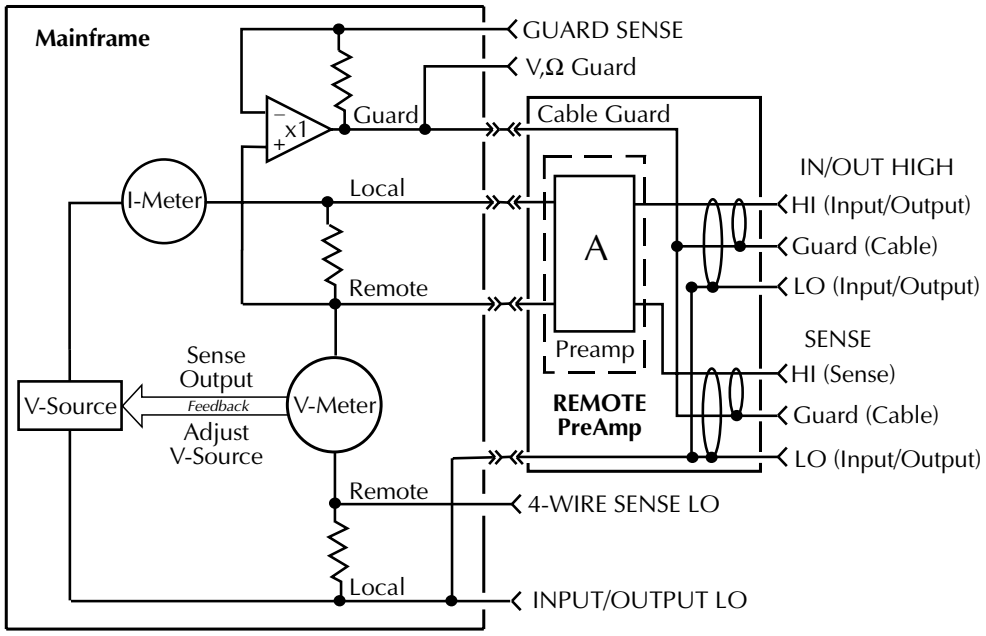
Source V

When configured to source voltage (V-Source) as shown in Figure 5-10, the SourceMeter functions as a low-impedance voltage source with current limit capability and can measure current (I-Meter) or voltage (V-Meter).

Sense circuitry is used to continuously monitor the output voltage and make adjustments to the V-Source as needed. The V-Meter senses the voltage at the input/output terminals (2-wire local sense) or at the DUT (4-wire remote sense using the sense terminals) and compares it to the programmed voltage level. If the sensed level and the programmed value are not the same, the V-Source is adjusted accordingly. Remote sense eliminates the effect of voltage drops in the test leads ensuring that the exact programmed voltage appears at the DUT.

NOTE *The voltage error feedback to the V-Source is an analog function. The source error amplifier is used to compensate for IR drop in the test leads.*

Figure 5-10
Source V



NOTE: The voltage error feedback to the V-Source is an analog function. The source error amplifer is used to compensate for IR drop in the leads.

Measure only (V or I)

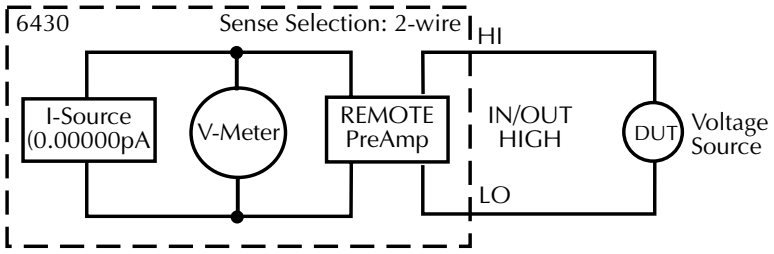
Figure 5-11 shows the configurations for using the SourceMeter exclusively as a voltmeter or ammeter. As shown in Figure 5-11A, the SourceMeter is configured to measure voltage-only by setting it to source 0A and measure voltage.

CAUTION **V-Compliance must be set to a level that is higher than the measured voltage. Otherwise, excessive current will flow into the SourceMeter. This current could damage the SourceMeter. Also, when connecting an external voltage to the I-Source, set the output off state to the high-impedance mode. See Section 12, *Output configuration*.**

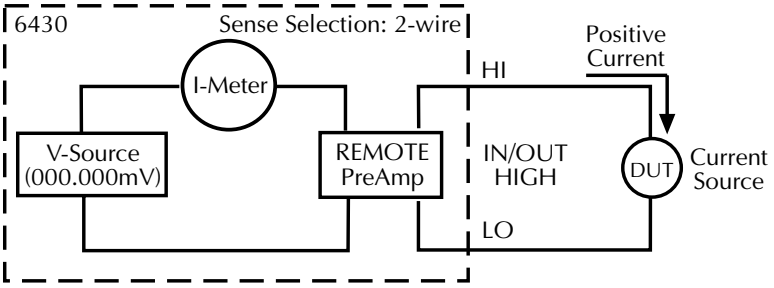
In Figure 5-11B, the SourceMeter is configured to measure current-only by setting it to source 0V and measure current. Note that in order to obtain positive (+) readings, conventional current must flow from IN/OUT HI to LO.

NOTE *If the Remote PreAmp is not used, use the INPUT/OUTPUT H1 and LO terminals on the mainframe. Note however, that when not using the Remote PreAmp, the 100nA through 1pA current ranges are not available.*

Figure 5-11
Measure-only (V or I)



A. Measure Voltage Only



NOTE: Positive current flowing out of input/output HI results in positive (+) measurements.

B. Measure Current Only

Guard

WARNING **Guard is at the same potential as input/output HI. Thus, if hazardous voltages are present at input/output HI, they are also present at the guard terminals.**

The driven guard is always enabled and provides a buffered voltage that is at the same level as the input/output HI (or sense HI for remote sense) voltage. The purpose of guarding is to eliminate the effects of leakage current (and capacitance) that can exist between input/output high and low. In the absence of a driven guard, leakage in the external test circuit could be high enough to adversely affect the performance of the SourceMeter.

Leakage current can occur through parasitic or non-parasitic leakage paths. An example of parasitic resistance is the leakage path across the insulator in a coax or triax cable. An example of non-parasitic resistance is the leakage path through a resistor that is connected in parallel to the DUT.

Guard modes — There are two programmable output impedance levels for the guard output. The high-impedance (~10kΩ) cable guard is used to reduce the effects of capacitance and leakage current paths in the test circuit. The low-impedance (<1Ω) ohms guard is used to cancel the effects of parallel resistances when measuring a resistor element of a resistor network.

Cable guard or ohms guard is available at the GUARD banana jack on the mainframe. Guard mode (Cable or Ohms) is selected from the V or I source configuration menu as explained in Section 2.

Cable guard is always available at the Remote PreAmp, regardless of the guard setting. Ohms guard is not available at the Remote PreAmp.

NOTE *Cable guard at the Remote PreAmp and guard accessed at the V,Ω GUARD terminal on the mainframe are different signals and should never be shorted together.*

Cable guard

WARNING **To prevent injury or death, a safety shield must be used to prevent physical contact with a guard plate or guard shield that is at a hazardous potential (>30Vrms or 42.4V peak). This safety shield must completely enclose the guard plate or shield and must be connected to safety earth ground. Figure 5-12B shows the metal case of a test fixture being used as a safety shield.**

Cable guard provides a high-impedance (~10kΩ) driven guard to prevent positive feedback, which could cause oscillations when using shielded cables. Cable guard is used to drive the shields of cables and test fixtures. From the Remote PreAmp, cable guard is extended to the test fixture using standard 3-slot triax cable (inner shield is guard). From the mainframe, cable guard is extended to a test fixture using a safety banana plug (such as the Model 8008-BAN). Inside the test fixture, the guard can be connected to a guard plate or shield that surrounds the DUT.

Inside the test fixture, a triaxial cable can be used to extend guard to the DUT. The center conductor of the cable is used for In/Out HI, the inner shield is used for guard, and the outer shield is used for In/Out LO and is connected to the safety shield (which is connected to safety earth ground).

A coaxial cable can be used if the guard potential does not exceed 30Vrms (42.4V peak). The center conductor is used for In/Out HI, and the outer shield is used for guard. For higher guard potentials, use a triaxial cable as previously explained.

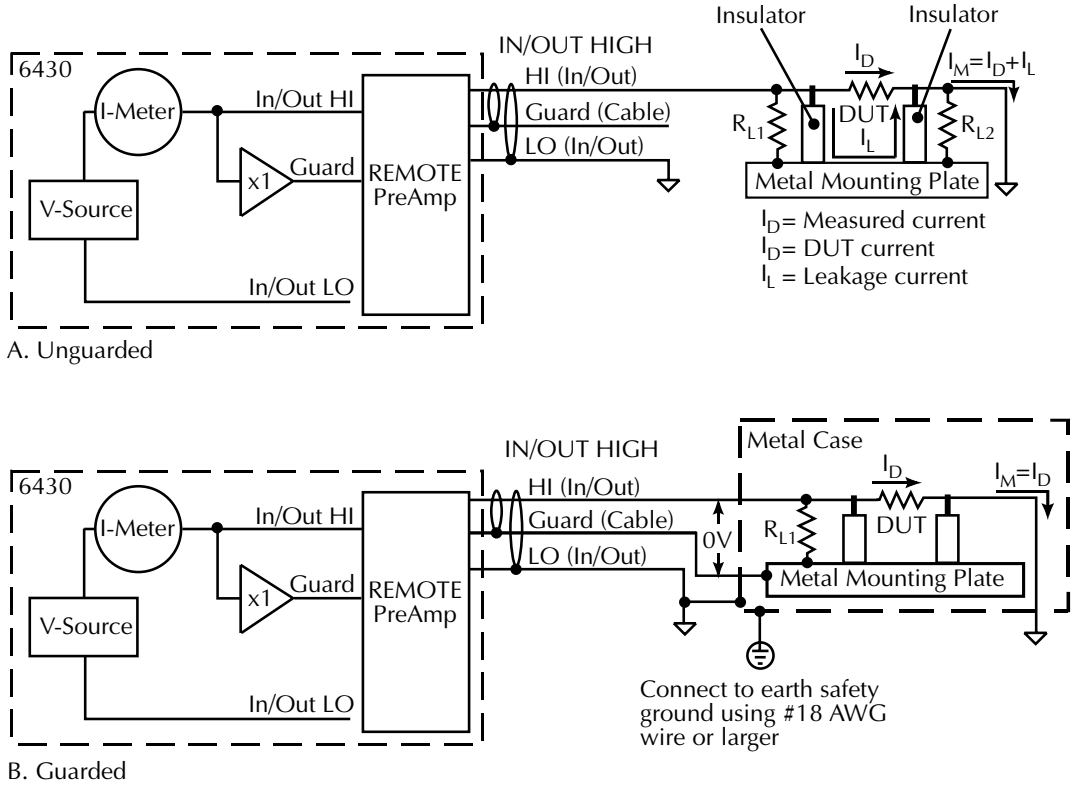
Figure 5-12 shows how cable guard can eliminate leakage current through the insulators in a test fixture. In Figure 5-12A, leakage current (I_L) flows through the insulators (R_{L1} and R_{L2}) to In/Out LO, adversely affecting the low-current (or high-resistance) measurement of the DUT.

In Figure 5-12B, the driven guard is connected to the metal guard plate for the insulators. Since the voltage on either end of R_{L1} is the same (0V drop), no current can flow through the leakage resistance path. Thus, the SourceMeter only measures the current through the DUT.

Cable guard should be used when sourcing or measuring low current (<1µA).

NOTE *When using shielded, triaxial, or coaxial cabling with guard, cable guard (not ohms guard) must be used to prevent oscillations. CABLE guard is the factory default setting.*

Figure 5-12
High-impedance measurements



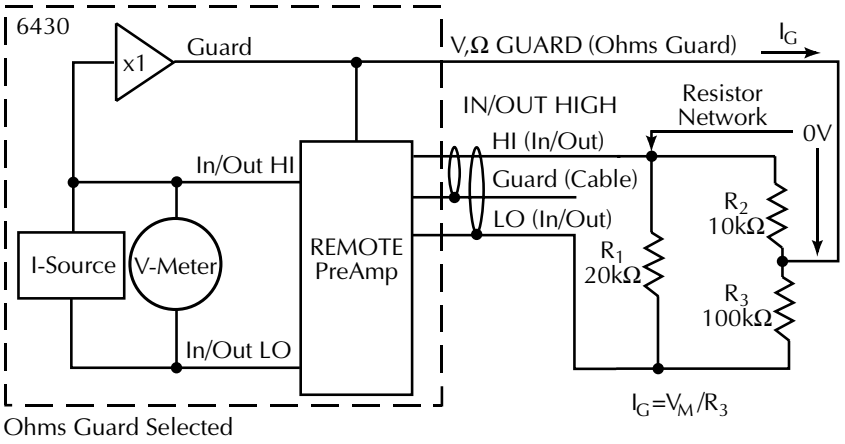
Ohms guard

The OHMS guard selection provides a low-impedance (<1Ω), high current (up to 50mA) driven guard. This lets you perform in-circuit ohms measurements of the DUT where other parallel resistive paths are present. These measurements are typically performed in Delta or Wye configurations.

NOTE *Ohms guard is only available at the V,Ω banana jack on the mainframe. It is not available at the Remote PreAmp. See also "6-wire ohms measurements" in Section 4 and "Ohms guard" in Section 2.*

If you want to measure the resistance of a single resistor in the network, you must use the ohms guard configuration. Figure 5-13 shows how to measure the resistance of R_1. Since the voltage on either side of R_2 is the same, no current can flow through it. Thus, all the programmed current (I_M) from the SourceMeter will flow through R_1. The voltage across R_1 is then measured, and an accurate resistance measurement is calculated, in this case 20kΩ.

Figure 5-13
In-circuit ohms measurements



NOTE *Ohms guard current (I_G) must not exceed 50mA. If it does, the guard voltage drops lower than the output voltage allowing leakage current. Thus, the guarded ohms measurement becomes corrupted.*

Guard sense

When the GUARD-to-LO resistance path is less than 1kΩ, remote guard sensing should be used to compensate for IR drop in the GUARD test lead and/or switch contacts on a switching card.

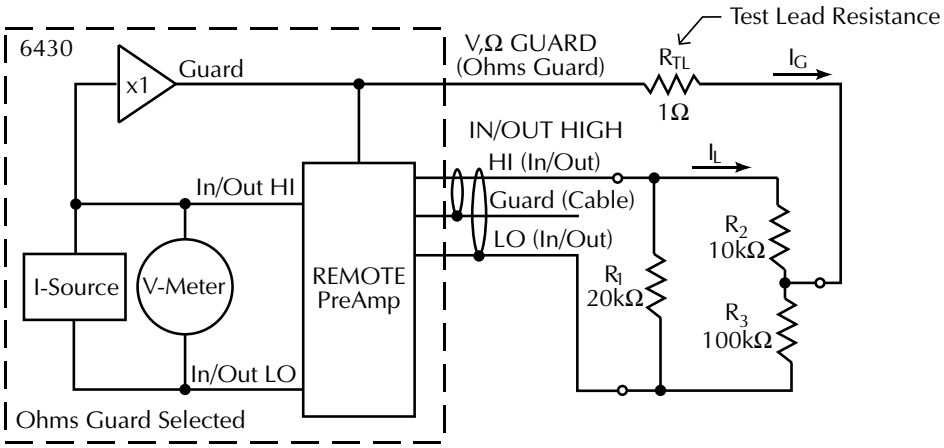
In Figure 5-14A, Figure 5-13 was modified by changing the value of R_3 to 100Ω and showing the 1Ω resistance (R_{TL}) of the GUARD test lead. Since the resistance path from GUARD-to-LO is less than 1kΩ, the IR drop in the guard test lead (R_{TL}) becomes significant. The guard voltage applied to the bottom of R_2 is now significantly lower than the In/Out HI voltage of the SourceMeter. As a result, leakage current (I_L) flows through R_2, adversely affecting the resistance measurement of R_1.

The guard test lead IR drop is compensated for by connecting GUARD SENSE as shown in Figure 5-14B. Sensing allows the guard voltage to be sensed (measured) at the resistor network for better guard voltage regulation. If the remotely sensed guard voltage is less than the output voltage of the SourceMeter, the guard voltage will be increased until the sensed guard voltage equals the output HI voltage.

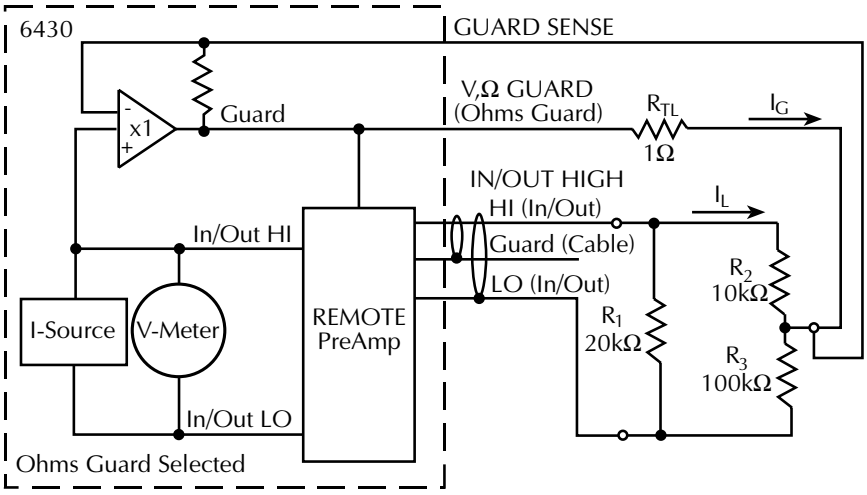
Note that in order to ensure that ohms guard current (I_G) in Figure 5-14 does not exceed 50mA, output voltage from the SourceMeter must not exceed 5V (50mA × 100Ω = 5V).

NOTE *For 6-wire ohms guard measurements, configure the output-off state to the GUARD mode. For details on the GUARD output-off state, see Section 12, "Output configuration."*

Figure 5-14
In-circuit ohms measurements using guard sense



A. Local Guard Sense



B. Remote Guard Sense

Data flow

Data flow for front panel operation is summarized by the block diagrams provided in Figure 5-15. Note that if REL is enabled, the result of the rel operation is sent to the other blocks.

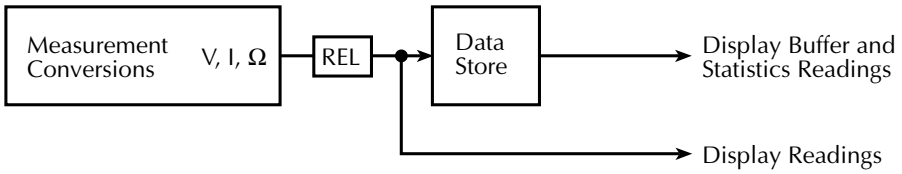
NOTE *See Appendix C for remote operation data flow information.*

With Math (FCTN) and Limit Tests (LIMITS) disabled (Figure 5-15A), the SourceMeter displays the measurement readings. If the data store is used, these readings are also stored in the buffer for later recall. Statistical data for these readings is also available upon recall.

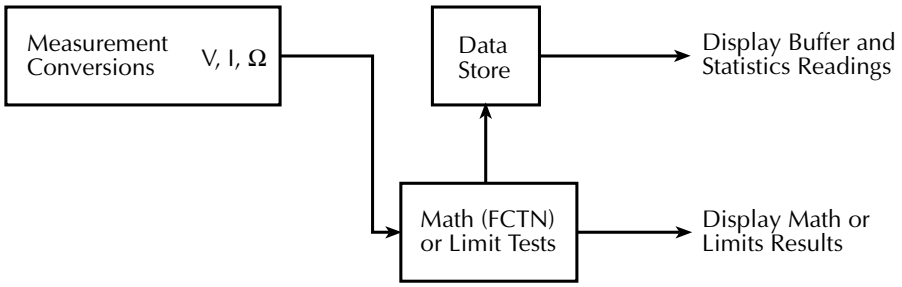
Figure 5-15B shows data flow when Math or Limit Tests is enabled. If Math is enabled, the result of the math operation is displayed. If Limit Tests is enabled, the raw reading along with the results of the tests (pass or fail) is displayed. As in the previous case, these readings can also be stored in the data store.

Figure 5-15C shows data flow when both Math and Limit Tests are enabled. The Math operation is performed first, and then limit tests are performed on that math result. The result of the math operation and the result of the limit tests (pass or fail) are displayed. As shown, these readings can also be stored in the data store.

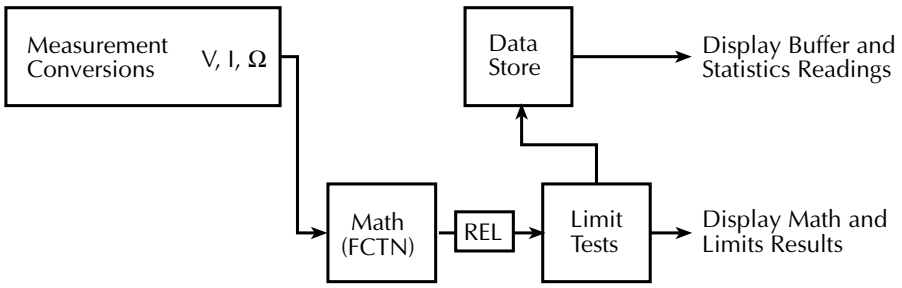
Figure 5-15
Data flow front panel



A. Math (FCTN) and limit tests disabled



B. Math (FCTN) or limit tests enabled



C. Both Math (FCTN) and limit tests enabled

Buffer considerations

When the SourceMeter is in the process of storing readings, configuration changes affect what gets stored in the buffer. These storage considerations and restrictions are summarized in Table 5-3.

Table 5-3
Buffer considerations

Configuration at start of the storage process	**What happens if the basic measurement function (V, I, or W) is changed**	**What happens if the MATH function is changed**	**What happens if REL or LIMITS is changed**
Measure V, I, or Ω	Buffer tracks	V, I, or Ω stored MATH not stored	V, I, or Ω stored REL or Limits not stored
MATH (FCTN) enabled	Buffer pauses	OK	MATH stored REL or Limits not stored
REL/LIMITS enabled	Buffer pauses	Buffer pauses	OK

The first column of Table 5-3 shows the SourceMeter configuration when the storage process is started. The next three columns show what happens when configuration changes are made while the SourceMeter is storing readings.

Changing V, I, or Ω measurement function

- If you started with only a basic measurement function selected, the buffer will track a basic measurement function change. For example, if you started in volts and changed to current, the buffer will store the current readings.
- If you started with MATH, REL, and/or LIMITS enabled, the buffer will stop storing readings if you change the basic measurement function. Storage will continue if you return to the original configuration.

See Section 3, *Basic source-measure procedure*, for more information on selecting the measurement function.

Changing MATH function

- If you started with only a basic measurement function selected, you can enable a MATH function, but only the voltage, current, or resistance component of the calculation will be stored in the buffer. The results of the MATH function will not be stored.
- If you started with a MATH function enabled, you can select a different MATH function. The results of the new MATH function are stored in the buffer.
- If you started with REL and/or LIMITS enabled, the buffer will stop storing readings if you select a MATH function. Storage will continue if you return to the original configuration.

See Section 7 for more information on MATH.

Changing REL or LIMITS

- If you started with only a basic measurement function selected, you can enable REL and/or LIMITS, but only the voltage, current, or resistance component of the operation will be stored in the buffer. The results of REL and/or LIMITS are not stored.
- If you started with a MATH function enabled, only the result of the MATH calculation will be stored in the buffer if REL and/or LIMITS is enabled.
- If you started with REL and/or LIMITS enabled, you can change REL and or LIMITS. The results of new REL and/or LIMITS are stored in the buffer.

See Section 7 for REL information and Section 11 for details on LIMITS.

6
Range, Digits, Speed, and Filters

- **Range and Digits** — Discusses available ranges, maximum readings, ranging limitations, manual and autoranging, and display resolution.
- **Speed** — Discusses speed settings, which are used to control the integration period of the A/D converter.
- **Filters** — Provides information on the 3-stage filtering process that can be used to reduce reading noise.

Range and digits

Range

The selected measurement range affects the accuracy of the measurements as well as the maximum signal that can be measured. Note that with the output off, dashed lines are displayed (i.e., --.---- µA), to indicate that measurements are not being performed.

Available ranges

The SourceMeter consists of a mainframe and a Remote PreAmp. The mainframe can be used with or without the Remote PreAmp. However, when not using the Remote PreAmp, the lower current ranges and higher resistance ranges are not available. Table 6-1 lists the available ranges for the SourceMeter.

Table 6-1
Model 6430 ranges

Voltage Ranges		Current Ranges		Ohms Ranges	
With Remote PreAmp	**Mainframe Only**	**With Remote PreAmp**	**Mainframe Only**	**With Remote PreAmp**	**Mainframe Only**
200V	200V	100mA	100mA	<2Ω*	<2Ω*
20V	20V	10mA	10mA	20Ω	20Ω
2V	2V	1mA	1mA	200Ω	200Ω
200mV	200mV	100µA	100µA	2kΩ	2kΩ
		10µA	10µA	20kΩ	20kΩ
		1µA	1µA	200kΩ	200kΩ
		100nA		2MΩ	2MΩ
		10nA		20MΩ	20MΩ
		1nA		200MΩ	
		100pA		2GΩ	
		10pA		20GΩ	
		1pA		200GΩ	
				2TΩ	
				20TΩ	

*Manual ohms mode only

Maximum readings

The full scale input for each voltage and current measurement range is 105.5% of the selected range. For example, ±2.11V is the full scale reading for the 2V range, ±105.5mA is the full scale reading for the 100mA range. The full scale reading for auto ohms is 110% of the selected ohms measurement range. For example, 2.2kΩ is the full scale reading for the 2kΩ range.

For manual ohms measurements, the display reading is the result of the V/I calculation. Effectively, there are no ohms ranges. Thus, there are never any leading zeroes in the display reading. For example, a resistor that is measured at 936.236kΩ will be displayed as 936.236kΩ (5½ digit resolution). The RANGE keys are used to select the voltage or current measurement range.

Input levels that exceed the maximum levels cause the "OVERFLOW" message to be displayed.

Ranging limitations

- When sourcing voltage (Source V), you cannot use the RANGE keys to change the voltage measurement (Measure V) range. Also, when sourcing current (Source I), you cannot use the RANGE keys to change the current measurement (Measure I) range. For these source-measure configurations, the measurement range is determined by the selected source range.
- With the 200V V-Source range selected, the highest current measurement range is 10mA. With the 100mA I-Source range selected, the highest voltage measurement range is 20V.
- The present I-Compliance range determines the highest current measurement range that can be selected. Similarly, the present V-Compliance range determines the highest voltage measurement range that can be selected. For example, if I-Compliance is on the 100mA range, the highest current measurement range that can be selected is 100mA. If V-Compliance is on the 2V range, the highest voltage measurement range that can be selected is 2V.

Manual ranging

For the Source V Measure I, Source I Measure V, and Ohms configurations, the RANGE ▲ and ▼ are used to select a fixed range. Note that the highest available range is dependent on the corresponding compliance setting. See *Ranging limitations*.

Within range compliance or if the instrument displays the "OVERFLOW" message on a particular range, select a higher range until an on-range reading is displayed. Use the lowest range possible without causing an overflow to ensure best accuracy and resolution.

Auto ranging

For the Source V Measure I, Source I Measure V, and Ohms configurations, press AUTO RANGE to enable auto ranging. The AUTO annunciator turns on when auto ranging is selected. With auto ranging selected, the instrument automatically chooses the best range to measure the applied signal. Note that the highest available range is dependent on the corresponding compliance setting. See *Ranging limitations*.

NOTE *With the median filter enabled, auto ranging could be very slow. See "Median filter" (in this section) for details.*

Source settling time can affect the time it takes the instrument to auto range. When the instrument auto ranges, both the source and sense circuits monitor each another, so if one takes longer to settle, the other will as well.

Auto range change mode

The auto range change mode determines how the instrument performs autoranging. In the SINGLE mode, the SourceMeter will auto range only after first taking a reading. In the MULTIPLE mode, the SourceMeter will auto range up on compliance in the Delay phase of the Source-Delay-Measure (SDM) cycle, thereby minimizing the possibility that a SourceMeter will be in compliance in a multiple-SourceMeter system. The SourceMeter can downrange only once a reading has been taken.

NOTE *See Section 5, "Source-delay-measure cycle" for more SDM information.*

With the auto range change mode set to MULTIPLE, you can also program the soak time, which specifies the amount of time after the first point of a sweep that the unit will sit in a loop actively auto ranging up and down to allow a multiple SourceMeter configuration to settle. This process will occur only during the first SDM cycle after the initial sweep trigger. See Section 10, *Trigger model*. This feature is especially useful for situations with long DUT settling times (such as low current measurements) when several down-range change cycles from the higher ranges are required.

NOTE *The soak time takes the place of the delay time only during the delay phase of the first SDM cycle after an initial sweep trigger. See Figure 10-1 for an overview of the trigger model.*

Selecting the auto range change mode

To configure the auto range change mode, press CONFIG then AUTO. Choose SINGLE SRC MTR or MULTIPLE as desired from the AUTO RANGE TYPE menu. If you choose MULTIPLE, you will also be prompted to enter the SOAK time, which can be programmed in the range of 0.000s to 9999.999s.

Auto range limits

Auto range limits are included to support the auto range change mode. For voltage and current, the upper limit is controlled by the compliance range and cannot be programmed. For the auto ohms mode, however, the upper limit is adjustable. The lower limit for all three functions is programmable and must be less than or equal to the upper limit. If the lower limit is equal to the upper limit, auto ranging is effectively disabled. When auto ranging is disabled, you can manually change to any range below the lower limit (V, I or Ohms) or any range above the upper limit (Ohms only).

Setting auto range limits

To set the upper or lower auto range limit press CONFIG ▲ or CONFIG ▼ respectively, then use the left and right cursor keys to set the limit at the ULIMIT or LLIMIT prompt. Remember that you cannot set the upper limit in the V and I modes, but the unit will display the upper limit with those two functions.

Digits

The display resolution of the measured reading depends on the DIGITS setting. This setting is global, which means the digits setting selects display resolution for all measurement functions.

The DIGITS setting has no effect on the remote reading format. The number of displayed digits does not affect accuracy or speed. Those parameters are controlled by the SPEED setting.

Setting display resolution

There are two ways to set display resolution:

- **DIGITS** — Press the DIGITS key until the desired number of digits is displayed.
- **CONFIG DIGITS** — Press CONFIG and then DIGITS to display the digits menu. Place the cursor on the desired number of digits (3.5, 4.5, 5.5, or 6.5) and press ENTER.

NOTE *The concurrent measurement (available on the secondary display by using the TOGGLE key) is always 5.5 digits.*

Changing SPEED changes DIGITS, but changing DIGITS does not change SPEED.

Remote range and digits programming

Table 6-2 summarizes the commands necessary to control range and digits. See Section 17 for more details on these commands.

Table 6-2
Range and digits commands

Commands	Description
:SENSe:CURRent:RANGe <n>	Select manual amps range (n = range).
:SENSe:CURRent:RANGe:AUTO <state>	Enable/disable auto amps range (state = ON or OFF).
:SENSe:CURRent:RANGe:AUTO:ULIMit?	Returns I compliance range.
:SENSe:CURRent:RANGe:AUTO:LLIMit <n>	Set lower limit for amps auto range (n = range).
:SENSe:VOLTage:RANGe <n>	Select manual volts measure range (n = range).
:SENSe:VOLTage:RANGe:AUTO <state>	Enable/disable auto volts range (state = ON or OFF).
:SENSe:VOLTage:RANGe:AUTO:ULIMit?	Returns V compliance range.
:SENSe:VOLTage:RANGe:AUTO:LLIMit <n>	Set lower limit for volts auto range (n = range).
:SENSe:RESistance:RANGe <n>	Select manual ohms range (n = range).
:SENSe:RESistance:RANGe:AUTO <state>	Enable/disable auto ohms range (state = ON or OFF).
:SENSe:RESistance:RANGe:AUTO:ULIMit?	Set upper limit for ohms auto range (n = range).
:SENSe:RESistance:RANGe:AUTO:LLIMit <n>	Set lower limit for ohms auto range (n = range).
:DISPlay:DIGits <n>	Set display digits (n = 4, 5, 6, or 7).

Range and digits programming example

Table 6-3 shows a programming example for controlling range and digits. The SourceMeter is set up as follows:

- Source function: volts
- Source level: 10V
- Measure function: amps
- Amps range: 10µA
- Display digits: 5½

Table 6-3
Range and digits programming example

Command	Description
*RST	Restore GPIB defaults.
:SOUR:FUNC VOLT	Volts source function.
:SOUR:VOLT 10	Output 10V.
:SENS:FUNC “CURR”	Amps measure function.
:SENS:CURR:RANG 10E-6	10mA range.
:DISP:DIG 5	5½ display digits.
:OUTP ON	Turn on output.
:READ?	Trigger and acquire reading.
:OUTP OFF	Turn off output.

Speed

The Speed/Accuracy menu is used to set the integration time of the A/D converter (period of time the input signal is measured). The integration time affects the usable digits, the amount of reading noise, and the ultimate reading rate of the instrument. The integration time is specified in parameters based on the Number of Power Line Cycles (NPLC), where 1 PLC for 60Hz is 16.67msec (1/60) and 1 PLC for 50Hz and 400Hz is 20msec (1/50).

In general, the fastest integration time (FAST; 0.01 PLC) results in increased reading noise and fewer usable digits. The slowest integration time (HI ACCURACY; 10 PLC) provides the best common-mode and normal-mode noise rejection. In-between settings are a compromise between speed and noise. The default power-on speed setting is HI ACCURACY (10 PLC).

Setting speed

Speed is set from the SPEED ACCURACY MENU and is structured as follows. Use Section 1, *Rules to navigate menus* to check and/or change the speed setting.

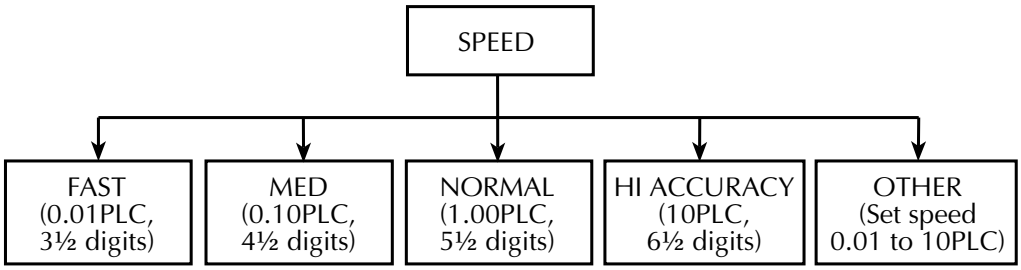
SPEED-ACCURACY MENU

Press SPEED or CONFIG SPEED to display the menu.

- **FAST** — Sets speed to 0.01 PLC and sets display resolution to 3½ digits.
- **MED** — Sets speed to 0.10 PLC and sets display resolution to 4½ digits.
- **NORMAL** — Sets speed to 1.00 PLC and sets display resolution to 5½ digits.
- **HI ACCURACY** — Sets speed to 10.00 PLC and sets display resolution to 6½ digits.
- **OTHER** — Use to set speed to any PLC value from 0.01 to 10. Display resolution is not changed when speed is set with this option.

NOTE After setting speed, display resolution can be changed using the DIGITS key.

Figure 6-1
Speed configuration menu tree



Remote speed programming

Speed commands

Table 6-4 summarizes commands to control speed. See Section 17 for more information.

Table 6-4
Speed commands

Command	Description
:SENSe:CURRent:NPLCycles <n>	Set amps speed (n = PLC, 0.01 to 10).
:SENSe:VOLTage:NPLCycles <n>	Set volts speed (n = PLC, 0.01 to 10).
:SENSe:RESistance:NPLCycles <n>	Set ohms speed (n =PLC, 0.01 to 10).

Speed programming example

Use the appropriate NPLC command to set the speed. For example, send the following command to set the amps speed to 10 PLC:

:SENS:CURR:NPLC 10

Filters

Filtering stabilizes noisy measurements caused by noisy input signals. However, the more filtering that is used, the slower the measurement process becomes. The SourceMeter uses three stages of filtering; repeat, median, and moving. The displayed, stored, or transmitted reading is simply the result of the filtering processes.

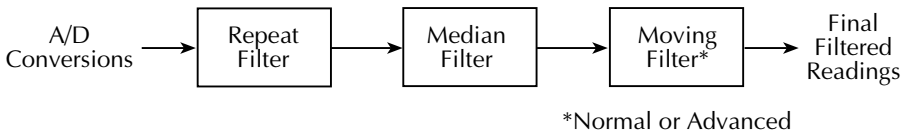
You can use the Auto Filter or you can manually configure the filters. With Auto Filter enabled, the filters are configured to provide heavy filtering on the low current ranges, and less filtering as the current range increases.

If you disable Auto Filter and manually configure the filters, that configuration is used for every voltage and current measurement range.

Filter stages

The SourceMeter uses a 3-stage filtering system as shown in Figure 6-2. The first stage applies the Repeat Filter to the measurement conversions. The second stage applies the Median Filter to the output of the first stage, and the last stage applies the Moving Filter to the output of the second stage. When a filter stage is disabled, a reading simply passes through it.

Figure 6-2
3-stage filtering



Each filter stage uses a stack to temporarily store readings to be filtered. The size of a stack, which is set by the user, determines how many readings will be filtered. A stack size of one disables that filter.

NOTE *A source level change due to a sweep step resets the filters. That is, readings are flushed from stack, and the filtering process starts over at the beginning. When not sweeping, source level changes do not reset the filters.*

NOTE *Any range change for source or measure will also reset the filters.*

Repeat filter

The Repeat Filter places the specified number of measurement conversions into a stack and averages them to yield a single Repeat Filter reading. The stack is then cleared, and the process starts over. For example, if the repeat count (stack size) is 10, every 10 measurement conversions will yield a single reading. Figure 6-3 illustrates the Repeat Filter process. The maximum count (stack size) for the Repeat Filter is 100. Note that setting the count to one disables the Repeat Filter.

Choose the Repeat Filter for sweeping so readings for other source levels are not averaged with the present source level.

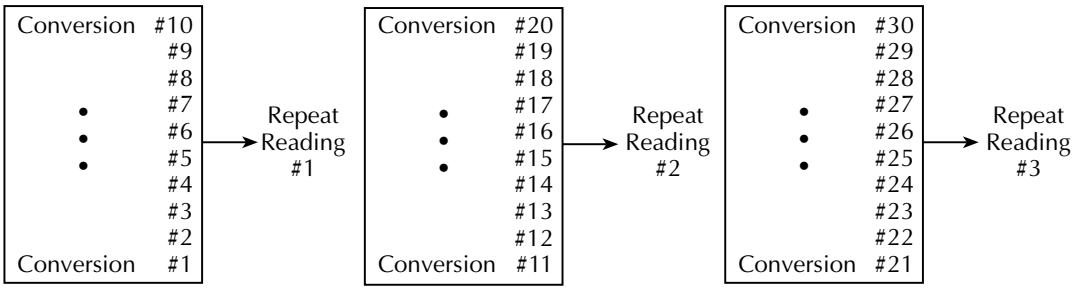


Figure 6-3
Repeat filter (count 10)

Median filter

The Median Filter is used to pass the “middle-most” reading from a group of readings that are arranged according to size. For example, assume the following readings:

2mA, 1nA, 3nA

The readings are placed in a stack, re-arranged in ascending order as follows:

1nA, 3nA, 2mA

From the above readings, it can be plainly seen that 3nA is the median (middle-most) reading. Therefore, the 3nA reading is allowed to pass, while the other two readings are discarded (filtered out). The Median Filter provides a good method to reject noise spikes.

The number of reading samples (stack size) for the Median Filter is determined by the selected rank (1 to 5) as follows:

Sample readings = 2n + 1

Where; n is the selected rank (0 to 5)

From the above equation, it can be seen that the minimum number of sample readings is 1 (n=0) and the maximum number is 11 (n=5). The following table shows the number of sample readings for each rank setting.

Rank setting	# of Sample readings
0	1
1	3
2	5
3	7
4	9
5	11

The first-in, first-out stack for the Median Filter operates as a moving type after it fills. For example, if the Median Filter is configured to sample 11 readings (Rank 5) as shown in Figure 6-4, the first filtered reading will be calculated (and displayed) after 11 readings are acquired and placed in its filter stack. Each subsequent reading will then be added to the stack (oldest reading discarded) and another Median Filter reading will be calculated and displayed.

NOTE *With auto range enabled, a range change cannot occur until a reading is yielded by the median filter process. Therefore, auto ranging could be very slow when the median filter is enabled.*

NOTE *If the Repeat Filter is enabled, the Median Filter operation will not start until after the Repeat Filter operation yields a reading. In other words, after a Repeat Filter reading is yielded, that reading will then be sent to the Median Filter stack.*

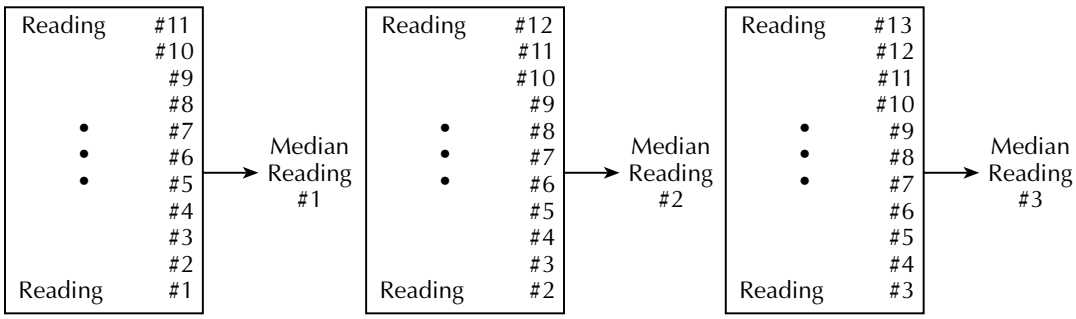


Figure 6-4 *Median filter (rank 5)*

Moving filter

The moving average filter uses a first-in, first-out stack. When the stack (filter count) becomes full, the readings are averaged, yielding a filtered reading. For each subsequent reading placed into the stack, the oldest reading is discarded. The stack is re-averaged, yielding a new reading.

When the filter is first enabled, the stack is empty. Keep in mind that a Moving Filter reading is not yielded until the stack is full. The first reading is placed in the stack and is then copied to the other stack locations in order to fill it. Therefore, the first filtered reading is the same as the first reading that entered the stack. Now the normal moving average filter process can continue. Note that a true average is not yielded until the stack is filled with new readings (no copies in stack). For example, in Figure 6-5, it takes ten filtered readings to fill the stack with new readings. The first nine filtered readings are calculated using copied readings.

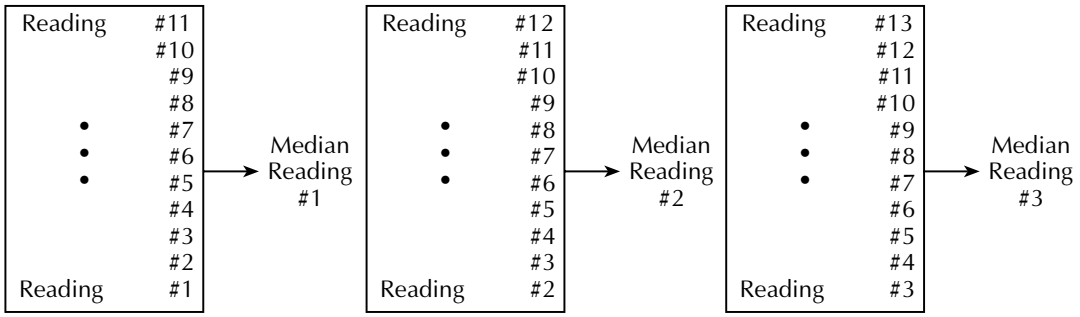


Figure 6-5
Moving filter (count 10)

Advanced filter — The Advanced Filter is part of the Moving Filter. With the Advanced Filter enabled, a user-programmable noise "window" is used with the Moving Filter. The noise window, which is expressed as a percentage of range (0-105%), allows a faster response time to large signal step changes. If the readings are within the noise window, the Moving Filter operates normally as previously explained. If, however, a reading falls outside the window, the stack is flushed of old readings and filled with the new reading.

For example, assume the window is set to 10% and the 10mA range is selected. Therefore, the noise window is ±1mA (10mA × 10% = 1mA). Also assume the first reading is 2mA. Per normal filter operation, the stack is filled with that reading. As long as each subsequent reading is within ±1mA of the previous reading, the filter operates normally. Now assume a 10mA noise spike occurs. This noise window violation causes the stack to flush out the old readings and fill it with 10mA reading.

NOTE *The Advanced Filter disables when Auto Filter is enabled.*

NOTE *If the Repeat or Median Filter is enabled, the Moving Filter operation will not start until after the previous filter yields a reading. In other words, after a reading is yielded from the Repeat or Median Filter, that reading will then be sent to the Moving Filter stack.*

Auto filter

When Auto Filter is enabled, it automatically selects filter settings that provide heavy filtering on the low current ranges, and less filtering as the current range increases. See Tables 6-5 through 6-7.

NOTE *Enabling Auto Filter disables the Advanced Filter.*

When Auto Filter is disabled, the present count and rank settings for the three filters are used for all measurement functions and ranges. For example, assume Auto Filter is enabled, speed is set to 1 PLC and the 10pA range is selected. For this configuration (as shown in Table 6-6), repeat count is 10, median rank is 3 and moving count is 5. If you disable Auto Filter, these settings will be retained for every voltage and current range.

Table 6-5
Auto filter settings where NPLC = 0.01 to 0.10

Current range	Repeat count	Median rank	Moving count
1pA	10	5	34
10pA	10	3	15
100pA	10	1	10
1nA	10	0	5
10nA	10	0	1
100nA	10	0	1
1µA	10	0	1
10µA	1	0	1
100µA	1	0	1
1mA	1	0	1
10mA	1	0	1
100mA	1	0	1

Table 6-6
Auto filter settings where NPLC = 0.11 to 1.00

Current range	Repeat count	Median rank	Moving count
1pA	10	5	34
10pA	10	3	15
100pA	10	1	5
1nA	10	0	5
10nA	1	0	1
100nA	1	0	1
1µA	1	0	1
10µA	1	0	1
100µA	1	0	1
1mA	1	0	1
10mA	1	0	1
100mA	1	0	1

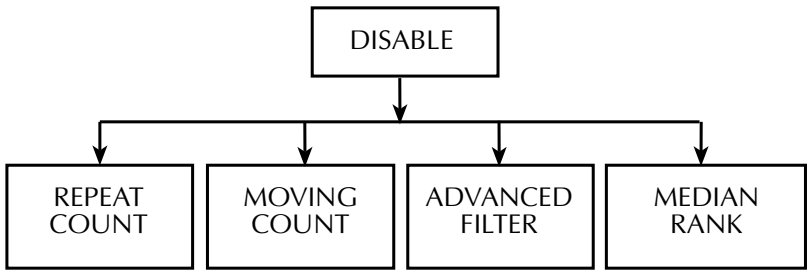
Table 6-7
Auto filter settings where NPLC = 1.01 to 10

Current range	Repeat count	Median rank	Moving count
1pA	1	5	34
10pA	1	3	15
100pA	1	1	5
1nA	1	0	5
10nA	1	0	1
100nA	1	0	1
1µA	1	0	1
10µA	1	0	1
100µA	1	0	1
1mA	1	0	1
10mA	1	0	1
100mA	1	0	1

Filter configuration

1. Press the CONFIG key and then the FILTER key to access the filter configuration menu. The blinking cursor will indicate the state of Auto Filter.
2. Use the ◀ or ▶ key to place the cursor on the desired Auto Filter selection (DISABLE or ENABLE), and press ENTER.
3. If you selected ENABLE, the FILT annunciator will turn on and the SourceMeter will exit from the menu structure. If you selected DISABLE, the Configure Filtering menu will be displayed. (See Figure 6-6.) Proceed to the next step.
4. Place the cursor on REPEAT COUNT and press ENTER to display the present repeat count for the Repeat Filter.
5. Use the ◀, ▶, ▲ and ▼ keys to display the desired repeat count (1 to 100), and press ENTER. Keep in mind that a count of one disables the Repeat Filter.
6. Place the cursor on MOVING COUNT and press ENTER to display the present moving count for the Moving Filter.
7. Use the ◀, ▶, ▲ and ▼ keys to display the desired moving count (1 to 100), and press ENTER. Keep in mind that a count of one disables the Moving Filter.
8. Place the cursor on ADVANCED and press ENTER. The blinking cursor will indicate the state of Advanced Filter.
9. Use the ◀ or ▶ key to place the cursor on the desired Advanced Filter selection (DISABLE or ENABLE), and press ENTER.
10. If you enabled the Advanced Filter, use the ◀, ▶, ▲ and ▼ keys to display the desired noise window (0% to 105%), and press ENTER.
11. Place the cursor on MEDIAN RANK and press ENTER to display the present median rank for the Median Filter.
12. Place the cursor on the desired rank value (0 to 5) and press ENTER. Keep in mind that a rank of 0 disables the Median Filter.
13. Use the EXIT key to back out of the menu structure.

Figure 6-6
Configure filtering menu tree



Filter control

When filtering is being applied to the input signal, the FILT annunciator will be on. When Auto Filter is enabled, the FILT annunciator will turn on to indicate that the Auto Filter configuration is being applied.

The FILTER key is used to control filtering. Pressing FILTER turns on the FILT annunciator to indicate that the filter configuration is being applied to the input. Pressing FILTER a second time turns the FILT annunciator off to indicate that filtering is turned off.

Remote filter programming

Filter commands

Table 6-8 summarizes filter commands. See Section 17 for more details.

NOTE *When Auto Filter is enabled, the filter configuration cannot be changed. Therefore, the commands in Table 6-8 for the Repeat Filter, Median Filter and Moving Filter are no-operations with Auto Filter on.*

Table 6-8
Filter commands

Commands	Description
for Auto Filter:	
[:SENSe]:AVERage:AUTO <state>	Enable/disable Auto Filter (state = ON or OFF).
for Repeat Filter:	
[:SENSe]:AVERage:REPeat:COUNt <n>	Set Repeat Filter count (n = count, 1 to 100).
[:SENSe]:AVERage:REPeat[:STATe] <state>	Enable/disable Repeat Filter (state = ON or OFF).
for Median Filter:	
[:SENSe]:MEDian:RANK <NRf>	Set Median Filter rank (NRf = rank, 0 to 5).
[:SENSe]:MEDian[:STATe] <state>	Enable/disable Median Filter (state = ON or OFF).
for Moving Filter:	
[:SENSe]:AVERage:COUNt <n>	Set Moving Filter count (n = count, 1 to 100).
[:SENSe]:AVERage[:STATe] <state>	Enable/disable Moving Filter (state = ON or OFF).
[:SENSe]:AVERage:ADVanced:NTOLerance <NRf>	Set Advanced Filter noise window in % (NRf = noise window, 0 to 105).
[:SENSe]:AVERage:ADVanced[:STATe] <state>	Enable/disable Advanced Filter (state = ON or OFF).

Filter programming example

Table 6-9 summarizes the command sequence to program filter aspects as follows:

- Auto Filter off
- Repeat Filter off
- Median Filter on, rank 5
- Moving Filter on, count 20, Advanced Filter off

Table 6-9
Filter programming example

Command	**Description**
:AVER:AUTO OFF	Disable Auto Filter.
:AVER:REPeat OFF	Disable Repeat Filter.
:MED:RANK 5	Set median rank to 5.
:MED ON	Enable Median Filter.
:AVER:COUN 20	Set moving count to 20.
:AVER ON	Enable Moving Filter.
:AVER:ADV OFF	Disable Moving Filter.

7
Relative and Math

- **Relative** — Discusses the relative (REL) mode that can be used to null offsets or subtract a baseline value from readings.
- **Math Operations** — Provides detailed information on the following math (FCTN) operations: power, offset-compensated ohms, varistor, alpha, voltage coefficient, and percent deviation.

Relative

The rel (relative) feature can be used to null offsets or subtract a baseline reading from present and future readings. With REL enabled, subsequent readings will be the difference between the actual input value and the rel value as follows:

Displayed Reading = Actual Input - Rel Value

Once a rel value is established for a measurement function, the value is the same for all ranges. For example, if 5V is set as a rel value on the 20V range, the rel value is also 5V on the 2V and 200mV ranges.

Selecting a range that cannot accommodate the rel value does not cause an overflow condition, but it also does not increase the maximum allowable input for that range. For example, on 20V range, the SourceMeter still overflows for a >21.1V input.

NOTE *When rel is enabled, the REL annunciator turns on. Changing measurement functions disables rel.*

Front panel rel

Enabling and disabling rel

Rel can be used to null out zero offsets or to establish a zero baseline by pressing the REL key. The reading (which becomes the rel value) is subtracted from itself. As a result, a zero reading is displayed. Pressing REL a second time disables rel.

Defining a rel value

A unique rel value can be established for the selected measurement function from the front panel as follows:

1. Press CONFIG and then REL. The present rel value will be displayed.
2. Set the desired rel value. See Section 1, *Rules to navigate menus* for details.
3. With the desired rel value displayed, press ENTER. The SourceMeter will return to the normal source-measure display with rel enabled. The reading will reflect the defined rel value.

Remote rel programming

Rel commands

Table 7-1 summarizes rel commands. See Section 17 for additional information.

Table 7-1
Rel commands

Command	Description
:CALCulate2:NULL:OFFSet <n> :CALCulate2:NULL:STATe <state> :CALCulate2:NULL:ACQuire	Define null (rel) value (n = rel value). Enable/disable rel (state = ON or OFF). Automatically acquire rel value (must have non-overflowed reading).

Rel programming example

Table 7-2 lists commands for setting up and enabling rel. These commands set up the SourceMeter as follows:

- Rel value: 5
- Rel state: enabled

Table 7-2
Rel programming example

Command	Description
:CALC2:NULL:OFFS 5 :CALC2:NULL:STAT ON	Rel value = 5. Enable rel.

Math operations

Math functions

The SourceMeter has built-in math functions to calculate the following:

- Power
- Offset Compensated Ω
- Varistor Alpha
- Voltage Coefficient
- Percent Deviation

The Power and Percent Deviation math functions use a single voltage and/or current measurement to perform the calculation. The Offset-Compensated Ω, Varistor Alpha, and Voltage Coefficient math functions require 2-point measurements to perform a calculation.

Power

This math function calculates power using the measured voltage and measured current values as follows:

$$\text{Power} = V \times I$$

where: V = measured voltage
I = measured current

Offset-compensated Ω

The presence of thermal EMFs (V_{EMF}) can adversely affect low-resistance measurement accuracy. To overcome these unwanted OFFset voltages use the Offset Compensated Ω measurement method. In general, this method measures resistance (V/I) at a specific I-Source level and then subtracts a resistance measurement made with the I-Source set to a different level (typically zero).

NOTE *Offset-compensated Ω is also available from the CONFIG OHMS menu structure. Using Offset-Compensated Ω from this menu automatically selects zero as one of the source values. For details, see Section 4, "Offset-compensated ohms."*

This two-point measurement method is mathematically expressed as:

$$\text{Offset-Compensated } \Omega = \Delta V / \Delta I \text{ where } \Delta V = V2 - V1 \text{ and } \Delta I = I2 - I1.$$

- V1 is the voltage measurement with the I-Source set to a specific level.
- V2 is the voltage measurement with the I-Source set to a different level (typically zero).
- I1 is the current measurement with the I-Source set to a specific level.
- I2 is the current measurement with the I-Source set to a different level (typically zero).

You will be prompted to enter the two I-Source values. See *Front panel math operations*.

Measuring high resistance devices — When using offset-compensated ohms to measure high resistance values, an appropriate source delay must be used to provide settled readings. There is a rise time associated with high ohms measurements. For normal ohms measurements, you can watch the reading change on the display. When it stops changing, you know you have the final, settled reading. For offset-compensated ohms, this process is not as straight forward since the source is constantly changing between two values. If measurements are performed while the source is still rising (or falling), incorrect offset-compensated ohms readings will result. Therefore, it is imperative that an adequate source delay be used to make sure that measurements occur while the source is at its final, settled values.

Settling times are drastically different from one type of resistor to another. Another factor that affects settling time is the test setup (i.e., cabling, fixturing, and guarding). These variables make it necessary for the user to characterize his test system to assure that the source delay setting is adequate.

NOTE *Source delay is set from the source configuration menu (press CONFIG > select SOURCE I (or V) > select DELAY). See "Source delay" in Section 3 for details.*

Varistor alpha

This math formula is used to determine ALPHA (α), which is the logarithmic ratio of two voltage measurement points on a non-linear V-I curve and is expressed as follows:

$$\alpha = \frac{\log(I2/I1)}{\log(V2/V1)}$$

where: V1 is the voltage measurement at the first I-Source point.
V2 is the voltage measurement at the second I-Source point.
The log (x) function uses the absolute value of x.

When configuring this math function, you will be prompted to enter the two I-source values. See *Front panel math operations*.

Voltage coefficient

High value or high-megohm resistors exhibit a change in resistance with a change in applied voltage. This effect is known as voltage coefficient. The voltage coefficient is the percent change in resistance per unit change in applied voltage and is defined as follows:

$$\text{Coefficient\%} = \frac{\Delta R}{R2 \times \Delta V} \times 100\%$$

where: $\Delta R = R2 - R1$
$\Delta V = V2 - V1$
R1 is the resistance measurement at the first source point.
R2 is the resistance measurement at the second source point.
V1 is the voltage measurement at the first source point.
V2 is the voltage measurement at the second source point.

If sourcing voltage, you will be prompted to enter the two V-source values. If sourcing current, you will be prompted to enter the two I-source values. See *Front panel math operations*.

Percent deviation

This calculation provides the percent deviation between the normal display reading and the user set reference value:

$$\%\text{Deviation} = \frac{(X - Y)}{Y} \times 100$$

where: X is the normal display measurement reading (V, I, or Ω).
Y is the reference value.

When prompted to enter the reference value (Y), you can enter the value or have the SourceMeter acquire the reference value. To acquire the reference value, turn on the output and press AUTO. The SourceMeter will perform a measurement and display that reading as the reference.

Limit Testing — After the reference value is entered, you will be prompted to enter high and low tolerances (in %) for the reference value. These tolerances set the high and low limits for Limit 2 test.

For example, perform the following steps to test 1kΩ, 1% resistors:

1. Select the Ω function, select the 1kΩ measurement range (or use AUTO range), and connect the resistor to be tested to the SourceMeter.
2. Configure the percent deviation math function:
   a. Press CONFIG, press FCTN, then select %DEV.
   b. Set the reference (REF) value to +1.000000 k, then press ENTER.
   c. Set the high tolerance (HI TOL) to 01.00%, then press ENTER.
   d. Set the low tolerance (LO TOL) to 01.00%, then press ENTER.
3. Turn the output on. The measured reading of the resistor is displayed.
4. Press FCTN to select the percent deviation math function. The actual tolerance of the resistor will be displayed along with the result of the limit test. If the resistor reading is within ±1% of 1kΩ, the "PASS" test message is displayed. If outside the 1% tolerance, the "FAIL" message is displayed.
5. When finished, turn the ouput off.

NOTE *The reading format is fixed at ±XXX.XXX%*

NOTE *Limit testing can be disabled by pressing the LIMIT key.*

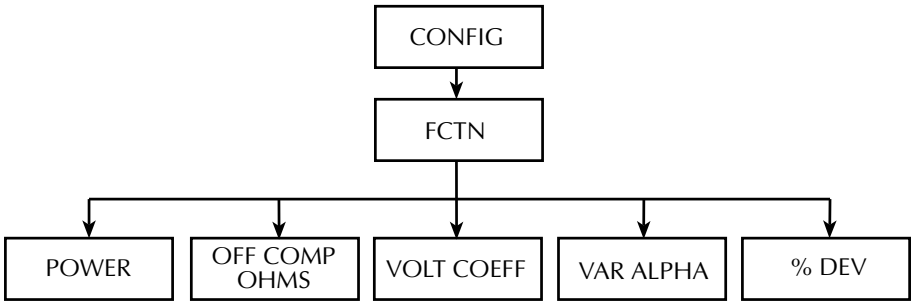
Front panel math operations

Perform the following steps to select and enable a math expression. Figure 7-1 shows the math configuration menu tree.

1. Select the appropriate source (V or I) for the math expression.
2. Press CONFIG and then FCTN to display the math expression selections. Place the cursor on the desired math expression and press ENTER:
   - For 2-point math expressions, you will be prompted to enter the two source values. Press ENTER after entering each source value.
   - For Percent Deviation, you will be prompted to set the reference value, and enter the tolerances for the reference. The following methods are available to set the reference value:
     - **User-specified reference value** — Enter the desired reference value and press ENTER.
     - **Acquire reference value** — With the output on, press the AUTO range key. The SourceMeter will perform a measurement and display that reading as the reference. Press ENTER to select that reference value.
3. Turn on the output by pressing the ON/OFF key.
4. Press the FCTN key to enable the selected math function. The MATH annunciator will turn on, and the result of the math expression will be displayed.

Note that with FCTN enabled, the sweep for a 2-point math expression runs continuously. Each sweep updates the reading. The source value cannot be changed while the 2-point sweep is running. However, the range keys remain active.

Figure 7-1
Math configuration menu tree



Remote math operations

Math commands

Table 7-3 summarizes commands to control the math functions. See Section 17 for more detailed information on these and other math commands.

Table 7-3
Math commands

Command	Description
:CALCulate:MATH:NAME <name>	Select match expression (name = “POWER”, “OFF-COMPOHM”, “VOLTCOEF”, “VARALPHA”).
:CALCulate:STATe <state>	Enable/disable math (state = ON or OFF).
:CALCulate:DATA?	Query math data.

Math programming example

Table 7-4 summarizes the basic command sequence for voltage coefficient testing, which is a change in resistance of resistive elements with applied voltage. Although such changes in resistance with voltage are present in virtually all resistors to at least some degree, voltage coefficients are most noticeable in high-value resistors (>$10^{10}\Omega$). See Figure 7-2 for DUT connections.

This example sets up the SourceMeter as follows:

- Source function: volts
- Sense functions: all
- Source delay: 1sec
- Start voltage: 10V
- Stop voltage: 50V
- Math expression: voltage coefficient

Table 7-4
Voltage coefficient programming example

Command	Description
*RST	Reset unit to GPIB defaults.
:SENS:FUNC:ON:ALL	Enable all sense functions.
:SENS:RES:MODE MAN	Manual resistance mode.
:SOUR:FUNC VOLT	Volts source function.
:SOUR:VOLT:STAR 10	10V start voltage.
:SOUR:VOLT:STOP 50	50V stop voltage.
:SOUR:VOLT:MODE SWE	Volts sweep mode.
:SOUR:SWE:POIN 2	Sweep points = 2.
:TRIG:COUN 2	Trigger count = 2.
:CALC:MATH:NAME “VOLTCOEF”	Select voltage coefficient math expression.
:CALC:STAT ON	Enable math.
:OUTP ON	Turn on output.
:INIT	Trigger sweep.
:CALC:DATA?	Request voltage coefficient data.

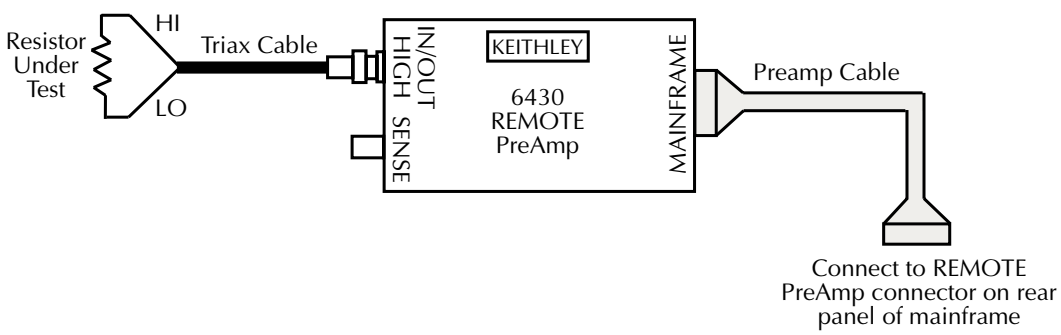


Figure 7-2
Connections for voltage coefficient tests

User-defined math functions

In addition to the pre-defined math functions, you can also define your own functions by using appropriate remote commands (user-defined math functions are not available from the front panel). The following paragraphs summarize the basic commands for user-defined functions and also list a basic programming example. See Section 17, *Calculate subsystems*, for more details on user-defined math functions.

Commands for user-defined math functions

Table 7-5 summarizes the commands for user-defined math functions. To define a math function:

1. If desired, assign units to the calculation result using :CALC:MATH:UNIT. Units is stored for the calculation.
2. Assign a name to the expression (using up to 10 ASCII characters) using the :CALC:MATH:NAME “user-name” command.
3. Define the expression using the :CALC:MATH:DEFine or :CALC:MATH:EXPression command. The new expression is the one that will be presently selected.
4. Enable the math function by sending :CALC:STATE ON.
5. Turn on the output by sending :OUTP ON, then send :INIT to trigger the unit.
6. Request the data with the :CALC:DATA? query.

Table 7-5
Commands for user-defined math functions

Command	Description
:CALCulate:MATH:UNITs <name>	Specified units for user-defined function (name = three ASCII characters in quotes).
:CALCulate:MATH:NAME <name>	Define math name (name = “user-name”).
:CALCulate:MATH[EXPression] <form>	Define math formula (form = formula) Valid names: VOLTage, CURRent, RESistance, TIME Valid math operators: + - * / ^ log, ln, sin, cos, tan, exp
:CALCulate:STATe <state>	Enable/disable math (state = ON or OFF).
:CALCulate:DATA?	Query math data.

User-defined math function programming example

Table 7-6 shows the command sequence for a typical user-defined math function. This example defines a percent deviation math function.

Table 7-6
User-defined math function programming example

Command	Description
*RST	Restore GPIB defaults.
:SENS:FUNC:OFF:ALL	Disable concurrent functions.
:SENS:FUNC:ON “RES”	Select resistance function.
:CALC:MATH:UNIT “%”	Define “%” units name.
:CALC:MATH:EXPR:NAME “PER_DEV”	Define math expression name.
:CALC:MATH:EXPR (((RES - 10e3) / 10e3) * 100)	Define math expression.
:CALC:STAT ON	Enable math data.
:OUTP ON	Turn on output.
:INIT	Trigger unit.
:CALC:DATA?	Request math data.

8
Data Store

- **Data Store Overview** — Outlines basic data store (buffer) capabilities.
- **Storing Readings** — Discusses the procedure for storing readings in the internal buffer.
- **Recalling Readings** — Provides detailed information for recalling readings stored in the buffer.
- **Buffer Statistics** — Discusses the various statistics available on buffer data including minimum and maximum values, average (mean), standard deviation, and peak-to-peak values.
- **Timestamp Format** — Explains how to select the timestamp format (absolute or delta) for recalled buffer readings.
- **Remote Command Data Store** — Summarizes the commands to control the data store and provides a programming example.

Data store overview

The SourceMeter has a data store (buffer) to store from 1 to 2500 source-measure readings. The instrument stores the source-measure readings that are displayed during the storage process. Each source-measure reading also includes the buffer location number and a timestamp. “Cmpl” will flash in buffer recall if the reading is in compliance.

The data store also provides statistical data on the measured readings stored in the buffer. These include minimum, maximum, mean, and standard deviation.

NOTE *For a sweep that has a finite sweep count, the readings are automatically stored in the buffer.*

Front panel data store

Storing readings

Perform the following steps to store readings:

1. Set up the SourceMeter for the desired configuration.
2. Press the STORE key.
3. Use the left and right cursor keys, and the SOURCE (▲ and ▼) or RANGE (▲ and ▼) keys to specify the number of readings to store in the buffer.
4. Press ENTER. The asterisk (*) annunciator turns on to indicate data storage operation. It will turn off when the storage is finished.
5. Turn on the output and (if necessary) trigger the unit to begin taking and storing readings.

Recalling readings

Readings stored in the buffer are displayed by pressing the RECALL key. The source-measure readings are positioned at the left side of the display, while the buffer location number and timestamp are positioned at the right side.

Buffer location number

The buffer location number indicates the memory location of the source-measure reading. Location #0000 indicates that the displayed source-measure reading is stored at the first memory location. If limit testing was performed, a “P” or an “F” will precede the buffer location number to indicate the pass/fail result of the test. Limit testing is covered in Section 11.

Timestamp

The first source-measure reading stored in the buffer (#0000) is timestamped at 0000000.000 seconds. Subsequent readings can be recalled in absolute or delta timestamp format. For the absolute format, the timestamp references readings to zero seconds. For the delta format, the timestamp indicates the time between the displayed reading and the reading before it. To set the timestamp format, see *Timestamp format* in this section.

Displaying other buffer readings

To display the other source-readings stored in the buffer, display the desired memory location number. The ▲ and ▼ keys for SOURCE and RANGE increment and decrement the selected digit of the location number. Cursor position is controlled by the left and right arrow keys. When scrolling forward past the last stored reading, the buffer wraps to the first stored reading. Conversely, when scrolling in reverse past the first stored reading, the buffer wraps to the last stored reading. A different key click tone announces the wrap-around.

The memory location number can also be keyed in using the 0 through 9 number keys. Position the cursor on the appropriate digit and press the desired number key. The cursor then moves right to the next least significant digit. For example, to display reading #0236, position the cursor all the way to the left (MSD) and press 0, 2, 3, 6. Note that if keying in a number that exceeds the buffer size, the reading at the highest memory location is displayed.

To exit from the data store recall mode, press EXIT.

Buffer statistics

With the data store in the recall mode, buffer statistics are displayed by using the TOGGLE key. Use the TOGGLE key to sequence through the statistics and return the SourceMeter to the normal data store recall state. Pressing EXIT at any time returns the instrument to the normal source-measure display state.

NOTE *Buffer statistics for V, I, Ω, and MATH are calculated and displayed separately. For example, if ohms readings are displayed, all buffer statistics displayed are based on ohms readings.*

Minimum and maximum

This mode displays the minimum and maximum readings stored in the buffer. The buffer location number and timestamp are also provided for these readings. If desired, you can go to those buffer locations to obtain more data about the readings.

Peak-to-peak

This mode displays the peak-to-peak reading (peak-to-peak = Maximum - Minimum).

Average

The average mode displays the mean (average) of all measured readings stored in the buffer. The following equation is used to calculate mean:

$$y = \frac{\sum_{i=1}^{n} X_i}{n}$$

where: y is the average.
X_i is a stored reading.
n is the number of stored readings.

Standard deviation

This mode displays the standard deviation of buffered readings. The following equation is used to calculate standard deviation:

$$y = \sqrt{\frac{\sum_{i=n-1}^{n} X_i^2 - \left(\frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)^2\right)}{n-1}}$$

where: y is the average.
X_i is a stored reading.
n is the number of stored readings.

Timestamp format

Buffer readings can be recalled using the absolute timestamp format or the delta format. For the absolute format, readings are referenced to zero seconds. For the delta format, the timestamp indicates the time between the displayed reading and the previous reading.

Perform the following steps to set the timestamp format:

1. While in the normal display mode, press CONFIG and then STORE to display the timestamp choices.
2. Place the cursor on ABSOLUTE or DELTA and press ENTER.

Timestamp accuracy

Because of internal timing methods, the timestamp value is only approximate. The method in which the timestamp is implemented limits its use in time-critical applications. If accurate test timing is crucial, it is recommended that an external timer be used in conjunction with the SourceMeter.

The timestamp is based on an oscillator with a frequency of approximately 8kHz. This oscillator is used as the system clock and is divided by eight to generate system "ticks" every millisecond. Therefore, the timestamp should provide lms resolution for test timing. However, since the actual oscillator frequency is 8.192kHz, a system tick occurs every 8.192kHz/8 or 1024 times a second, which results in a system tick every 0.9765625ms. As a result, the reported timestamp value is off by 24ms every second. Thus, to obtain more accurate timestamp values, simply multiply the timestamp displayed on the front panel or returned via remote by a factor of 0.9765625.

Buffer considerations

From the front panel, 2,500 source-measure readings can be stored and accessed using the method described earlier in this section. Over the bus, however, there are actually two separate 2,500 reading buffers for a total of 5,000 readings. The :TRACe buffer is a 2,500 reading buffer used by front panel data store, bus :TRACe commands, and to store sweep data, and it is battery backed-up. The READ? buffer is a separate 2,500 reading buffer that can only be accessed over the bus using the :READ? command. You can store and access data from these two buffers separately as outlined below.

Using :TRACe commands to store data

Use :TRAC:POIN <n> and :TRIG:COUN <n> followed by :TRAC:FEED:CONT NEXT to store data. (n = number of readings; 2,500 maximum.) Turn on the output with :OUTP ON and then send :INIT to take the unit out of idle and store readings. After data is stored, send :TRAC:DATA? to access it. See Table 8-1 for a summary of these commands and *:TRACe subsystem* in Section 17 for more details.

Using :READ? to store data

Use :TRIG:COUN <n> to set the number of readings to be stored. (n = number of readings; 2,500 maximum.) Turn on the output with :OUTP ON and then send the :READ? command to trigger and access readings. (Once you access these readings, you will still be able to access previously stored. :TRACe buffer readings using :TRAC:DATA?.) See Section 10 and *Trigger subsystem* in Section 17 for triggering details, and Section 16 for information on the :READ? command.

Remote command data store

Data store commands

Table 8-1 summarizes commands associated with data store operation. See *TRACe subsystem* and *CALCulate3* in Section 17 for more detailed information on these commands.

Table 8-1
Data store commands

Command	Description
:TRACe:DATA?	Read contents of buffer.
:TRACe:CLEar	Clear buffer.
:TRACe:FREE?	Read buffer memory status.
:TRACe:POINts <n>	Specify buffer size (n = buffer size.)
:TRACe:POINts:ACTual?	Query number of stored readings.
:TRACe:FEED <name>	Specify reading source. Name = SENSe[1] (raw readings), CALCulate[1] (Calc1 readings), or CALCulate2 (Calc2 readings).
:TRACe:FEED:CONTrol <name>	Start or stop buffer. Name = NEXT (fill buffer and stop) or NEVer (disable buffer).
:TRACe:TSTamp:FORMat <name>	Select timestamp format. Name = ABSolute (reference to first buffer reading) or DELTa (time between buffer readings).
:CALCulate3:FORMat <name>	Select buffer statistic (name = MEAN, SDEViation, MAXimum, MINimum, or PKPK).
:CALCulate3:DATA?	Read buffer statistic data.*

*If :TRACe:FEED is set to :SENSe[1], this command will return one V, I, Ω, and MATH result.

Data store programming example

Table 8-2 summarizes the commands for basic data store operation. These commands set up the SourceMeter as follows:

- Reading source: raw readings.
- Number of points: 10.
- Acquired data: buffer readings, mean (average), and standard deviation.

NOTE *You can determine when the buffer is full by reading the appropriate status register bit. See Section 14 for details on the status structure.*

Table 8-2
Data store example

Command	**Description**
*RST	Restore GPIB defaults.
:SOUR:VOLT 10	Source 10V.
:TRAC:FEED SENS	Store raw readings in buffer.
:TRAC:POIN 10	Store 10 readings in buffer.
:TRAC:FEED:CONT NEXT	Enable buffer.
:TRIG:COUN 10	Trigger count = 10.
:OUTP ON	Turn on output.
:INIT	Trigger readings.
:TRACE:DATA?	Request raw buffer readings.
:CALC3:FORM MEAN	Select mean buffer statistic.
:CALC3:DATA?	Request buffer mean data.
:CALC3:FORM SDEV	Select standard deviation statistic.
:CALC3:DATA?	Request standard deviation data.

9
Sweep Operation

- **Sweep Types** — Describes the four basic sweep types: Linear staircase, logarithmic staircase, custom, and source memory sweep.
- **Configuring and Running a Sweep** — Discusses the procedure for setting up and performing sweeps including selecting and configuring a sweep, setting the delay, and performing a sweep.

Sweep types

The four basic sweep types described in the following paragraphs include:

- Linear staircase
- Logarithmic staircase
- Custom
- Source memory

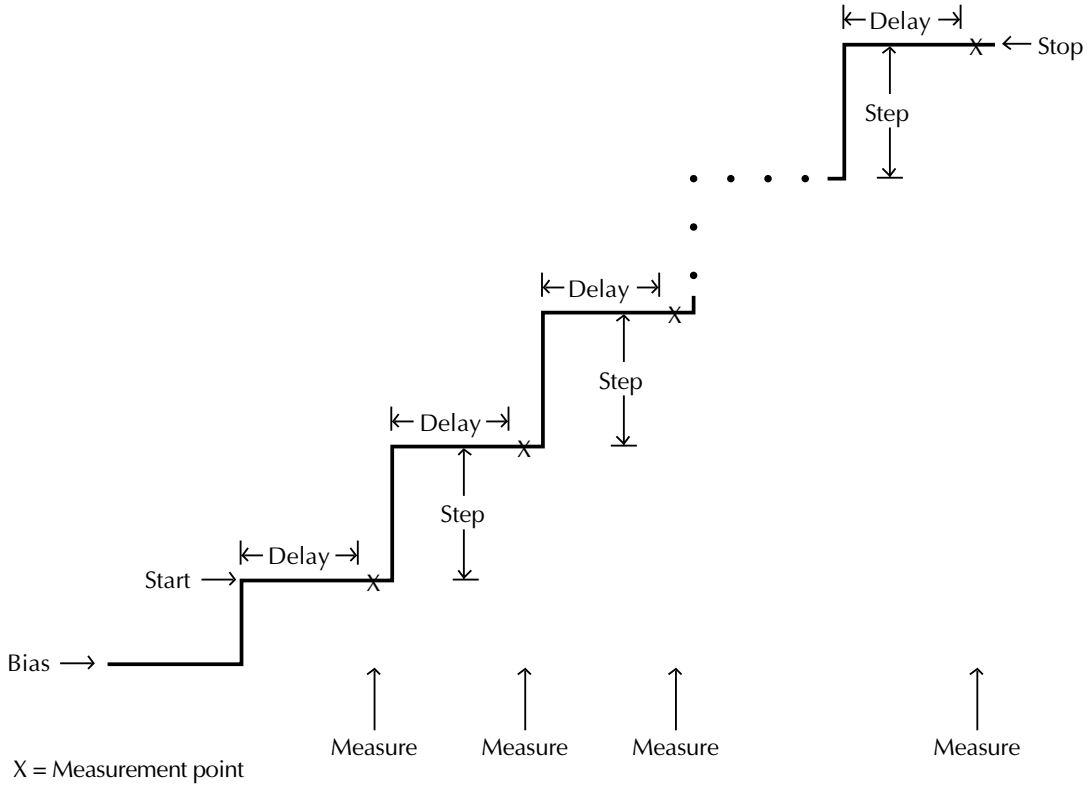
NOTE *Only voltage or current sweeps can be performed. Sweep readings are automatically stored in the buffer. See Section 8 for details on the data store (buffer).*

Linear staircase sweep

As shown in Figure 9-1, this sweep steps from a start source value to an ending (stop) source value. Programmable parameters include the start, stop, and step source levels.

When this sweep is triggered to start, the output will go from the bias level to the start source level. The output will then change in equal steps until the stop source level is reached. With trigger delay set to zero, the time duration at each step is determined by the source delay and the time it takes to perform the measurement (NPLC setting). Note that the delay cannot change once a sweep is configured and running and is the same for all steps.

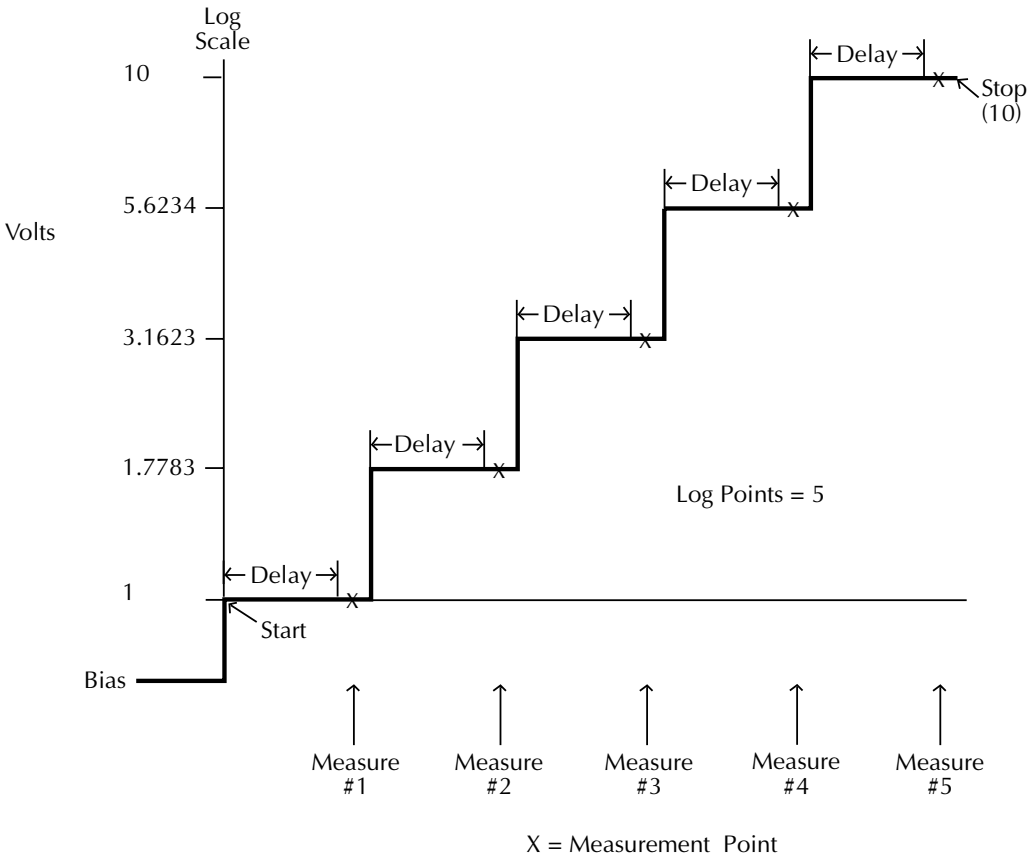
Figure 9-1
Linear staircase sweep



Logarithmic staircase sweep

This sweep is similar to the linear staircase sweep. The steps, however, are done on a logarithmic scale as shown in the example sweep in Figure 9-2. This is a 5-point log sweep from 1 to 10V. As with the staircase sweep, the delay period is the same for all steps.

Figure 9-2
Logarithmic staircase sweep (example 5-point sweep from 1 to 10 volts)



The programmable parameters for a log sweep include the start and stop levels and the number of measurement points for the sweep. The specified start, stop, and point parameters determine the logarithmic step size for the sweep. Step size for the sweep in Figure 9-2 is calculated as follows:

$$\text{Log Step Size} = \frac{\log10(\text{stop}) - \log10(\text{start})}{\text{Points} - 1}$$

$$= \frac{\log10(10) - \log10(1)}{5 - 1}$$

$$= \frac{(1 - 0)}{4}$$

$$= 0.25$$

Thus, the five log steps for this sweep are 0, 0.25, 0.50, 0.75, and 1.00. The actual V-Source levels at these points are listed in Table 9-1 (the V-Source level is the anti-log of the log step).

Table 9-1
Logarithmic sweep points

Measure point	Log step	V-Source level (volts)
Point 1	0	1
Point 2	0.25	1.7783
Point 3	0.50	3.1623
Point 4	0.75	5.6234
Point 5	1.0	10

When this sweep is triggered to start, the output will go from the bias level to the start source level (1V) and sweep through the symmetrical log points. With trigger delay set to zero, the time duration at each step is determined by the source delay and the time it takes to perform the measurement (NPLC setting).

Custom sweep

This sweep type lets you configure a customized sweep. Programmable parameters include the number of measurement points in the sweep and the source level at each point.

When this sweep is started, the output goes from the bias level to the first source-measure point in the sweep. The sweep will continue through the source-measure points in the order they were programmed and stop after the last source-measure point. With trigger delay set to zero, the time duration at each step is determined by the source delay and the time it takes to perform the measurement (NPLC setting). This delay is the same for all sweep points.

Custom sweep examples

The custom sweep can be configured to provide a 50% duty cycle pulse sweep. Figure 9-3 shows a pulse sweep that provides three 1V pulses on a 0V bias level. This pulse sweep is configured by specifying six points for the custom sweep. The specified voltage levels at points P0, P2, and P4 are 1V, and the specified voltage levels at points P1, P3, and P5 are 0V. Six measurements are performed for this sweep, three at 1V and three at 0V.

Figure 9-3
Custom pulse sweep

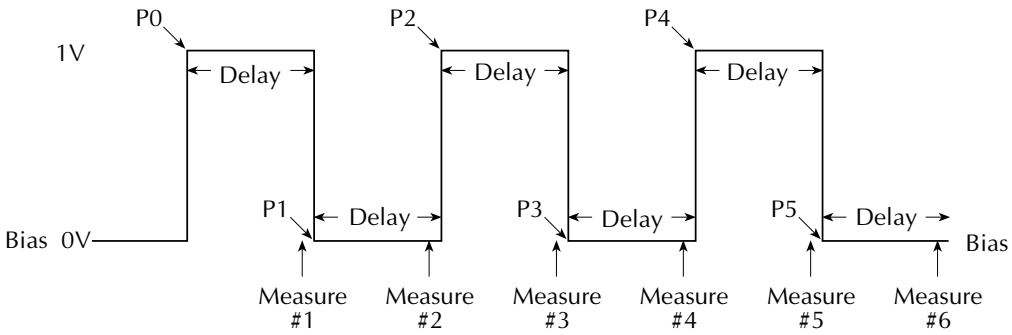
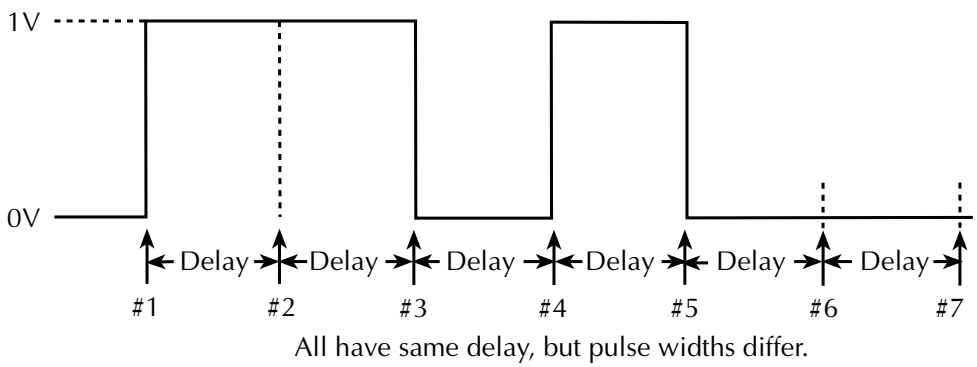


Figure 9-4 shows a custom sweep example with different pulse widths. In this example, the first two points are configured with the same source value so that the duration of the first pulse is effectively doubled.

Figure 9-4
Custom sweep with different pulse widths



Source memory sweep

For a source memory sweep, up to 100 setup configurations can be saved in memory. When the sweep is performed, the setup at each memory point is recalled. This allows multiple functions and math expressions to be used in a sweep. For example, the first point in a source memory sweep may source voltage and measure current, the next point may source current and measure voltage, the third point may source voltage and measure voltage, and the last point may use a math expression. This feature allows you to customize each sweep point with specific instrument settings instead of being tied to one set of settings for all sweep points.

Once source memory setups are saved and the sweep is initiated, the SourceMeter then sequences through the setups very rapidly. This feature allows you to use the instrument as a fast, automatic test sequencer.

Sweep configuration

The user specifies the number of memory location points to sweep and where to start the sweep. For example, you can specify a six point sweep that starts at memory location 98. When the sweep is started, the setups at memory location points 98, 99, 100, 1, 2, and 3 are recalled. When sweeping past point 100, the sweep automatically wraps back to memory location point 1. These and other components of the sweep are configured from the CONFIGURE SWEEPS menu.

NOTE *These and other components of the sweep are configured from the CONFIGURE SWEEPS menu. See "Configuring and running a sweep" later in this section.*

Setups are saved in battery backed-up memory, and they remain and can be recalled even if the SourceMeter looses external power.

NPLC caching can be used to speed up source memory sweeps. See "NPLC caching" in Section 3.

Saving and restoring source memory setups

Source memory setups are saved in memory and restored from the SAVESETUP (SOURCE MEMORY) option of the MAIN MENU. (See Section 1, *Main Menu*.)

NOTE *Source memory setups are different from the power-on and user-defined setups, which are programmed from the SAVESETUP (GLOBAL) MAIN MENU option. See Section 1 for details.*

Saving source memory setups

Perform the following steps to save source memory setups:

1. Configure the SourceMeter for the desired source, measure, and/or math expression operation.
2. Press MENU to display the MAIN MENU:
   - Select SAVESETUP.
   - Select SOURCE MEMORY.
   - Select SAVE.
   - Use the ▲ and ▼ keys, and the cursor keys to display the desired memory location, and press ENTER.
   - Use the EXIT key to back out of the menu structure.
3. Configure the SourceMeter for the next point in the sweep and repeat Step 2 to save that setup in the next memory location.
4. Repeat Step 3 for all points in the sweep.

Restoring source memory setups

In addition to automatically sweeping through source memory locations (see *Configuring and running a sweep* later in this section), you can also recall them individually as follows:

1. Press MENU to display the MAIN MENU.
2. Select SAVESETUP, then press ENTER.
3. Choose SOURCE MEMORY, then press ENTER.
4. Select RESTORE, then press ENTER.
5. Select the source memory location to restore (1-100), then press ENTER.

Saving multiple source memory sweeps

If desired, you can save multiple source memory sweeps in the 100 memory locations. For example, you could save setups in locations 1 through 4 for one sweep, and other setups in any other range of memory locations such as locations 50 through 58. To select which sweep to execute, simply select two settings: (1) the sweep start location, and (2) the number of sweep points. (See *Performing a source memory sweep* later in this section.)

Saved source memory configurations

Table 9-2 summarizes the configurations that are saved at each source memory location along with the equivalent remote command. See Section 17 for more details on these remote

commands. The SCPI command reference tables, Tables 17-1 through 17-11, also list source memory parameters.

Table 9-2
Source memory saved configurations

Mode	**Remote command**
Current integration rate	SENSe[1]:CURRent:NPLCycles
Resistance integration rate	SENSe[1]:RESistance:NPLCycles
Voltage integration rate	SENSe[1]:VOLTage:NPLCycles
Concurrent functions	SENSe[1]:FUNCtion:CONCurrent
Enable functions	SENSe[1]:FUNCtion:ON
Disable functions	SENSe[1]:FUNCtion:OFF
Manual/auto ohms	SENSe[1]:RESistance:MODE
Offset-compensated ohms	SENSe[1]:RESistance:OCOMpensated
Enable/disable filter	SENSe[1]:AVERage:STATe
Filter type	SENSe[1]:AVERage:TCONtrol
Filter count	SENSe[1]:AVERage:COUNt
Source mode	SOURce[1]:FUNCtion:MODE
Source delay	SOURce[1]:DELay
Source auto delay	SOURce[1]:DELay:AUTO
Scaling factor*	SOURce[1]...X...:TRIGgered:SFACtor
Enable/disable scaling*	SOURce[1]...X...:TRIGgered:SFACtor:STATe
Source Value, Range, Auto Range	
Sense Protection, Range, Auto Range	
Enable/disable auto-zero	SYSTem:AZERo:STATe
Enable/disable remote sense	SYSTem:RSENse
Front/rear terminals	ROUTe:TERMinals
Enable/disable CALC1	CALCulate1:STATe
CALC1 math expression	CALCulate1:MATH[:EXPRession]:NAME
CALC2 input path	CALCulate2:FEED
REL value	CALCulate2:NULL:OFFSet
REL on/off	CALCulate2:NULL:STATe
Limit 1 on/off	CALCulate2:LIMit[1]:STATe
Limit 1 fail conditions	CALCulate2:LIMit[1]:COMPliance:FAIL
Limit 1 bit pattern	CALCulate2:LIMit[1]:COMPliance:SOURce2
Enable/disable Limit X**	CALCulate2:LIMitX:STATe
Limit X upper limit	CALCulate2:LIMitX:UPPer[:DATA]
Limit X upper bit pattern	CALCulate2:LIMitX:UPPer:SOURce2
Limit X lower limit	CALCulate2:LIMitX:LOWer[:DATA]
Limit X lower bit pattern	CALCulate2:LIMitX:LOWer:SOURce2
Composite limits bit pattern	CALCulate2:CLIMits:PASS:SOURce2
Next pass memory location	CALCulate2:CLIMits:PASS:SMLocation
Trigger delay	TRIGger:DELay

*X = CURRent or VOLTage.
**Limit X = Limit 2, 3, 5-12.

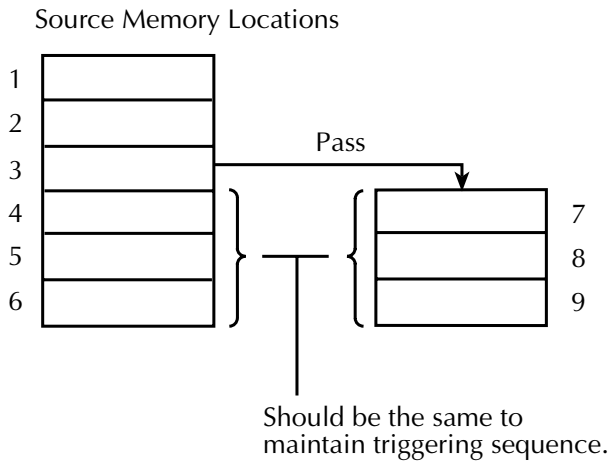
Sweep branching

When using a Source Memory Sweep while performing limit tests, the normal sequence of sweep memory points can be changed. This is useful when, based on the results of an initial test, a different set of tests are needed.

The sweep can branch to a specified memory location point, or proceed to the next memory location in the list. When a memory location is specified, the sweep will branch to that memory location if the test is successful (PASS condition). If not successful (FAIL condition), the sweep proceeds to the next memory location in the list. With NEXT selected (the default), the sweep proceeds to the next memory location in the list regardless of the outcome of the test (PASS or FAIL condition).

Figure 9-5 shows a six-point sweep branching example. In this case, the unit is programmed to branch to location 7 when a pass condition occurs at location 3.

Figure 9-5
Six-point test branching example



Caution must be used when branching since infinite memory loops can inadvertently be created. A single Source Memory Sweep will always sweep the number of points specified, regardless of how many branches were taken.

Memory sweep branching option is set from the PASS (SRC MEM LOC) item of the CONFIG LIMITS MENU. (See Section 11, *Limit testing* and *Configure limit tests* for details.) Via remote, use the :CALCulate2:CLIMits:PASS:SMLocation command. (See Section 17, *Configuring and running a sweep*.) See *Diode test example* below for a typical example.

NOTE *Branch on fail is available via remote only with CALC2:CLIM:FAIL:SML. See Section 17 for details.*

Testing polarized devices — Branching can simplify the testing of polarized devices such as diodes. Because a diode is polarity sensitive, you normally have to be careful when installing it in the component handler. Installing the diode one way forward biases it, and installing it the other way reverse biases it. Memory sweep branching can eliminate this installation problem.

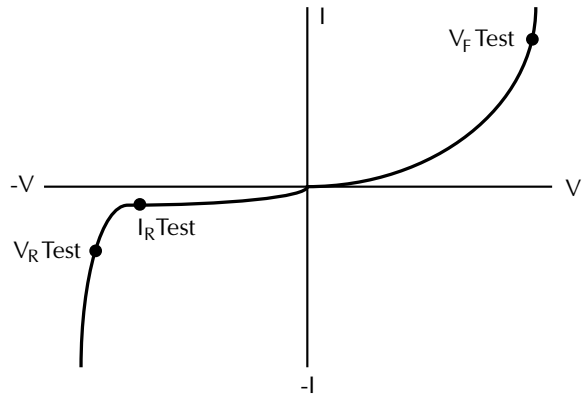
If, for example, your test requires that the diode be forward biased, you can configure the compliance limit test (LIMIT 1) to fail if out of compliance. This fail condition would indicate that the diode is forward biased, and the memory sweep will proceed to the next source memory location to perform the source-measure operation. If, however, the diode is installed backwards, the compliance limit test will PASS (in compliance). The pass condition will cause the sweep to branch to a memory location where the polarity of the source is reversed, again forward biasing the diode for the source-measure operation.

This branching technique simplifies installation of the diode in the component handler because polarity is no longer a concern. If the diode is installed backwards, the sweep will branch to a memory location that reverses source polarity.

Diode test example

Limit testing and a source memory sweep can be used to test a diode. Three tests that are typically performed on a diode include the Forward Voltage Test (V_F), Reverse Breakdown Voltage Test ($V_{R)}$ and Leakage Current Test (I_R). Figure 9-6 illustrates the test points on a typical diode curve.

Figure 9-6
Typical diode I-V curve and test points (not to scale)



Forward Voltage Test (V_F) — This test involves sourcing a specified forward bias current within the normal operating range of the diode, then measuring the resulting voltage drop. To pass the test, the voltage must be within the specified minimum and maximum values.

Reverse Breakdown Test (V_R) — A specified reverse current bias is sourced and the resulting voltage drop across the diode is measured. The voltage reading is compared to a specified minimum limit to determine the pass/fail status of the test.

Leakage Current Test (I_R) — The leakage test verifies the low level of current that leaks across the diode under reverse voltage conditions. A specified reverse voltage is sourced, then the resultant leakage current is measured. Good diodes have leakage current that is less than or equal to the specified maximum value.

This test example also uses sweep branching to simplify handling of each diode. No matter how the polarity sensitive diode is installed in the test fixture, it will be biased properly. See *Sweep branching* for details.

Testing process — The test uses seven SMLs (source memory locations). However, only four memory locations are used for each tested diode. If the diode is installed correctly, tests at locations 001, 002, 003, and 004 are performed. If the diode is installed backwards, tests at locations 001, 005, 006, and 007 are performed. To sweep four memory locations, the sweep count must be set to four. The source memory sweep is summarized as follows:

SML 001 — Compliance Test

- Limit 1 test – Fail if in compliance, branch to source memory location 005 for "pass" condition.
- Summary – Limit 1 test is configured such that if the diode is installed correctly in the test fixture, it will fail the compliance test and operation will proceed to the tests at memory locations 002, 003, and 004. If the diode is installed backwards, it will pass the compliance test, and operation will branch around locations 002, 003, and 004 to perform the tests at locations 005, 006, and 007. Source Memory Location 002 - Forward Voltage Test (diode installed correctly).

SML 002 — Forward Voltage Test

- Source I, Measure V.
- Limit 2 test – Min/max limits for voltage reading.
- Summary – The voltage measurement and the result of the test (pass or fail) is stored in the buffer.

SML 003 — Reverse Breakdown Test

- Source -I, Measure V.
- Limit 2 test – Min/max limits for voltage reading.
- Summary – The voltage measurement and the result of the test (pass or fail) is stored in the buffer.

SML 004 — Leakage Current Test

- Source -V, Measure I.
- Limit 2 test – Min/max limits for current reading.
- Summary – The current measurement and the result of the test (pass or fail) is stored in the buffer.

SML 005 — Forward Voltage Test

- Source -I, Measure V.
- Limit 2 test – Min/max limits for voltage reading.
- Summary – This test is the same as the test at memory location 002, except the source current is reversed to properly bias the diode that was installed backwards.

SML 006 — Reverse Breakdown Test

- Source +I, Measure V.
- Limit 2 test – Min/max limits for voltage reading.
- Summary – This test is the same as the test at memory location 003, except the source current is reversed to properly bias the diode that was installed backwards.

SML 007 — Leakage Current Test

- Source +V, Measure I.
- Limit 2 test – Min/max limits for current reading.
- Summary – This test is the same as the test at memory location 004, except the source voltage is reversed to properly bias the diode that was installed backwards.

Test results — The test results for the 4-point source memory sweep are stored in the buffer. Stored readings are accessed by pressing the RECALL key. Each of the four reading numbers are preceded by a "P" or an "F" to indicate the "Pass" or "Fail" result of the corresponding test. See Section 8 for details on the data store.

Configuring and running a sweep

Front panel sweep operation

Configuring a sweep

The sweep configuration menu is structured as follows and shown in Figure 9-7. Note that bullets indicate the primary items of the sweep menu and dashes indicate the options of each menu item. Using Section 1, *Rules to navigate menus*, go through the following menu to select and configure the desired sweep.

CONFIGURE SWEEPS menu:

Press CONFIG then SWEEP to display the sweep configuration menu.

- TYPE – Use this menu item to select the type of sweep:
  - STAIR – When the linear staircase sweep is selected, you will be prompted to enter the START, STOP, and STEP levels.
  - LOG – When the logarithmic staircase sweep is selected, you will be prompted to enter the START and STOP levels and specify the number of measurement points.
  - CUSTOM – With the custom sweep selected, you specify the number of measurement points (# POINTS) in the sweep and the source level at each point (ADJUST POINTS). With the INIT option, you can set a consecutive range of measurement points in the sweep to a specific level. For example, assume that for a 20-point custom voltage sweep (# POINTS = 20), you want points 10 through 15 to be set for 1V. After selecting the INIT option, set the VALUE to +1.000000V, set the START PT to 10, and set the STOP PT to 15.
  - SRC MEMORY – With the Source Memory Sweep selected, you specify the memory location START point to start the sweep (1 is the default) and the number of memory location points (# POINTS) in the sweep. When configured to sweep past point 100, the sweep automatically wraps around to point 1.

- SWEEP COUNT – Use this menu item to specify how many sweeps to perform:
  - FINITE – Use this option to enter a discrete number of sweeps to perform with the results stored in the data store buffer. The maximum number of finite sweeps that can be performed is determined as follows:

    maximum finite sweep count = 2500 / # Points in sweep
  - INFINITE – Select this option to continuously repeat the configured sweep. Use the EXIT key to stop the sweep. Data is not stored in the buffer.
- SOURCE RANGING – Use this menu item to control source ranging (ignored in source memory):
  - BEST FIXED – With this option, the SourceMeter will select a single fixed source range that will accommodate all of the source levels in the sweep. For example, if the minimum and maximum source levels in the sweep are 1V and 30V, the 200V source range will be used.
  - AUTO RANGE – With this option, the SourceMeter will select the most sensitive source range for each source level in the sweep. For example, for a 1V source level, the 2V source range will be used, and for a 3V source level, the 20V source range will be used. Note that the range changing process of AUTO RANGE may cause transients in the sweep. If these transients cannot be tolerated, use the BEST FIXED source range.
  - FIXED – With this option, the source remains on the range presently on when the sweep is started. For sweep points that exceed the source range capability, the source will output the maximum level for that range. For example, if the source is on the 2V range when the sweep is started, it will remain on the 2V range for the entire sweep. If the configured sweep points are 1V, 2V, 3V, 4V, and 5V, the sweep will be 1V, 2V, 2.1V, 2.1V, and 2.1V.

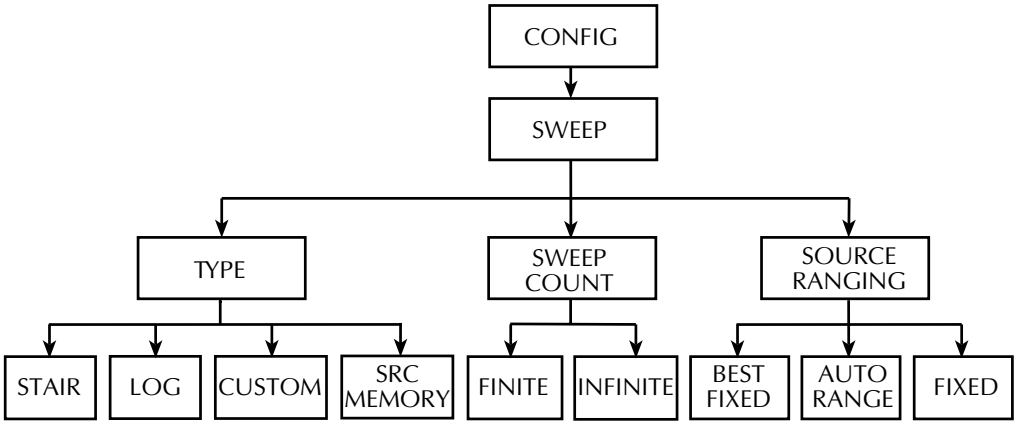


Figure 9-7
Sweep configuration menu tree

Setting delay

Generally, the time duration spent at each step (or point) of a sweep consists of the source delay and the time it takes to perform the measurement (NPLC setting).

The source delay is part of the SDM cycle and is used to allow the source to settle before the measurement is made. See Section 5, *Source-delay-measure cycle* for details.

The total time period of the source delay could include an auto-delay and/or a user programmed delay. With auto-delay enabled, 1ms of delay is used. The user programmable source delay adds 0000.0000 to 9999.9990 seconds of delay. See Section 3, *Source delay* to set these delays.

Additional delay for a sweep is available by using the trigger delay. This user-specified delay (0000.0000 to 9999.99990 seconds) occurs before each SDM cycle (device action) of the sweep. Thus, the trigger delay is executed before each new source-point in the sweep. See Section 10, *Trigger model* and *Configuring triggering* to set trigger delay.

NOTE *For linear staircase, log staircase, and custom sweeps, source delay, trigger delay, and NPLC settings are global and affect all sweep points simultaneously. For source memory sweep only, both the source delay and NPLC settings can be set to different values for each point in the sweep.*

Trigger count and sweep points

The trigger count and number of sweep points should be the same or multiples of one another. For example, with five sweep points and a trigger count of 10, the sweep will run twice. See Section 10 for details on trigger count.

Performing sweeps

Procedures for the various sweep types are covered below.

NOTE *The following procedure assumes that the SourceMeter is already connected to the DUT as explained in Section 2.*

WARNING **Hazardous voltages (≥30V rms) can appear on the selected INPUT/ OUTPUT LO or Remote PreAmp terminals when performing fast pulse sweep operations. To eliminate this shock hazard, connect the LO terminal to earth ground. The ground connection can be made at the chassis ground screw on the rear panel or to a known safety earth ground.**

Performing a linear staircase sweep

Step 1: Configure source-measure functions.

Configure the SourceMeter for the desired source-measure operations as follows:

1. Select the desired source function by pressing SOURCE V or SOURCE I.
2. Set the source level and compliance limit to the desired values.
3. Press MEAS V or MEAS I to select the desired measurement function, then choose the desired measurement range.

See Section 3, *Basic source-measure*, for more information.

The source level you set becomes the bias level for the sweep. When turned on, the output will maintain this bias level until the sweep is started. Typically, 0V or 0A is used as the bias level.

If using a fixed measurement range, make sure it can accommodate every measurement point in the sweep. Otherwise, use autoranging.

Step 2: Configure sweep.

Configure the sweep as follows:

1. Press CONFIG then SWEEP.
2. Select TYPE, then press ENTER.
3. Select STAIR, then press ENTER.
4. At the prompts, enter the desired START, STOP, and STEP values.
5. From the CONFIGURE SWEEPS menu, select SWEEP COUNT, press ENTER, then choose FINITE or INFINITE as desired.
6. Again from the CONFIGURE SWEEPS menu, choose SOURCE RANGING, press ENTER, then select BEST FIXED, AUTO RANGE, or FIXED as appropriate.
7. Press EXIT to return to normal display.

Step 3: Set delay.

Set the source delay as follows:

1. Press CONFIG then SOURCE V or SOURCE I depending on the selected source function.
2. Select DELAY, then press ENTER.
3. Set the delay to the desired value, then press ENTER.
4. Press EXIT to return to normal display.

Step 4: Turn output on.

Press the ON/OFF OUTPUT key to turn the output on (OUTPUT indicator turns on). The SourceMeter will output the programmed bias level.

Step 5: Run sweep.

To run the sweep, press the SWEEP key. After the sweep is completed, turn the output off by pressing the ON/OFF OUTPUT key.

Step 6: Read buffer.

Use the RECALL key to access the source-measure readings stored in the buffer. Use the TOGGLE to display statistical information. (See Section 8, *Data store*.)

Performing a log staircase sweep

Step 1: Configure source-measure functions.

Configure the SourceMeter for the desired source-measure operations as follows:

1. Select the desired source function by pressing SOURCE V or SOURCE I.
2. Set the source level and compliance limit to the desired values.
3. Press MEAS V or MEAS I to select the desired measurement function, then choose the desired measurement range.

Step 2: Configure sweep.

Configure the sweep as follows:

1. Press CONFIG then SWEEP.
2. Select TYPE, then press ENTER.
3. Select LOG, then press ENTER.
4. At the prompts, enter the desired START, STOP, and NO OF POINTS values.
5. From the CONFIGURE SWEEPS menu, select SWEEP COUNT, press ENTER, then choose FINITE or INFINITE as desired.
6. Again from the CONFIGURE SWEEPS menu, choose SOURCE RANGING, press ENTER, then select BEST FIXED, AUTO RANGE, or FIXED as appropriate.
7. Press EXIT to return to normal display.

Step 3: Set delay.

Set the source delay as follows:

1. Press CONFIG then SOURCE V or SOURCE I depending on the selected source function.
2. Select DELAY, then press ENTER.
3. Set the delay to the desired value, then press ENTER.
4. Press EXIT to return to normal display.

Step 4: Turn output on.

Press the ON/OFF OUTPUT key to turn the output on (OUTPUT indicator turns on). The SourceMeter will output the programmed bias level.

Step 5: Run sweep.

To run the sweep, press the SWEEP key. After the sweep is completed, turn the output off by pressing the ON/OFF OUTPUT key.

Step 6: Read buffer.

Use the RECALL key to access the source-measure readings stored in the buffer. Use the TOGGLE to display statistical information.

Performing a custom sweep

Step 1: Configure source-measure functions.

Configure the SourceMeter for the desired source-measure operations as follows:

1. Select the desired source function by pressing SOURCE V or SOURCE I.
2. Set the source level and compliance limit to the desired values.
3. Press MEAS V or MEAS I to select the desired measurement function, then choose the desired measurement range.

Step 2: Configure sweep.

Configure the sweep as follows:

1. Press CONFIG then SWEEP.
2. Select TYPE, then press ENTER.
3. Select CUSTOM, then press ENTER.
4. Use the displayed menu selections to enter the desired # POINTS, individual point values (ADJUST POINTS), and INIT (initial) value.
5. From the CONFIGURE SWEEPS menu, select SWEEP COUNT, press ENTER, then choose FINITE or INFINITE as desired.
6. Again from the CONFIGURE SWEEPS menu, choose SOURCE RANGING, press ENTER, then select BEST FIXED, AUTO RANGE, or FIXED as appropriate.
7. Press EXIT to return to normal display.

Step 3: Set delay.

Set the source delay as follows:

1. Press CONFIG then SOURCE V or SOURCE I depending on the selected source function.
2. Select DELAY, then press ENTER.
3. Set the delay to the desired value, then press ENTER.
4. Press EXIT to return to normal display.

Step 4: Turn output on.

Press the ON/OFF OUTPUT key to turn the output on (OUTPUT indicator turns on). The SourceMeter will output the programmed bias level.

Step 5: Run sweep.

To run the sweep, press the SWEEP key. After the sweep is completed, turn the output off by pressing the ON/OFF OUTPUT key.

Step 6: Read buffer.

Use the RECALL key to access the source-measure readings stored in the buffer. Use the TOGGLE to display statistical information.

Performing a source memory sweep

Step 1: Store setups in source memory.

Store instrument setups in source memory as follows:

1. Configure the SourceMeter for various desired operating modes such as source, measure, delay, and/or math expression operation. See Table 9-2 for settings that can be stored in each source memory location.
2. Press MENU to display the MAIN MENU:
   - Select SAVESETUP.
   - Select SOURCE MEMORY.
   - Select SAVE.
   - Use the ▲ and ▼ keys, and the cursor keys to display the desired memory location, and press ENTER.
   - Use the EXIT key to back out of the menu structure.
3. Repeat Steps 1 and 2 for all points in the sweep.

Step 2: Configure sweep

Configure the sweep as follows:

1. Press CONFIG then SWEEP.
2. Select TYPE, then press ENTER.
3. Select SRC MEMORY, then press ENTER.
4. Use the menu selections to enter the desired START memory location and # POINTS for the source memory sweep.
5. From the CONFIGURE SWEEPS menu, select SWEEP COUNT, press ENTER, then choose FINITE or INFINITE as desired.
6. Again from the CONFIGURE SWEEPS menu, choose SOURCE RANGING, press ENTER, then select BEST FIXED, AUTO RANGE, or FIXED as appropriate.
7. Press EXIT to return to normal display.

Step 3: Turn output on.

Press the ON/OFF OUTPUT key to turn the output on (OUTPUT indicator turns on).

Step 4: Run sweep.

To run the sweep, press the SWEEP key. After the sweep is completed, turn the output off by pressing the ON/OFF OUTPUT key.

Step 5: Read buffer.

Use the RECALL key to access the source-measure readings stored in the buffer. Use the TOGGLE to display statistical information.

Remote sweep operation

Staircase sweep commands

Table 9-3 summarizes remote commands used for linear and log staircase sweep operation. See Section 17, *Configure voltage and current sweeps*, for more details on these commands.

Table 9-3
Linear and log staircase sweep commands

Command	Description
:SOURce:CURRent:MODE SWEep	Select current source sweep mode.
:SOURce:CURRent:STARt <n>	Specify sweep start current (n = current).
:SOURce:CURRent:STOP <n>	Specify sweep stop current (n = current).
:SOURce:CURRent:STEP <n>	Specify sweep step current (n = current).
:SOURce:CURRent:CENTer <n>	Specify sweep center current (n = current).
:SOURce:CURRent:SPAN <n>	Specify sweep span current (n = current).
:SOURce:VOLTage:MODE SWEep	Select voltage source sweep mode.
:SOURce:VOLTage:STARt <n>	Specify sweep start voltage (n = voltage).
:SOURce:VOLTage:STOP <n>	Specify sweep stop voltage (n = voltage).
:SOURce:VOLTage:STEP <n>	Specify sweep step voltage (n = voltage).
:SOURce:VOLTage:CENTer <n>	Specify sweep center voltage (n = voltage).
:SOURce:VOLTage:SPAN <n>	Specify sweep span voltage (n = voltage).
:SOURce:SWEep:RANGing <name>	Select source ranging (name = BEST, AUTO, or FIXed).
:SOURce:SWEep:SPACing <name>	Select sweep scale (name = LINear or LOGarithmic).
:SOURce:SWEep:POINts <n>	Set number of sweep points (n = points).
:SOURce:SWEep:DIREction <name>	Set sweep direction. Name = UP (sweep start to stop) or DOWn (sweep stop to start).

Staircase sweep programming example

As an example of linear staircase sweep operation, assume the SourceMeter is to be used to generate the I-V characteristics of a diode. Many diode tests, such as breakdown voltage and leakage current, require only single-point measurements. Some, such as quality-assurance analysis of marginal parts, involve performing a complete I-V sweep for detailed analysis.

For the purposes of this test, assume the following basic sweep parameters:

Source Function: current
Sense Function: volts
Source Mode: sweep
Start Current: 1mA
Stop Current: 10mA
Step Current: 1mA
Voltage Compliance: 1V
Source Delay: 100ms

Figure 9-8 shows typical test connections for this test, and Figure 9-9 shows a typical diode curve. Note that the diode anode is connected to HI, and the cathode is connected to LO. These connections are required to properly forward bias the diode for the purposes of the test. The test connections could also be reversed by using negative sweep voltage parameters.

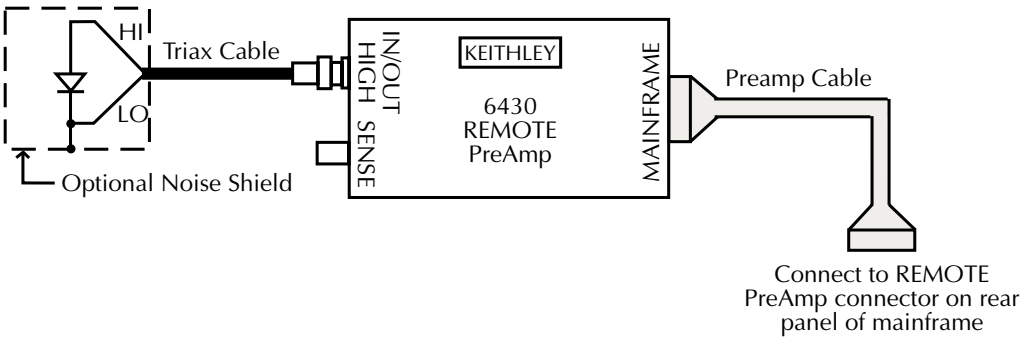


Figure 9-8
Connections for diode I-V tests

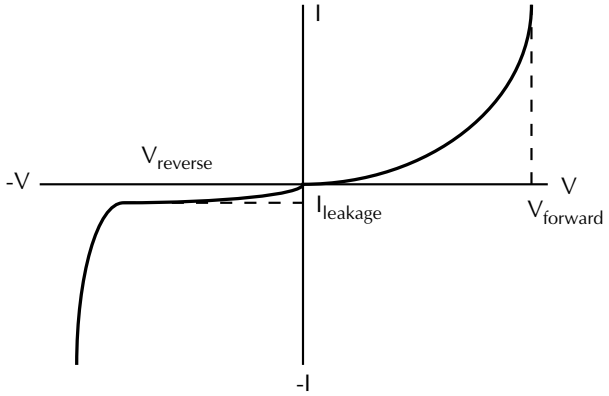


Figure 9-9
Diode I-V curve

Table 9-4 lists the command sequence for the diode programming example.

Table 9-4
Staircase sweep programming example (diode test)

Command	Description
*RST	Restore GPIB default conditions.
:SENS:FUNC:CONC OFF	Turn off concurrent functions.
:SOUR:FUNC CURR	Current source function.
:SENS:FUNC 'VOLT:DC'	Volts sense function.
:SENS:VOLT:PROT 1	1V voltage compliance.
:SOUR:CURR:START 1E-3	1mA start current.
:SOUR:CURR:STOP 10E-3	10mA stop current.
:SOUR:CURR:STEP 1E-3	1mA step current.
:SOUR:CURR:MODE SWE	Select current sweep mode.[1]
:SOUR:SWE:RANG AUTO	Auto source ranging.
:SOUR:SWE:SPAC LIN	Select linear staircase sweep.
:TRIG:COUN 10	Trigger count = # sweep points.[2]
:SOUR:DEL 0.1	100ms source delay.
:OUTP ON	Turn on source output.
:READ?	Trigger sweep, request data.

[1]This command should normally be sent after START, STOP, and STEP to avoid delays caused by rebuilding sweep when each command is sent.
[2]For single sweep, trigger count should equal number of points in sweep: Points = (Stop-Start)/Step + 1. You can use SOUR:SWE:POIN? query to read the number of points.

Custom sweep commands

Table 9-5 summarizes remote commands used for custom sweep operation. See Section 17, *Configure list*, for more details on these commands.

Table 9-5
Custom sweep commands

Command	Description
:SOURce:CURRent:MODE LIST	Select current list (custom) sweep mode.
:SOURce:VOLTage:MODE LIST	Select voltage list (custom) sweep mode.
:SOURce:LIST:CURRent <list>	Define I-source (list = I1, I2,… In).
:SOURce:LIST:CURRent:APPend <list>	Add I-source list value(s) (list =I1, I2,…In).
:SOURce:LIST:CURRent:POINts?	Query length of I-source list.
:SOURce:LIST:VOLTage < list>	Define V-source list (list = V1, V2,… Vn).
:SOURce:LIST:VOLTage:APPend <list>	Add V-source list value(s) (list =V1, V2,…Vn).
:SOURce:LIST:VOLTage:POINts?	Query length of V-source list.
:SOURce:SWEep:RANGing <name>	Select source ranging (name = BEST, AUTO, or FIXed).

Custom sweep programming example

As an example of custom sweep operation, assume a five-point sweep with the following parameters:

Source Function: volts
Sense Function: current
Voltage Sweep Mode: list (custom sweep)
Sweep Voltage Points: 7V, 1V, 3V, 8V, 2V
Current Compliance: 100mA
Source Delay: 100ms

Table 9-6 summarizes the basic remote command sequence for performing the custom sweep described above.

Table 9-6
Custom sweep programming example

Command	Description
*RST	Restore GPIB default conditions.
:SENS:FUNC:CONC OFF	Turn off concurrent functions.
:SOUR:FUNC VOLT	Volts source function.
:SENS:FUNC 'CURR:DC'	Current sense function.
:SENS:CURR:PROT 0.1	100mA current compliance.
:SOUR:VOLT:MODE LIST	List volts sweep mode.
:SOUR:LIST:VOLT 7,1,3,8,2	7V, 1V, 3V, 8V, 2V sweep points.
:TRIG:COUN 5	Trigger count = # sweep points.
:SOUR:DEL 0.1	100ms source delay.
:OUTP ON	Turn on source output.
:READ?	Trigger sweep, request data.

Source memory sweep commands

Table 9-7 summarizes remote commands used for custom sweep operation. See Section 17, *Configure memory sweep*, for more details on these commands.

Table 9-7
Source memory sweep commands

Command	Description
:SOURce:FUNCtion MEM	Select memory sweep mode.
:SOURce:MEMory:POINts <n>	Specify number of sweep points (n = points).
:SOURce:MEMory:STARt <n>	Select source memory start location (n =location).
:SOURce:MEMory:RECall <n>	Return to specified setup (n = memory location).
:SOURce:SAVE <n>	Save setup in memory (n = memory location).

Source memory sweep programming example

As an example of source memory sweep operation, assume a three-point sweep with the following operating modes:

Source Memory Location #1: source voltage, measure current, 10V source value
Source Memory Location #2: source current, measure voltage, 100mA source value
Source Memory Location #3: source current, measure current, 100mA source value

Table 9-8 summarizes the basic remote command sequence for performing the basic source memory sweep described above.

Table 9-8
Source memory sweep programming example

Command	Description
*RST	Restore GPIB default conditions.
:SENS:FUNC:CONC OFF	Turn off concurrent functions.
:SOUR:FUNC MEM	Source memory sweep mode.
:SOUR:MEM:POIN 3	Number memory points = 3.
:SOUR:MEM:STAR 1	Start at memory location 1.
:SOUR:FUNC VOLT	Volts source function.
:SENS:FUNC ‘CURR:DC’	Current sense function.
:SOUR:VOLT 10	10V source voltage.
:SOUR:MEM:SAVE 1	Save in source memory location 1.
:SOUR:FUNC CURR	Current source function.
:SENS:FUNC ‘VOLT:DC’	Volts sense function.
:SOUR:CURR 100E-3	100mA source current.
:SOUR:MEM:SAVE 2	Save in source memory location 2.
:SENS:FUNC ‘CURR:DC’	Current sense function.
:SOUR:MEM:SAVE 3	Save in source memory location 3.
:TRIG:COUN 3	Trigger count = # sweep points.
:OUTP ON	Turn on source output.
:READ?	Trigger sweep, request data.

Sweep branching program example

The code fragment below is a Visual Basic sweep branching subroutine. This example sets up source memory locations 1-3 as indicated in code comments. Location 100 is used as a dummy location. Failure at any one of locations 1-3 causes a branch to location 100 to stop the sweep as soon as possible in the event of failure. For all three source memory locations, operating modes are set as follows:

- Source function: volts, 10V output voltage
- Measurement function: current, 100mA range, 105mA compliance
- Delay: 1s

Test limits for the three memory locations are:

- Location 1: 10mA to 20mA
- Location 2: 20mA to 30mA
- Location 3: 30mA to 40mA

```
Attribute VB_Name = "Headers"
Option Explicit

Public Sub RunSourceMemory()

Dim intGPIB As Integer
Dim strAnswer As String

intGPIB = 24                                          ' Primary address = 24.

Call OutputCmd(intGPIB, ":TRAC:CLE")                  'Clear Readings from Buffer

'Setup Source Memory Location 1
'------------------------------
Call OutputCmd(intGPIB, "*RST")                       'Restore GPIB default conditions.
Call OutputCmd(intGPIB, ":SOUR:FUNC VOLT")            'Current Source Function.
Call OutputCmd(intGPIB, ":SENS:FUNC 'CURR:DC'")       'Current Sense Function.
Call OutputCmd(intGPIB, ":SENS:CURR:PROT .105")       'Set 105mA Compliance
Call OutputCmd(intGPIB, ":SENS:CURR:RANGE .1")        'Set 100mA Current Measure Range
Call OutputCmd(intGPIB, ":SOUR:DEL 1")                'Set Source Delay to 1
Call OutputCmd(intGPIB, ":SOUR:VOLT 10")              '10V Source Voltage.
Call OutputCmd(intGPIB, ":CALC2:FEED CURR")           'Send Current(A) Readings to Buffer

Call OutputCmd(intGPIB, ":CALC2:LIM1:STAT ON")        'Set Limit1 on
Call OutputCmd(intGPIB, ":CALC2:LIM1:COMP:FAIL IN")   'Set Fail Mode to In Compliance
Call OutputCmd(intGPIB, ":CALC2:LIM1:COMP:SOUR2 8")   'Set Digital Output Pattern for Compliance Failure

Call OutputCmd(intGPIB, ":CALC2:LIM2:STAT ON")        'Set Limit2 on
Call OutputCmd(intGPIB, ":CALC2:LIM2:UPP 2E-2")       'Set Upper Limit to 20mA
Call OutputCmd(intGPIB, ":CALC2:LIM2:LOW 1E-3")       'Set Lower Limit to 10mA
Call OutputCmd(intGPIB, ":CALC2:LIM2:UPP:SOUR2 2")    'Set Digital Output Pattern for Upper Limit #2
Failure
Call OutputCmd(intGPIB, ":CALC2:LIM2:LOW:SOUR2 3")    'Set Digital Output Pattern for Lower Limit #2
Failure
Call OutputCmd(intGPIB, ":CALC2:CLIM:PASS:SOUR2 13") 'Set Digital Output Pattern for Limit #2 Passing

Call OutputCmd(intGPIB, ":CALC2:CLIM:MODE GRAD")      'Set Limit Results to Grading
Call OutputCmd(intGPIB, ":CALC2:CLIM:BCON END")       'Set Binning Control to End
Call OutputCmd(intGPIB, ":CALC2:CLIM:PASS:SML NEXT") 'Set SML Pass Location
Call OutputCmd(intGPIB, ":CALC2:CLIM:FAIL:SML 100")   'Set SML Fail Location
Call OutputCmd(intGPIB, ":SOUR:MEM:SAVE 1")           'Save in Source Memory Location 1.
```

```
'Setup Source Memory Location 2
'------------------------------
Call OutputCmd(intGPIB, "*RST")                      'Restore GPIB default conditions.
Call OutputCmd(intGPIB, ":SOUR:FUNC VOLT")           'Current Source Function.
Call OutputCmd(intGPIB, ":SENS:FUNC 'CURR:DC'")      'Current Sense Function.
Call OutputCmd(intGPIB, ":SENS:CURR:PROT .105")      'Set 105mA Compliance
Call OutputCmd(intGPIB, ":SENS:CURR:RANGE .1")       'Set 100mA Current Measure Range
Call OutputCmd(intGPIB, ":SOUR:DEL 1")               'Set Source Delay to 1
Call OutputCmd(intGPIB, ":SOUR:VOLT 10")             '10V Source Voltage.
Call OutputCmd(intGPIB, ":CALC2:FEED CURR")          'Send Current(A) Readings to Buffer

Call OutputCmd(intGPIB, ":CALC2:LIM1:STAT ON")       'Set Limit 1 on
Call OutputCmd(intGPIB, ":CALC2:LIM1:COMP:FAIL IN")  'Set Fail Mode to In Compliance
Call OutputCmd(intGPIB, ":CALC2:LIM1:COMP:SOUR2 5")  'Set Digital Output Pattern for Compliance Failure

Call OutputCmd(intGPIB, ":CALC2:LIM2:STAT ON")       'Set Limit2 on
Call OutputCmd(intGPIB, ":CALC2:LIM2:UPP 3E-2")      'Set Upper Limit to 30mA
Call OutputCmd(intGPIB, ":CALC2:LIM2:LOW 2E-2")      'Set Lower Limit to 20mA
Call OutputCmd(intGPIB, ":CALC2:LIM2:UPP:SOUR2 4")   'Set Digital Output Pattern for Upper Limit #2
Failure
Call OutputCmd(intGPIB, ":CALC2:LIM2:LOW:SOUR2 5")   'Set Digital Output Pattern for Lower Limit #2
Failure
Call OutputCmd(intGPIB, ":CALC2:CLIM:PASS:SOUR2 14") 'Set Digital Output Pattern for Limit #2 Passing

Call OutputCmd(intGPIB, ":CALC2:CLIM:MODE GRAD")     'Set Limit Results to Grading
Call OutputCmd(intGPIB, ":CALC2:CLIM:BCON END")      'Set Binning Control to End
Call OutputCmd(intGPIB, ":CALC2:CLIM:PASS:SML NEXT") 'Set SML Pass Location
Call OutputCmd(intGPIB, ":CALC2:CLIM:FAIL:SML 100")  'Set SML Fail Location
Call OutputCmd(intGPIB, ":SOUR:MEM:SAVE 2")          'Save in Source Memory Location 2.


'Setup Source Memory Location 3
'------------------------------
Call OutputCmd(intGPIB, "*RST")                      'Restore GPIB default conditions.
Call OutputCmd(intGPIB, ":SOUR:FUNC VOLT")           'Current Source Function.
Call OutputCmd(intGPIB, ":SENS:FUNC 'CURR:DC'")      'Current Sense Function.
Call OutputCmd(intGPIB, ":SENS:CURR:PROT .105")      'Set 105mA Compliance
Call OutputCmd(intGPIB, ":SENS:CURR:RANGE .1")       'Set 100mA Current Measure Range
Call OutputCmd(intGPIB, ":SOUR:DEL 1")               'Set Source Delay to 1
Call OutputCmd(intGPIB, ":SOUR:VOLT 10")             '10V Source Voltage.
Call OutputCmd(intGPIB, ":CALC2:FEED CURR")          'Send Current(A) Readings to Buffer

Call OutputCmd(intGPIB, ":CALC2:LIM1:STAT ON")       'Set Limit 1 on
Call OutputCmd(intGPIB, ":CALC2:LIM1:COMP:FAIL IN")  'Set Fail Mode to In Compliance
Call OutputCmd(intGPIB, ":CALC2:LIM1:COMP:SOUR2 10") 'Set Digital Output Pattern for Compliance Failure

Call OutputCmd(intGPIB, ":CALC2:LIM2:STAT ON")       'Set Limit2 on
Call OutputCmd(intGPIB, ":CALC2:LIM2:UPP 4E-2")      'Set Upper Limit to 40mA
Call OutputCmd(intGPIB, ":CALC2:LIM2:LOW 3E-3")      'Set Lower Limit to 30mA
Call OutputCmd(intGPIB, ":CALC2:LIM2:UPP:SOUR2 6")   'Set Digital Output Pattern for Upper Limit #2
Failure
Call OutputCmd(intGPIB, ":CALC2:LIM2:LOW:SOUR2 7")   'Set Digital Output Pattern for Lower Limit #2
Failure
Call OutputCmd(intGPIB, ":CALC2:cLIM:PASS:SOUR2 15") 'Set Digital Output Pattern for Limit #2 Passing

Call OutputCmd(intGPIB, ":CALC2:CLIM:MODE GRAD")     'Set Limit Results to Grading
Call OutputCmd(intGPIB, ":CALC2:CLIM:BCON END")      'Set Binning Control to End
Call OutputCmd(intGPIB, ":CALC2:CLIM:PASS:SML NEXT") 'Set SML Pass Location
Call OutputCmd(intGPIB, ":CALC2:CLIM:FAIL:SML 100")  'Set SML Fail Location
Call OutputCmd(intGPIB, ":SOUR:MEM:SAVE 3")          'Save in source memory location 3.
```

```
‘Setup Source Memory Location 100 (Dummy Location)   ‘Turn off everything to increase speed.
‘-----------------------------------------------------
‘ Using a Dummy Location allows the Source Memory
‘ Sweep to stop testing the DUT as quickly as possible.
‘ This allows the test setup to ensure high yields and
‘ to not waste test time on devices that fail early
‘ in the Source Memory Sweep.
‘-----------------------------------------------------
Call OutputCmd(intGPIB, “*RST”)                      ‘Restore GPIB default conditions.
Call OutputCmd(intGPIB, “:SOUR:DEL 0”)               ‘Set Source Delay to 0
Call OutputCmd(intGPIB, “:SOUR:VOLT 0”)              ‘Set Source Voltage to 0
Call OutputCmd(intGPIB, “:SENS:FUNC:OFF:ALL”)        ‘Turn off all Measure Functions

Call OutputCmd(intGPIB, “:CALC2:LIM1:STAT OFF”)      ‘Turn Limit 1 Off
Call OutputCmd(intGPIB, “:CALC2:LIM2:STAT OFF”)      ‘Turn Limit 2 Off
Call OutputCmd(intGPIB, “:CALC2:CLIM:PASS:SML NEXT”) ‘Set SML Pass Location
Call OutputCmd(intGPIB, “:CALC2:CLIM:FAIL:SML 100”)  ‘Set SML Fail Location
Call OutputCmd(intGPIB, “:SOUR:MEM:SAVE 100”)        ‘Save in source memory location 100.

Call OutputCmd(intGPIB, “*RST”)                      ‘Restore GPIB default conditions.
Call OutputCmd(intGPIB, “:CALC2:CLIM:BCON END”)
Call OutputCmd(intGPIB, “:SENSE:FUNC:CONC OFF”)      ‘Turn off Concurrent Functions.
Call OutputCmd(intGPIB, “TRIG:COUN 3”)               ‘Trigger count = # sweep points.
Call OutputCmd(intGPIB, “:SOUR:FUNC MEM”)            ‘Source Memory sweep Mode.
Call OutputCmd(intGPIB, “:SOUR:MEM:POIN 3”)          ‘Number of Memory Points = 3.
Call OutputCmd(intGPIB, “:SOUR:MEM:STAR 1”)          ‘Start @ Memory Location 1.
Call OutputCmd(intGPIB, “SOUR2:CLE:AUTO ON;:SOUR2:CLE:AUTO:DEL 1”) ‘Set Digital I/O auto-clear
Call OutputCmd(intGPIB, “:CALC2:cLIM:PASS:SOUR2 12”  ‘Set Digital Output Pattern for Limit #2 Passing
Call OutputCmd(intGPIB, “OUTPUT ON”)                 ‘Turn on Output
Call OutputCmd(intGPIB, “:INIT”)                     ‘Trigger Sweep.

End Sub
```

10 Triggering

- **Trigger Model** — Discusses the trigger model, including various layers, event detection, delay, and device action.
- **Trigger Link** — Discusses the trigger link, including input triggers, output triggers, and external triggering example.
- **Configuring Triggering** — Details how to configure the various triggering aspects.
- **Remote Triggering** — Details the remote trigger model, summarizes trigger commands, and gives a basic triggering example.

Trigger model (front panel operation)

The flowchart in Figure 10-1 summarizes triggering for front panel operation. The trigger model is modeled after the remote commands used to control triggering. Refer to *Trigger model (remote operation)* later in this section. Key trigger model settings are included in the flowchart. Note that the BENCH defaults are denoted by the "✣" symbol.

The primary actions of the trigger model are Source, Delay, and Measure. The source action outputs the programmed voltage or current value, and the programmed delay provides a settling period for the source before the measurement is performed.

The trigger model consists of two layers (Arm Layer and Trigger Layer) to provide versatility. Programmable counters allow operations to be repeated, and various input and output trigger options are available to provide source-measure synchronization between the SourceMeter and other instruments (via the Trigger Link).

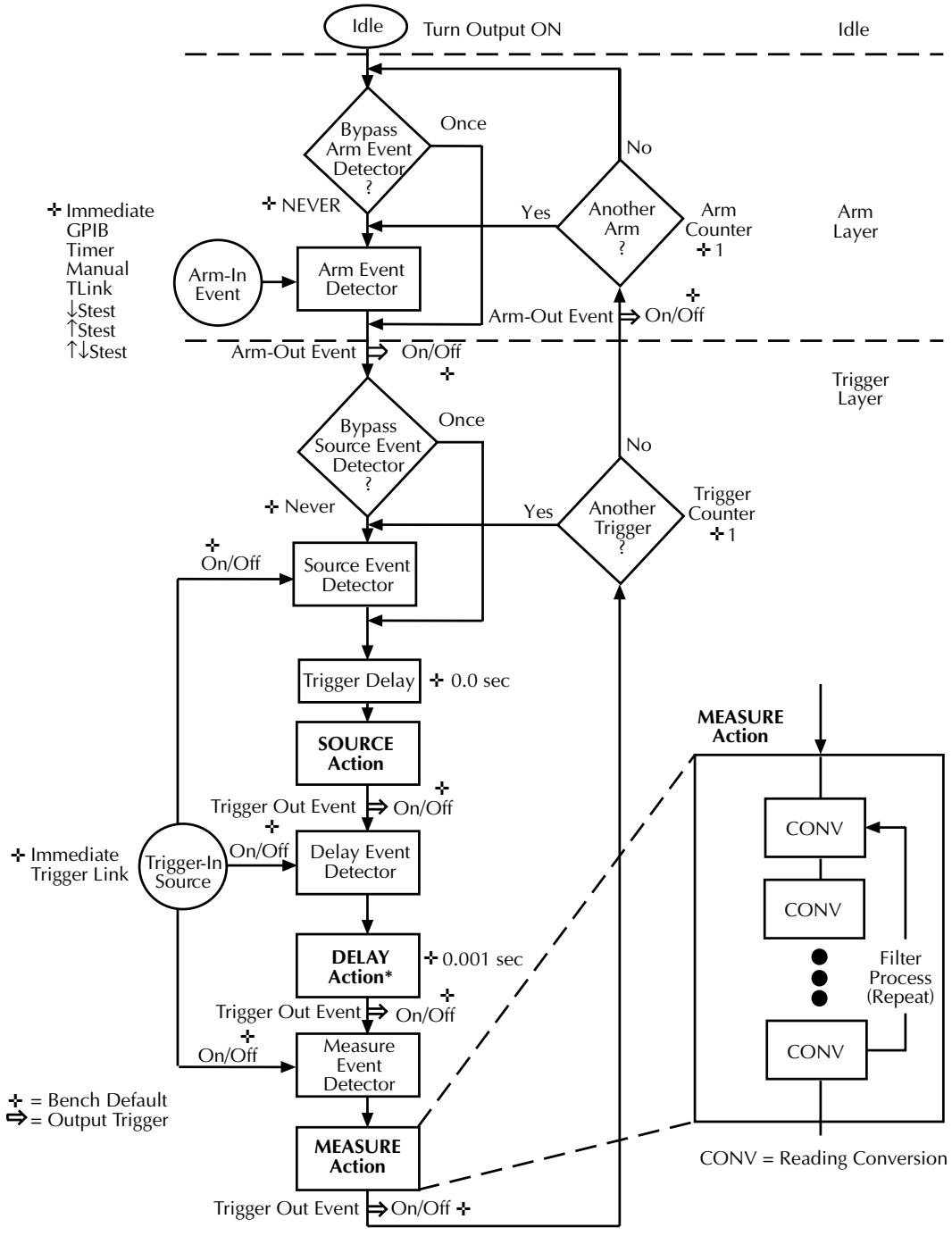
Unless otherwise noted, the programmable aspects of the trigger model are performed from the CONFIGURE TRIGGER menu. See *Configuring triggering*.

Idle

The SourceMeter is in idle when it is not operating in the Arm Layer or Trigger Layer of the trigger model. When in idle, the ARM annunciator is off. To take the SourceMeter out of idle, turn the output ON.

The SourceMeter can be returned to idle at any time by selecting the HALT menu item of the CONFIGURE TRIGGER menu. See *Configuring triggering*.

Figure 10-1
Trigger model (front panel operation)



*Soak time takes the place of the delay time only during the first SDM cycle after initial sweep trigger if the unit is in the MULTIPLE mode. See Section 6, *Auto range change mode*.

Event detection

In general, operation is held up at an Event Detector until the programmed event occurs. Note however, that if an event detector has a bypass, operation can be programmed to loop around the event detector.

Arm layer

Event Detector Bypass — As shown in Figure 10-1, there is a bypass for the Arm Event Detector. This bypass can only be used if TLINK or STEST is the selected Arm-In Event. The bypass serves to "jump-start" operation. With the event detector bypass set to ONCE, operation will loop around the Arm Event Detector when the output is turned ON.

The programmable arm-in events for the Arm Layer are described as follows:

IMMEDIATE — Event detection occurs immediately allowing operation to continue.

GPIB — Event detection occurs when a bus trigger (GET or *TRG) is received.

TIMER — With the Timer selected, event detection occurs immediately when the output is turned ON. On repeated passes via "Another Arm ? Yes", event detection occurs when the programmed timer interval expires. If operation takes the "Another Arm ? No" route, the Timer resets allowing event detection to again occur immediately.

MANUAL — Event detection occurs when the TRIG key is pressed.

TLINK — Event detection occurs when an input trigger via the Trigger Link input line is received (see Trigger link for more information). With TLink selected, you can loop around the Arm Event Detector by setting the event detector bypass to ONCE.

↓**STEST** — Event detection occurs when the SOT (start of test) line of the Digital I/O port is pulsed low. This pulse is received from the handler to start limit testing. See Section 11.

↑**STEST** — Event detection occurs when the SOT (start of test) line of the Digital I/O port is pulsed high. This pulse is received from the handler to start limit testing. See Section 11.

↑↓**STEST** — Event detection occurs when the SOT (start of test) line of the Digital I/O port is pulsed either high or low. This pulse is received from the handler to start limit testing. See Section 11.

NOTE *STEST can be used only at the beginning of a sweep and should not be used to trigger each point in a sweep.*

Trigger layer

The Trigger Layer uses three event detectors; one for each action (Source, Delay, and Measure).

Event Detector Bypass — As shown in Figure 10-1, there is a bypass for the Source Event Detector. This bypass is in effect only if Trigger Link is the selected Trigger-In Source. With this event detector bypass set to ONCE, operation will proceed around the Source Event Detector.

The programmable trigger-in sources for the Trigger Layer are described as follows:

IMMEDIATE — With Immediate selected, event detection for the three detectors is satisfied immediately. Operation proceeds through the Trigger Layer to perform the Source, Delay, and Measure actions.

TRIGGER LINK — With Trigger Link selected, event detection at each enabled detector occurs when an input trigger via the Trigger Link input line is received. For example, if the Trigger In Event for the Source Event Detector is ON, operation will hold up at that detector until an input trigger is received. If, however, the Source Event Detector is disabled (OFF), operation will not hold up. Operation will simply continue on and perform the Source action.

With the Trigger Link Trigger-In Source selected, operation will go around the Source Event Detector (Figure 10-1) by setting the event detector bypass to ONCE.

Trigger delay

A programmable delay is available before the Source Action. The Trigger Delay can be manually set from 0.00000 to 999.99990 seconds. Note that this delay is separate from the Delay Action of the SDM cycle. The Delay Action is discussed next.

Source, delay, and measure actions

The SDM cycle of the SourceMeter consists of three actions: Source, Delay, and Measure:

SOURCE Action — Any programmed output voltage or current level changes are performed.

DELAY Action — This programmable delay is used to allow the source to settle before a measurement is performed. It can be manually set from 0.00000 to 9999.99900 seconds, or Auto Delay can be enabled. With Auto Delay enabled, the SourceMeter automatically selects a nominal delay period based on the selected function and range.

NOTE *The Delay Action is set from the CONFIGURE V-SOURCE or CONFIGURE I-SOURCE menu. See Section 3, "Source delay."*

In MULTIPLE mode, the soak time takes the place of the delay time only during the first SDM cycle after the initial sweep trigger. See Section 6, "Auto range change mode."

MEASURE Action — During this phase of the SDM cycle, the measurement process takes place. If the repeat filter is enabled, as shown in the blow-up drawing for Measure Action, the instrument samples the specified number of reading conversions to yield a single filtered reading (measurement). If using the moving filter or if the filter is disabled, only a single reading conversion will yield a reading.

Counters

Programmable counters are used to repeat operations within the trigger model layers. For example, if performing a 10-point sweep, the trigger counter would be set to 10. Operation will stay in the Trigger Layer until the 10 source-delay-measure points of the sweep are performed.

If you wanted to repeat the sweep three times, the arm counter would be set to three. Three 10-point sweeps can then be performed for a total of 30 source-delay-measure actions.

The maximum buffer size for the SourceMeter is 2500 readings. The product of the two counter values cannot exceed 2500. For example, if you set an arm count of two, the maximum trigger count will be 1250 (2500 / 2 = 1250). However, you can set the arm count to INFINITE. With an infinite arm count, the maximum trigger count is 2500.

NOTE *When a sweep is configured, the trigger model settings will not change until the sweep is started. After the sweep is finished, the trigger model will reset back to the previous settings.*

Output triggers

The SourceMeter can be programmed to output a trigger (via rear panel Trigger Link connector) after various trigger model operations. An output trigger is used to trigger another instrument to perform an operation. See *Trigger link* for more information.

Trigger Layer Output Triggers — After each action (Source, Delay, and Measure), the SourceMeter can be programmed to send out an output trigger if Trigger Link is the selected Trigger-In Source. For example, if the Trigger Out Event for Measure is ON, an output trigger will be sent after the Measure action. When used with a scanner, an output trigger after each measurement can signal the scanner to select the next channel in the scan.

Arm Layer Output Triggers — The SourceMeter can also be programmed to output a trigger when operation enters the Trigger Layer, or after operation leaves the Trigger Layer and enters back into the Arm Layer. This output trigger is typically sent to another instrument to signal the end of a scan or sweep.

Bench defaults

The bench defaults are listed as follows. They are also denoted in Figure 10-1 by the "✣" symbol.

- Arm-In Event = Immediate
- Trigger-In Source = Immediate
- Arm Count = 1
- Trigger Count = 1
- Trigger Delay = 0.0 sec
- Delay Action = 0.001 sec
- Source Trigger In Event = On
- Delay Trigger In Event = Off
- Measure Trigger In Event = Off
- Trigger Out Events = All Trigger Out Events are disabled (off)
- Arm Out Events = Off
- Event Detection Bypasses = Never (both layers)

When the output is turned ON, the SourceMeter will run in a continuous loop around the trigger model. After each Measure Action, operation will continue at the top of the trigger model. The SourceMeter can be returned to idle by turning the output OFF.

Operation summary

The trigger model is designed to offer versatility for the various source-measure applications. Typically, it allows you to perform a specified number of measurements at various source levels.

For example, assume you want to perform three measurements each at two different V-source levels (1V and 2V). To do this, set the arm count to two, the trigger count to three, and use a 6-point Custom Sweep configured as follows:

P0000 = 1V
P0001 = 1V
P0002 = 1V
P0003 = 2V
P0004 = 2V
P0005 = 2V

When the sweep is started, operation falls into the Trigger Layer and performs three measurements at the 1V source level. Operation then loops back into the Trigger Layer to perform three measurements at the 2V source level. The six readings are stored in the buffer.

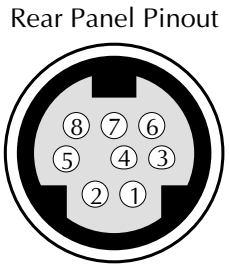
Note that after the sweep is finished, the SourceMeter does not return to idle. Operation continues at the top of the trigger model. Subsequent measurements are performed at the 2V level and are not stored in the buffer.

For details on the Custom Sweep, see Section 9.

Trigger link

Input and output triggers are received and sent via the rear panel TRIGGER LINK connector. The trigger link has four lines. At the factory, line #2 is selected for output triggers, and line #1 is selected for input triggers. These input/output line assignments can be changed from the CONFIGURE TRIGGER menu. See *Configuring triggering* later in this section. The connector pinout is shown in Figure 10-2.

Figure 10-2
Rear panel pinout

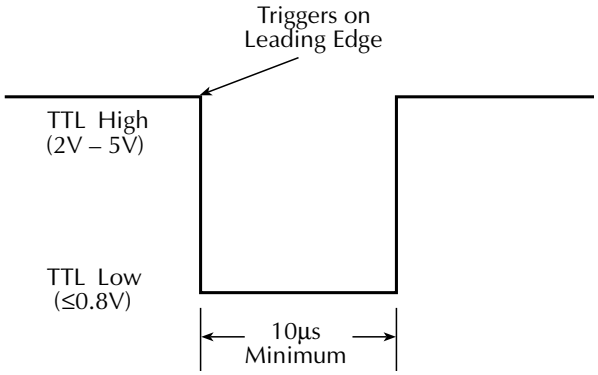


Pin Number	Description
1	Trigger Link 1
2	Trigger Link 2
3	Trigger Link 3
4	Trigger Link 4
5	Trigger Link 5 (not used)
6	Trigger Link 6 (not used)
7	Ground
8	Ground

Input trigger requirements

An input trigger is used to satisfy event detection for a trigger model layer that is configured for the TRIGGER LINK event. See *Trigger model*. The input requires a falling-edge, TTL compatible pulse with the specifications shown in Figure 10-3.

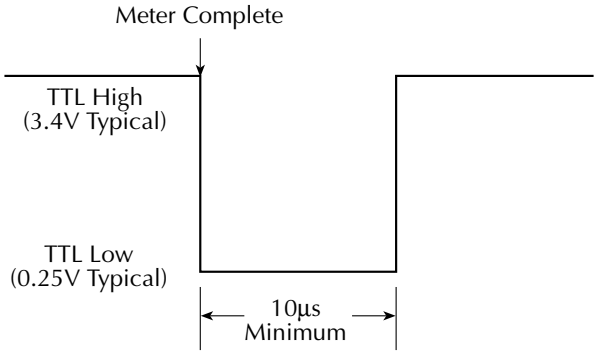
Figure 10-3
Trigger link input pulse specifications



Output trigger specifications

The SourceMeter can be programmed to output a trigger after various trigger model actions. See *Trigger model*. The output trigger provides a TTL-compatible output pulse that can be used to trigger other instruments. The specifications for this trigger pulse are shown in Figure 10-4. A trigger link line can source 1mA and sink up to 50mA.

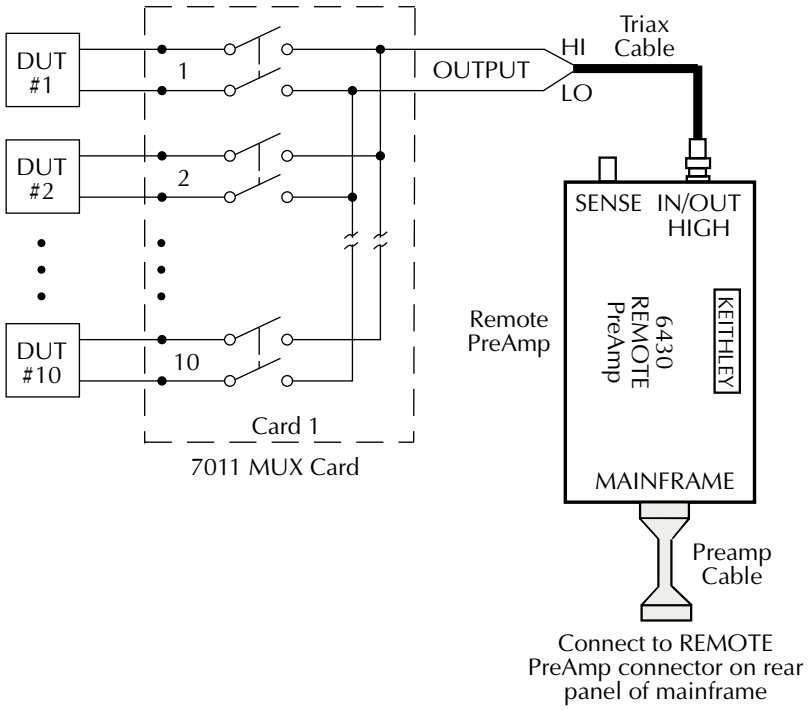
Figure 10-4
Trigger link output pulse specifications



External triggering example

In a simple test system, you may want to close a switching channel and then measure the resistance of the DUT connected to that channel. This test system is shown in Figure 10-5, which uses a SourceMeter to measure 10 DUTs switched by a Model 7011 multiplexer card in a Model 7001/7002 Switch System.

Figure 10-5
DUT test system



The Trigger Link connections for this test system are shown in Figure 10-6. Trigger Link of the SourceMeter is connected to Trigger Link (IN or OUT) of the switching mainframe. Note that with the default trigger settings of the switching mainframe, line #1 is an input, and line #2 is an output.

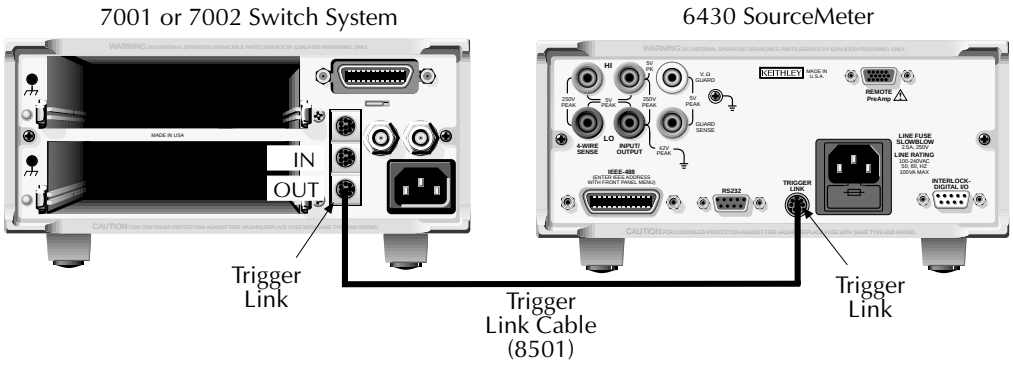


Figure 10-6
Trigger link connections

For this example, the SourceMeter and Switching Mainframe are configured as follows.

SourceMeter setup

Step 1: Restore bench defaults

Press the MENU key, select SAVESETUP, then press the ENTER key. From the SAVESETUP menu, select GLOBAL, then press ENTER. From the GLOBAL SETUP MENU, select RESET, then press ENTER. Select BENCH, then press ENTER.

Step 2: Set up trigger parameters

Press the CONFIG key, and then the TRIG key to access the CONFIGURE TRIGGER menu. Select TRIG-LAYER, and then press ENTER to access the CONFIGURE TRIG-LAYER menu.

Step 3: Set trigger-in event to TRIGGER-LINK

Select TRIGGER-IN, then press ENTER. Select TRIGGER-LINK, then press ENTER.

Step 4: Set trigger input line to #2

Select #2, then press ENTER three times to return to CONFIGURE TRIG-LAYER menu.

Step 5: Set trigger output line to # 1

Select TRIGGER-OUT, then press ENTER. Select LINE, then press ENTER. Select #1, then press ENTER.

Step 6: Set trigger out events to MEAS=ON (all others to OFF)

Select EVENTS, then press ENTER. Select MEAS=OFF and toggle the value to ON using the ▲ and ▼ keys. Press ENTER, and then press EXIT to return to the CONFIGURE TRIG-LAYER menu.

Step 7: Set trigger count to 10

Use the right cursor key to scroll to the far right of the menu selections and select COUNT, then press ENTER. Set the count to 10, then press the ENTER key. Press the EXIT key twice to leave CONFIGURE TRIGGER menus.

Step 8: Enable auto output off

Press the CONFIG key and then the ON/OFF key to access the CONFIGURE OUTPUT menu. Select AUTO-OFF, then press ENTER. Select ENABLE, then press ENTER. Select ALWAYS, then press ENTER. Press the EXIT key to leave the CONFIGURE OUTPUT menu.

Switching mainframe setup

Step 1: Restore bench defaults

Press the MENU key, select SAVESETUP, and then press ENTER. From the SAVESETUP menu, select RESET, then press ENTER. Press ENTER to confirm the action. Press ENTER to return to the SETUP MENU. Press EXIT to leave the SETUP MENU. Press EXIT to leave the MAIN MENU.

Step 2: Set up scan list: 1!1 - 1!10

Press the SCAN LIST key. Press 1, 1 - 1, 1, 0 , then press the ENTER key.

Step 3: Set then number of scans to 1

Press the SCAN key, select SCAN-CONTROL, and then press ENTER. From the SCAN CONTROL menu, select NUMBER-OF-SCANS, then press ENTER. Select ENTER-SCAN-COUNT, then press ENTER. Set the count to 1, then press ENTER. Press the EXIT key to return to the CONFIGURE SCAN menu.

Step 4: Set channel spacing to trigger-link

Select CHAN-CONTROL from the CONFIGURE SCAN menu, then press ENTER. Select CHANNEL-SPACING from the CHANNEL CONTROL menu, then press ENTER. Select TRIGLINK, then press ENTER. Select ASYNCHRONOUS, then press ENTER. Press ENTER, ENTER, then EXIT, EXIT, EXIT to leave the CONFIGURE SCAN menu.

Operation

1. To store the readings in the SourceMeter buffer, press STORE, and set the buffer size for 10. When ENTER is pressed, the asterisk (*) annunciator will turn on to indicate the buffer is enabled. See Section 8 for details.
2. Turn the SourceMeter OUTPUT ON. The SourceMeter waits for an external trigger from the switching mainframe.
3. Press STEP on the Model 7001/7002 to take it out of idle and start the scan. The scanner's output pulse triggers the SourceMeter to take a reading and store it. The SourceMeter then sends a trigger pulse to the switching mainframe to close the next channel. This process continues until all 10 channels are scanned, measured, and stored.

Details of this testing process are explained in the following paragraphs and are referenced to the operation model shown in Figure 10-7.

A) Turning the SourceMeter OUTPUT ON places it at point A in the flowchart, where it waits for an external trigger.

B) Pressing STEP takes the Model 7001/2 out of the idle state and places operation at point B in the flowchart.

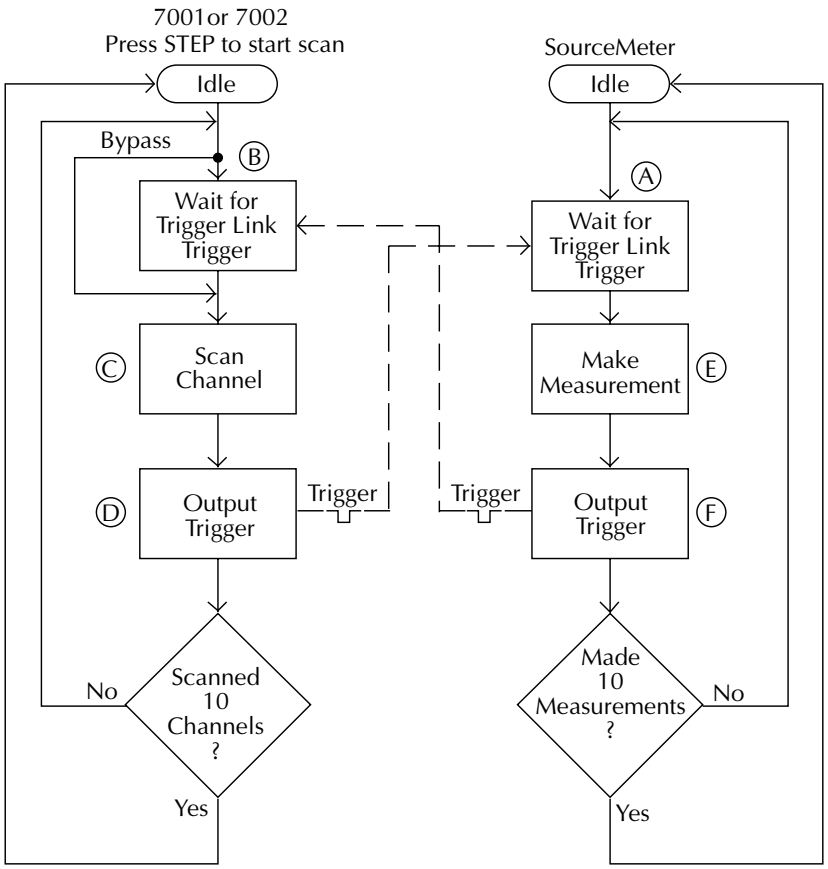


Figure 10-7
Operation model for triggering example

C) For the first pass through the model, the scanner does not wait at point B. Instead, it closes the first channel (point C).

D) After the relay settles, the Model 7001/2 outputs a trigger pulse. Since the instrument is programmed to scan 10 channels, operation loops back to point B, where it waits for an input trigger.

E) and F) With the SourceMeter operation at point A, the output trigger pulse from the Model 7001/2 triggers a measurement of DUT #1 (point E). After the measurement is complete, the SourceMeter outputs a trigger pulse and then loops back to point A, where it waits for another input trigger.

The trigger applied to the Model 7001/2 from the SourceMeter closes the next channel in the scan, which then triggers the SourceMeter to measure that DUT. This process continues until all 10 channels are scanned and measured.

Configuring triggering

Triggering is configured from the CONFIGURE TRIGGER menu and is structured as follows.

NOTE *See "Trigger model" for details on the following programmable aspects of triggering.*

CONFIGURE TRIGGER menu

Press CONFIG and then TRIG to display the menu shown below and in Figure 10-8. (Note that bullets indicate the primary items of the menu, while dashes and slashes indicate options. See Section 1, *Rules to navigate menus* to check and/or change trigger options.)

- **ARM LAYER** — Use this menu item to configure the arm layer of the trigger model:
  - **ARM IN** — Use to select the detection event for the arm layer:
    / IMMEDIATE — Event detection occurs immediately.
    / MANUAL — Event detection occurs when the TRG key is pressed.
    / GPIB — Event detection occurs when a bus trigger (GET or *TRG) is received.
    / TIMER — Initially, event detection is satisfied immediately. Subsequent event detection occurs after the timer interval elapses. After selecting this arm event, you will be prompted to specify the timer interval (in seconds).
    / MANUAL — Event detection occurs when the TRIG key is pressed.
    / TLINK — After selecting this arm event, you will be prompted to select the input line for the Trigger Link and the state of the event detection bypass. With ONCE selected, operation will loop around the arm event detector on each new pass through the trigger model. With NEVER selected, operation always waits for the input trigger.

/ ↓STEST — Event detection occurs when the SOT line of the Digital I/O port is pulsed low. After selecting this arm event, you will be prompted to select the state of the event detection bypass. With ONCE selected, operation will loop around the arm event detector on each new pass through the trigger model. With NEVER selected, operation always waits for the input trigger.

/ ↑STEST — Event detection occurs when the SOT line of the Digital I/O port is pulsed high. After selecting this arm event, you will be prompted to select the state of the event detection bypass.

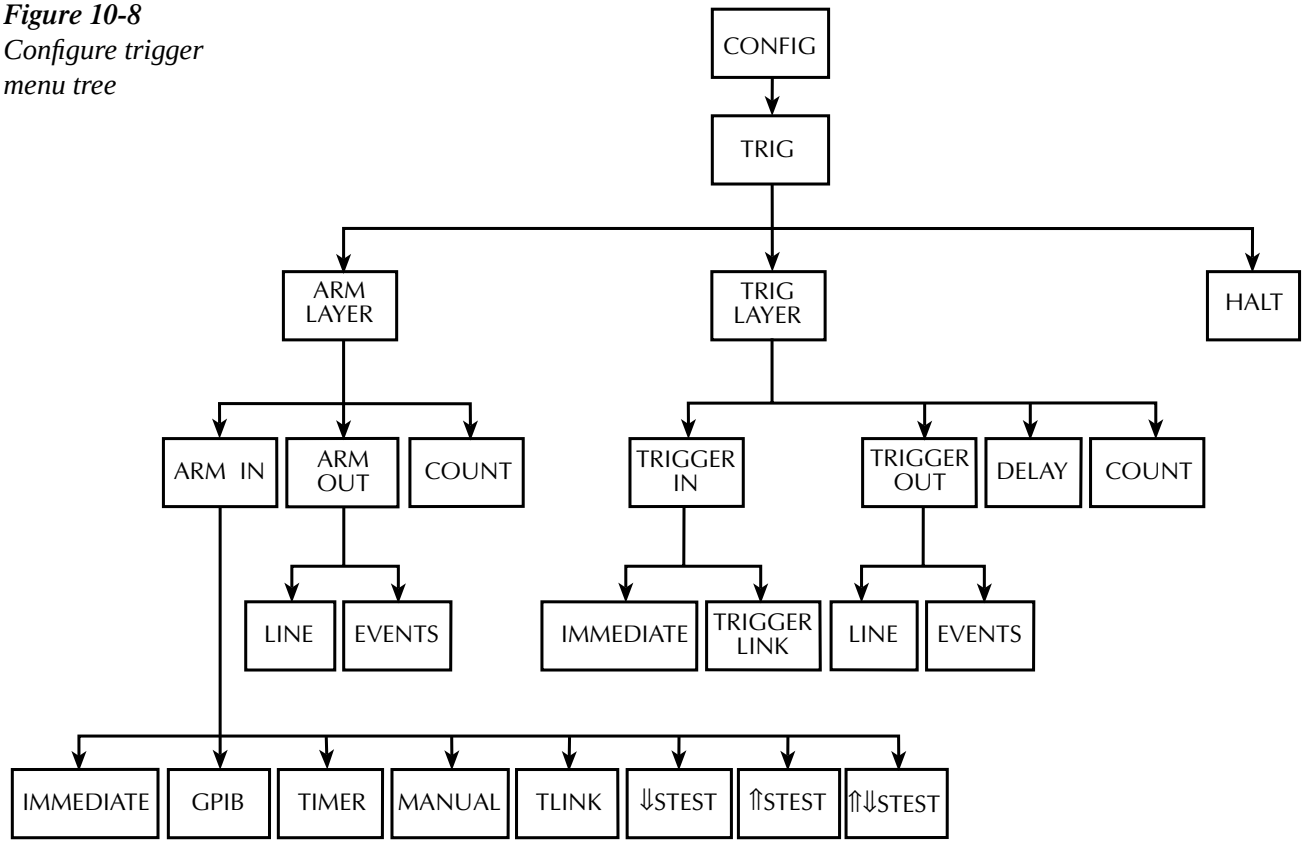
/ ↑↓STEST — Event detection occurs when the SOT line of the Digital I/O port is pulsed either high or low. After selecting this arm event, you will be prompted to select the state of the event detection bypass.

- **ARM OUT** — Use to configure the arm layer output trigger:
  / LINE — Select the Trigger Link line for the output trigger: line #1, #2, #3, or #4.
  / EVENTS — Enable (ON) or disable (OFF) the arm layer output triggers. TRIG LAYER EXIT ON enables an output trigger on exiting the trigger layer, while TL ENTER ON enables a trigger on entering the trigger layer.
- **COUNT** — Specify the arm count, FINITE (programmable count) or INFINITE (never ending count).

• **TRIG LAYER** — Use this menu item to configure the trigger layer of the trigger model:
- **TRIGGER IN** — Use to select the detection event for the trigger layer:
  / IMMEDIATE — Event detection occurs immediately.
  / TRIGGER LINK — After selecting this trigger-in source, you will be prompted in sequence as follows:
    > TRIG-IN TLINK LINE — Select the input line (#1, #2, #3, or #4) for the Trigger Link.
    > EVENT DETECT BYPASS — Set the bypass for the Source Event Detector. With ONCE, operation will loop around the Source Event Detector. With NEVER selected, operation will wait for an input trigger.
    > TRIGGER IN EVENTS — Enable (ON) or disable (OFF) trigger-in events (SOURCE, DELAY, and MEASURE). With a trigger-in event ON, operation will wait at that event for an input trigger. With the trigger-in event OFF, operation will not wait. It will simply continue on and perform the appropriate action.
- **TRIGGER OUT** — Use to configure the trigger layer output trigger:
  / LINE — Select the Trigger Link line for the output trigger; line #1, #2, #3, or #4.
  / EVENTS — Enable (ON) or disable (OFF) output triggers that occur after the source, delay, and measure actions.
- **DELAY** — Specify the time delay (in seconds) for the trigger delay.
- **COUNT** — Specify the trigger count.

- **HALT** — Use to return the SourceMeter to the idle state. HALT does not turn off the output. The programmed source level will still be available at the OUTPUT terminals. The following actions will take the SourceMeter out of idle:
  - Turn the output off and then on again.
  - Re-select the arm or trigger event.
  - Exit from the menu structure, and then re-enter it by pressing CONFIG and then TRIG.

Figure 10-8
Configure trigger menu tree



Remote triggering

Trigger model (remote operation)

The trigger model flowchart in Figure 10-9 summarizes remote trigger operation. Operation is controlled by SCPI commands from the Trigger Subsystem. Key remote commands are included in the trigger model. Also note that the GPIB defaults are denoted by the "✣" symbol.

The primary actions of the trigger model are Source, Delay, and Measure. The source action outputs the programmed voltage or current value, and the programmed delay provides a settling period for the source before the measurement is performed.

The trigger model consists of two layers (Arm Layer and Trigger Layer) to provide versatility. Programmable counters allow operations to be repeated, and various input and output trigger options are available to provide source-measure synchronization between the SourceMeter and other instruments (via the Trigger Link).

Idle and initiate

The instrument is considered to be in the idle state (ARM annunciator off) when it is not operating within the trigger model layers. While in the idle state, the instrument cannot perform any measurements. An initiate command is required to take the instrument out of idle. The following commands perform an initiate operation:

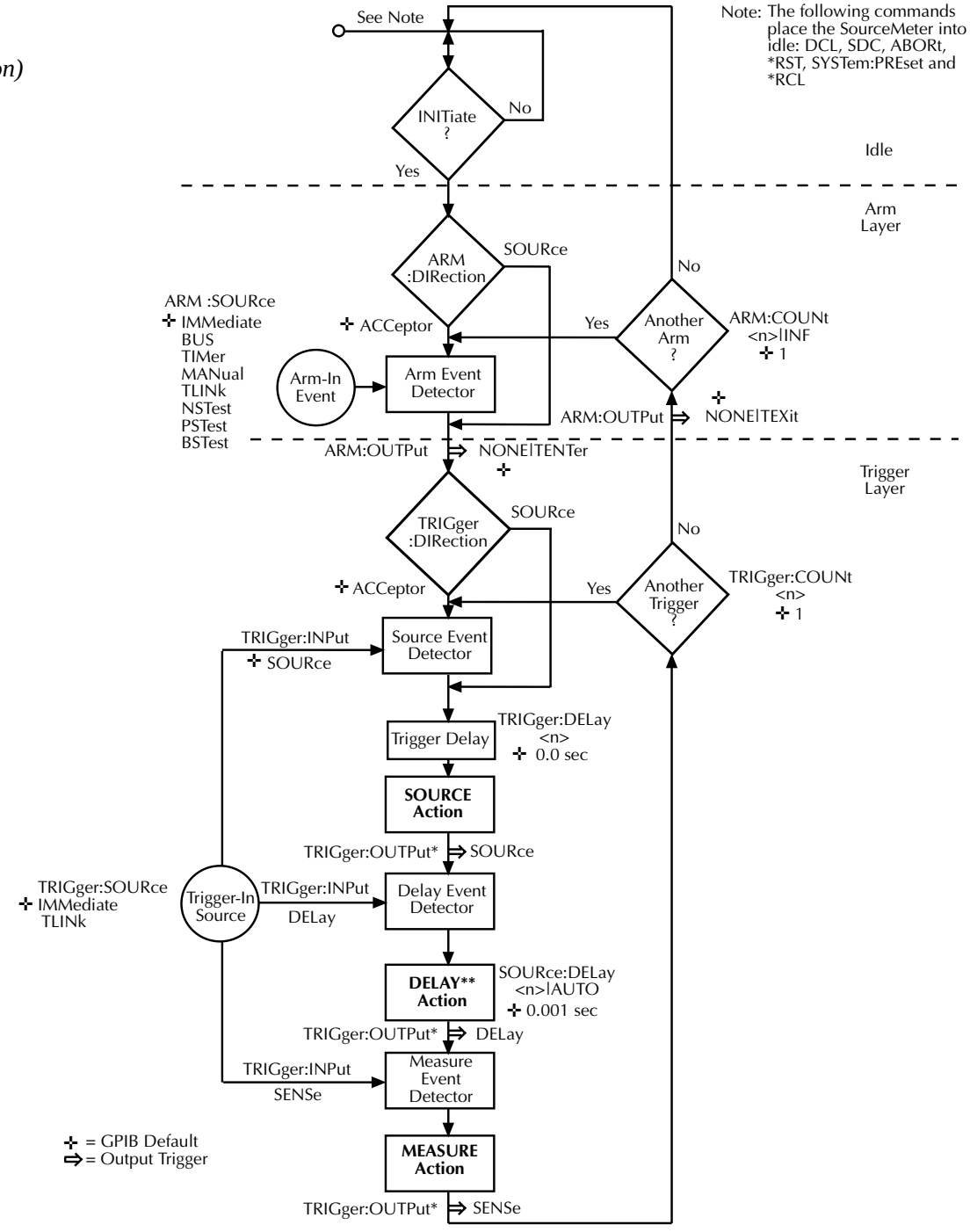
- :INITiate
- :READ?
- :MEASure?

Conversely, if the unit is taking readings, most commands (except DCL, SDC, IFC, and ABORt) are queued up and will not be executed until the unit returns to idle.

When auto output-off is disabled (:SOURce1:CLEar:AUTO OFF), you must first turn the source output on before sending the :INITiate or :READ? command. The :MEASure? command will automatically turn the output on. Note that after the instrument returns to the idle state, the output will remain on.

When auto output-off is enabled (:SOURce1:CLEar:AUTO ON), any of the above three commands can be used to initiate operation. The source output will automatically turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement is completed.

Figure 10-9
Trigger model
(remote operation)



* GPIB default parameter for TRIGGER:OUTPut is NONE

** In :SYSTem:RCMode MULTiple, the soak time programmed with :SOURce[1]:SOAK takes the place of the delay time only during the first SDM cycle after the initial sweep trigger. See Section 17 for details.

While operating within the trigger model (ARM indicator on), most commands will not be executed until the SourceMeter completes all of its programmed source-measure operations and returns to the idle state. The IFC (interface clear), SDC (selected device clear) and DCL (device clear) commands can be executed under any circumstance while operating within the trigger model. They will abort any other command or query.

- :ABORt
- :SYSTem:PRESet
- *TRG or GET
- *RST
- *RCL

NOTE *SDC, DCL, or :ABORt place the SourceMeter in the idle state. For fastest response, use SDC or DCL to return to idle.*

Event detection

Once the instrument is taken out of idle, operation proceeds through the trigger model to perform the Source, Delay, and Measure actions.

In general, operation is held up at an event detector until the programmed event occurs. Note however, that if an event detector has a bypass (:DIRection), operation can be programmed to loop around the event detector.

Arm layer

Event Detector Bypass — As shown in Figure 10-9, there is a bypass (ARM:DIRection) for the Arm Event Detector. This bypass can only be used if TLINk, PSTest, NSTest, or BSTest is the selected Arm-In Event. The bypass serves to “jump-start” operation. With the bypass set to SOURce, operation will loop around the Arm Event Detector when an INITiate command is sent (assuming the output is turned ON).

The programmable arm-in events for the Arm Layer are described as follows:

IMMediate — Event detection occurs immediately allowing operation to continue.

BUS — Event detection occurs when a bus trigger (GET or *TRG) is received.

TIMer — Event detection occurs immediately on the initial pass through the trigger model. Each subsequent detection is satisfied when the programmed timer interval elapses. The timer resets to its initial state when the instrument goes into idle.

MANual — Event detection occurs when the TRIG key is pressed. The SourceMeter must be in LOCAL mode for it to respond to the TRIG key. Press the LOCAL key or send LOCAL 24 over the bus to take the SourceMeter out of remote.

TLINk — Event detection occurs when an input trigger via the Trigger Link input line is received (see *Trigger Link* for more information). With TLINk selected, you can loop around the Arm Event Detector by setting the event detector bypass (ARM:DIRection) to SOURce.

NSTest — Event detection occurs when the SOT (start of test) line of the Digital I/O port is pulsed low. This pulse is received from the handler to start limit testing. See Section 11.

PSTest — Event detection occurs when the SOT (start of test) line of the Digital I/O port is pulsed high. This pulse is received from the handler to start limit testing. See Section 11.

BSTest — Event detection occurs when the SOT (start of test) line of the Digital I/O port is pulsed either high or low. This pulse is received from the handler to start limit testing. See Section 11.

NOTE *NSTest, PSTest, and BSTest can be used only at the beginning of a sweep and should not be used to trigger each point in a sweep.*

Trigger layer

The Trigger Layer uses three event detectors; one for each action (Source, Delay, and Measure).

Event Detector Bypass — As shown in Figure 10-9, there is a bypass (TRIGger:DIRection) for the Source Event Detector. This bypass is in effect only if TLINk is the selected Trigger-In Source. With this event detector bypass set to SOURce, operation will proceed around the Source Event Detector.

The programmable trigger-in sources for the Trigger Layer are described as follows:

IMMediate — With Immediate selected, event detection for the three detectors is satisfied immediately. Operation proceeds through the Trigger Layer to perform the Source, Delay, and Measure actions.

TLINk — With TLINk selected, event detection at each enabled detector occurs when an input trigger via the Trigger Link input line is received. A detector is enabled by including its parameter name with the TRIGger:INPut command.

For example, to enable the Delay Event Detector and Measure Event Detector, the following command must be sent:

TRIGger:INPut DELay, SENSe

The above command disables the Source Event Detector since its parameter name (SOURce) is not included in the parameter list.

With the Source Event Detector disabled, operation will not hold up. It will simply continue on and perform the Source Action. Operation will hold up at the Delay Event Detector until an input trigger is received, and then it will hold up at the Measure Event Detector until another input trigger is received.

Trigger delay

A programmable delay is available before the Source Action. The Trigger Delay can be manually set from 0.00000 to 999.99990 seconds. Note that this delay is separate from the Delay Action of the SDM cycle. The Delay Action is discussed next.

Source, delay, and measure actions

The SDM cycle of the SourceMeter consists of three actions: Source, Delay, and Measure:

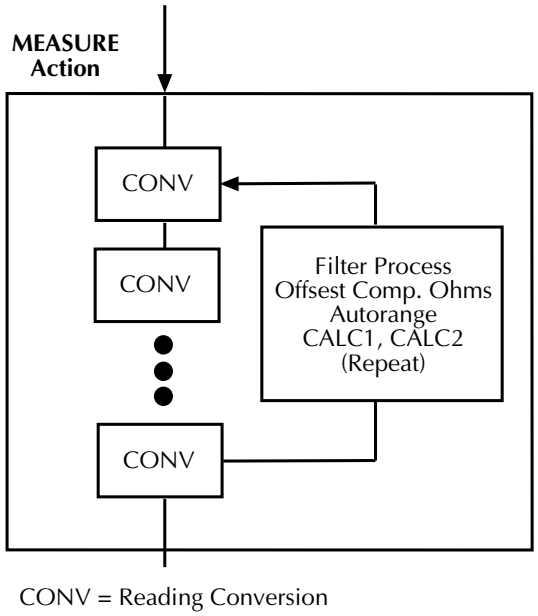
SOURCE Action — Any programmed output voltage or current level changes are performed.

DELAY Action — This programmable delay is used to allow the source to settle before a measurement is performed. It can be manually set from 0.00000 to 9999.99900 seconds, or Auto Delay can be enabled. With Auto Delay enabled, the SourceMeter automatically selects a nominal delay period based on the selected function and range.

NOTE *In the :SYSTem:RCMode MULTiple mode, the soak time programmed with :SOURce[1]:SOAK takes the place of the delay time only during the first SDM cycle after the initial sweep trigger. See Section 17.*

MEASURE Action — During this phase of the SDM cycle, the measurement process takes place. If the repeat filter is enabled, as shown in Figure 10-10, the instrument samples the specified number of reading conversions to yield a single filtered reading (measurement). If using the moving filter or if the filter is disabled, only a single reading conversion will yield a reading.

Figure 10-10
Measure action



Counters

Programmable counters are used to repeat operations within the trigger model layers. For example, if performing a 10-point sweep, the trigger counter would be set to 10 (TRIGger:COUNt 10). Operation will stay in the Trigger Layer until the 10 source-delay-measure points of the sweep are performed.

If you wanted to repeat the sweep three times, the arm counter would be set to three (ARM:COUNt 3). Three 10-point sweeps can then be performed for a total of 30 source-delay-measure actions.

The maximum buffer size for the SourceMeter is 2500 readings. The product of the finite values of the two counters cannot exceed 2500. For example, if you set an arm count of two, the maximum trigger count will be 1250 (2500 / 2 = 1250). However, you can set the arm count to infinite (INF). With an infinite arm count, the maximum trigger count is 2500.

NOTE *With front panel operation only, when a sweep is configured, the trigger model settings will not change until the sweep is started. After the sweep is finished, the trigger model will reset back to the previous settings.*

Output triggers

The SourceMeter can be programmed to output a trigger (via rear panel Trigger Link connector) after various trigger model operations. An output trigger is used to trigger another instrument to perform an operation. See Trigger link earlier in this section for more information.

Trigger Layer Output Triggers — The SourceMeter can be programmed to output a trigger after each action of the SDM cycle (Source, Delay, and Measure). Output triggers are controlled with the TRIGger:OUTPut command.

For example, to output a trigger after the Measure Action, the following command must be sent:

TRIGger:OUTPut SENSe

The above command disables output triggers for the Source and Delay Actions since their parameter names (SOURce and DELay) are not included in the parameter list.

When used with a scanner, an output trigger after each measurement can signal the scanner to select the next channel in the scan.

Arm Layer Output Triggers — As shown in Figure 10-9, the SourceMeter can be programmed to output a trigger when operation leaves the Arm Layer and enters the Trigger Layer, or after operation leaves the Trigger Layer and enters back into the Arm Layer. This output trigger is typically sent to another instrument to signal the end of a scan or sweep. The ARM:OUTPut command is used to control these output triggers. The TENTer parameter enables the trigger on entering the Trigger Layer, the TEXit parameter enables the trigger on exiting the Trigger Layer, and the NONE parameter disables both output triggers.

GPIB defaults

The GPIB defaults are listed as follows. They are also denoted in Figure 10-9 by the "✣" symbol.

- Arm-In Event = Immediate
- Trigger-In Source = Immediate
- Arm Count = 1
- Trigger Count = 1
- Trigger Delay = 0.0 sec
- Delay Action = 0.001 sec
- Enabled event detector = Source Event Detector (Delay and Measure detection disabled)
- Enabled output triggers = None
- Event detection bypasses = Acceptor (both layers)

With output turned ON (OUTPut ON), the SourceMeter will perform one SDM cycle when the INITiate command is sent. After the measurement, the SourceMeter returns to the idle state.

Operation summary

The trigger model is designed to offer versatility for the various source-measure applications. Typically, it allows you to perform a specified number of measurements at various source levels.

For example, assume you want to perform three measurements each at two different V-source levels. (1V and 2V). To do this, set the arm count to two (arm:count 2), the trigger count to three (trigger:count 3), and use the list sourcing mode with the following defined list:

source:list:volt 1, 1, 1, 2, 2, 2

On the first pass through the trigger model, three measurements will be performed at the 1V source level. On the second pass, three measurements will be performed at the 2V source level. After the last measurement, the SourceMeter returns to the idle state. Note that the product of the arm count (finite value) and trigger count determines the number of measurements that are performed. In this example, six measurements are performed (2×3).

For details on the list source mode, see Section 17, *SOURce Subsystem*.

Remote trigger commands

Table 10-1 summarizes remote trigger commands. These commands are covered in more detail in Section 17 except for *TRG, a common command covered in Section 15.

Table 10-1
Remote trigger command

Command	Description
:INITiate	Take SourceMeter out of idle state.
:ABORt	Abort operation, return to idle.
:ARM:COUNt <n>	Set arm count (n = count).
:ARM:SOURce <name>	Specify arm control source. Name = IMMediate, TLINk, TIMer, MANual, BUS, NSTest, PSTest, or BSTest.
:ARM:TIMer <n>	Set arm layer timer interval (n = interval).
:ARM:DIRection <name>	Control arm bypass. (Name = SOURce or ACCeptor).
:ARM:ILINe <NRf>	Select arm layer input line. (NRf = input line #).
:ARM:OLINe <NRf>	Select arm layer output line (NRf = output line #).
:ARM:OUTPut <event list>	Select arm layer output events. (Event list = TENTer, TEXit, or NONE).
:TRIGger:CLEar	Clear any pending input triggers immediately.
:TRIGger:COUNt <n>	Set trigger count (n = count).
:TRIGger:DELay <n>	Set trigger delay (n = delay).
:TRIGger:SOURce <name>	Specify trigger control source. Name = IMMediate or TLINk.
:TRIGger:DIRection <name>	Control trigger bypass. (Name = SOURce or ACCeptor).
:TRIGger:ILINe <NRf>	Select trigger layer input line (NRf = input line).
:TRIGger:OLINe <NRf>	Select trigger layer output line (NRf = output line).
:TRIGger:INPut <event list>	Select trigger input layer events. (Event list = SOURce, DELay, SENSe, or NONE).
:TRIGger:OUTPut <event list>	Select trigger layer output events. (Event list = SOURce, DELay, SENSe, or NONE).
*TRG	Trigger SourceMeter (if BUS source selected).

Remote trigger example

Table 10-2 summarizes the command sequence for basic trigger operation. These commands set up the SourceMeter as follows:

- Arm layer source: bus
- Arm layer count: 2
- Trigger layer delay: 0.1s
- Trigger layer count: 10
- Trigger layer output events: source and sense
- Trigger layout trigger link output line: 1

After the unit is set up, :INIT is sent to take the unit out of idle. *TRG is sent to trigger the unit, after which it cycles 10 times through the trigger layer. A second *TRG is required to trigger the unit the second time, and it then completes the second cycle through the trigger layer.

NOTE *You must allow sufficient time between the first and second *TRG commands, or the second trigger will be ignored.*

Table 10-2
Remote triggering example

Command	**Description**
*RST	Restore GPIB defaults.
:SOUR:VOLT 10	Source 10V.
:ARM:SOUR BUS	Select bus arm layer source (*TRG command).
:ARM:COUN 2	Arm layer count = 2.
:TRIG:DEL 0.1	0.1s trigger layer delay.
:TRIG:COUN 10	Trigger layer count = 10.
:TRIG:OUTP SOUR,SENS	Source, sense output trigger events.
:TRIG:OLIN 1	Trigger output line = #1.
:OUTP ON	Turn on output.
:INIT	Take unit out of idle.
*TRG	Trigger first sequence.
*TRG	Trigger second sequence.
:OUTP OFF	Turn off output.
:FETC?	Request readings.

11
Limit Testing

- **Types of Limits** — Discusses the three types of limits: compliance, coarse limits, and fine limits. Also summarizes the two operating modes; grading and sorting.
- **Operation Overview** — Covers binning control and pass/fail conditions.
- **Binning Systems** — Details the handler interface, as well as single-element and multiple-element binning.
- **Digital Output Clear Pattern** — Details the digital output bit pattern that occurs after a binning operation.
- **Configuring and Performing Limit Tests** — Describes how to configure the SourceMeter for limit testing and summarizes a typical test procedure.
- **Remote Limit Testing** — Summarizes limit commands and provides a basic programming example.

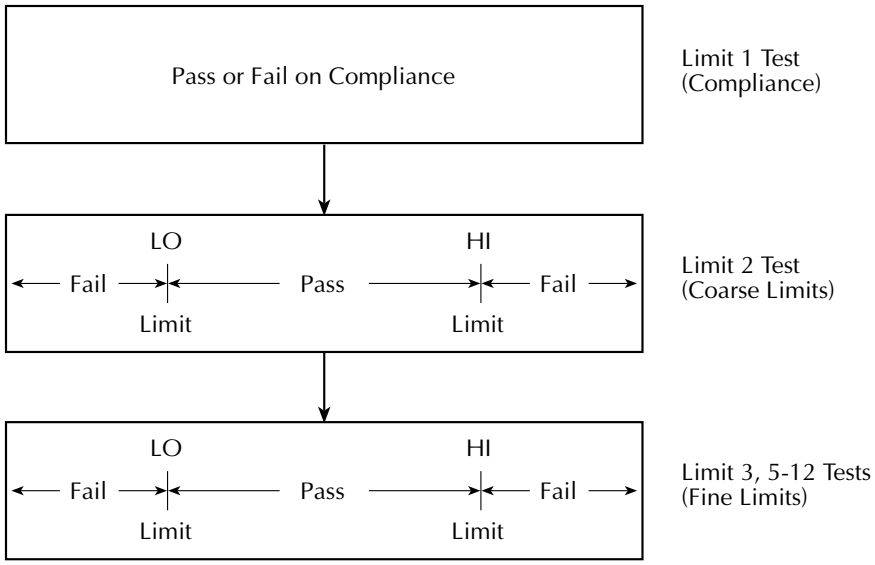
Types of limits

As shown in Figure 11-1, there are 11 limit tests that can be performed on a DUT.

- Limit 1: compliance test
- Limit 2: course limits
- Limits 3, 5-12: fine limits

A test is only performed if it is enabled. Thus, you can perform one, two, or all 11 tests. The tests are always performed in the order shown in the drawing.

Figure 11-1
Limits tests



Pass/fail information

Pass/fail information for limit tests can be obtained as follows:

- A “PASS” or “FAIL” indication on the front panel display.
- By programming the unit to output specific pass/fail bit patterns on the Digital I/O port, which can be used to control other equipment such as a device handler for binning operations. See *Binning systems* later in this section and Section 12, *Digital I/O port*, for more information.
- With the :CALCulate2:LIMit<n>:FAIL? query via remote, where <n> is the limit test number (Section 17, *CALCulate 2*).
- By reading various status bits (Section 14, *Status structure*, and Section 17, *FORMat subsystem*.)
- By noting a “P” or “F” preceding buffer location numbers (Section 8, *Buffer location number*).

Data flow

All limit tests are part of the CALC2 data block. See Appendix C for an overview on how limit testing fits into the overall data flow through the SourceMeter.

Limit 1 test (compliance)

This hardware (H/W) test checks the compliance state of the SourceMeter. It uses the programmed compliance as the test limit. At or above the programmed limit, the instrument is in compliance. Below the limit, the instrument is not in compliance.

For example, assume you want to "pass" resistors that are below 1kΩ. To do this set the I-Source to output 1mA at a compliance limit of 1V, and configure the test to fail on compliance. If, for example, the resistor under test is 750Ω, output voltage will be 0.75V (1mA × 750Ω = 0.75V). Since the output voltage is below the 1V limit, the test passes. If the resistor is 1kΩ (or more), output voltage will be 1V (1mA × 1kΩ = 1V). Since the 1V limit is reached, which places the SourceMeter in compliance, the test fails.

The Limit 1 test can be used to determine the polarity of a device, such as a diode. By using this test with a source memory sweep, you can branch to a different setup at a specified memory location when the device is installed backwards. See the programming example at the end of this section for details on diode testing.

Limit 2, limit 3, and limit 5-12 tests

These software (S/W) tests are used to determine if a DUT is within specified high and low limits. Typically, the Limit 2 test is used to test for "coarse" tolerance limits, and the Limit 3 and Limit 5-12 tests are used for "fine" tolerance limits.

For example, assume you want to sort resistors into three groups: 1%, 5%, and >5% tolerance. To do this, configure Limit 2 test for 5% HI and LO limits, and Limit 3 test for 1% HI and LO limits. If Limit 2 fails, the handler places the DUT in the bin labeled >5%. If Limit 2 passes, Limit 3 test is run. If Limit 3 fails, the DUT is placed in the bin labeled 5%. If Limit 3 passes, the handler places the DUT in the bin labeled 1%.

NOTE *Limit 2 can be used with the percent deviation math function. See "Percent deviation" in Section 7 for details.*

Limit test modes

There are two modes of operation for limit tests; grading and sorting. For Limit 1 test (compliance), operation is similar for both limit test modes. If Limit 1 test fails, the "FAIL" message is displayed and the testing process for that DUT (or DUT element) is terminated. A pass condition allows the testing process to proceed to the next enabled limit test.

With the grading mode selected, each enable software test (Limit 2, 3, 5-12) is performed until a failure occurs. When a test fails, the "FAIL" message is displayed and the testing process for that DUT (or DUT element) is terminated.

With the sorting mode selected, each enabled software test (Limit 2, 3, 5-12) is performed until a test passes. When a test passes, the "PASS" message is displayed and the testing process for that DUT is terminated.

Binning

Even though no additional equipment is required to perform limit tests on the DUT, the SourceMeter is typically used with a component handler to perform binning operations. After the testing process, the DUT will be placed in an assigned bin.

For the grading mode, the binning system can be further automated by adding a scanner. With the use of a scanner, the tests can be repeated (cycled) to test individual elements of a single package (i.e., resistor network). See *Binning systems* for more information on using component handlers and scanners to perform binning operations.

Operation overview

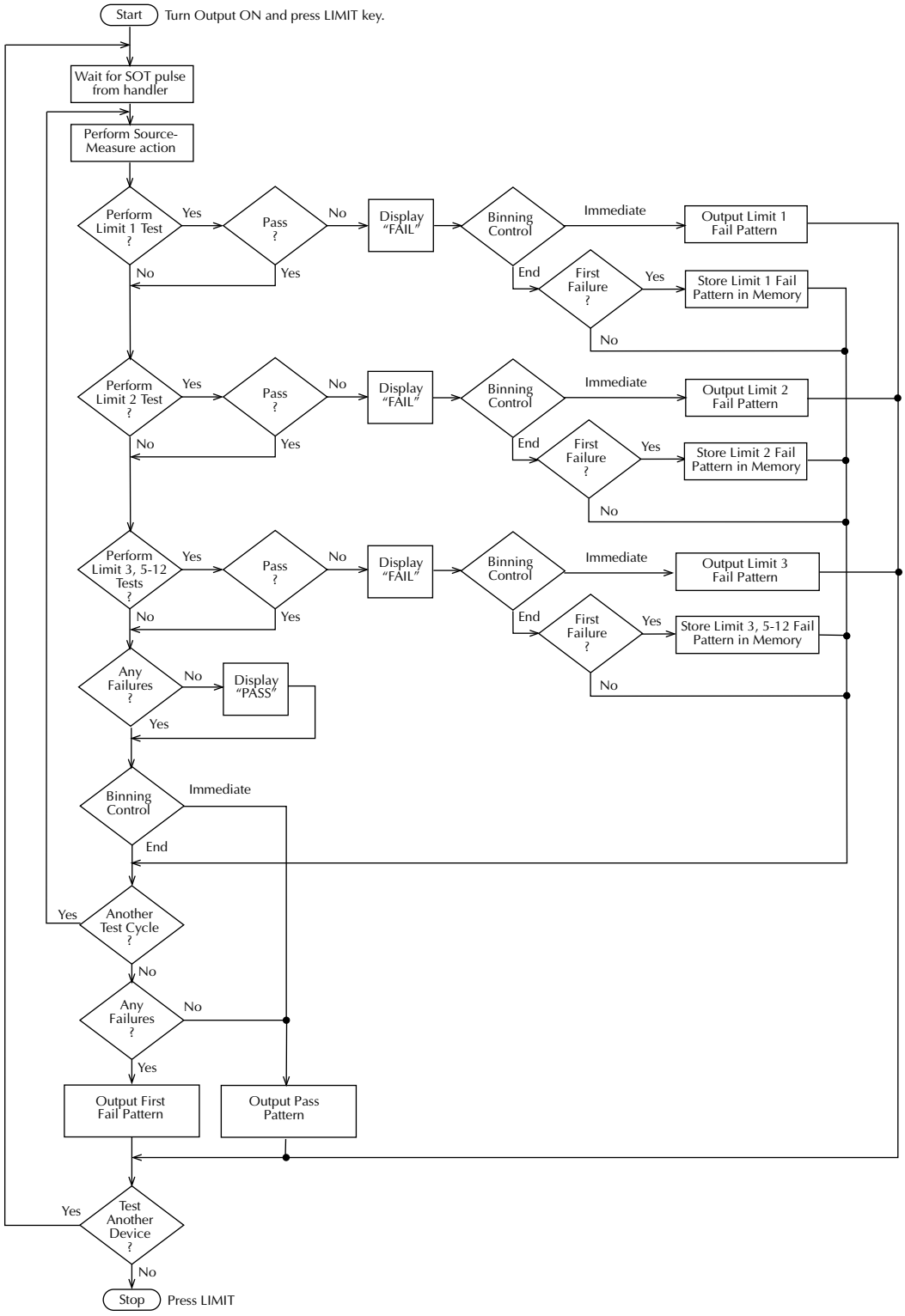
Grading mode

Grading mode limits operation is detailed by the flowchart in Figure 11-2. A test is only performed if it is enabled. If disabled, operation proceeds to the next test. The following assumes the first three limit tests are enabled and the digital output of the SourceMeter is connected to a component handler for DUT binning. See *Binning systems*. If a handler is not used, ignore digital input/output (handler interface) actions.

With the limit tests properly configured, turn the SourceMeter output on and press the LIMIT key. The testing process will start when the component handler sends the SOT (start-of-test) strobe pulse to the SourceMeter. Note that if a handler is not used, testing will start when LIMIT is pressed. Pressing LIMIT a second time terminates the testing process.

As shown in the flowchart, limit tests are performed after a measurement conversion.

Figure 11-2
Grading mode limit testing



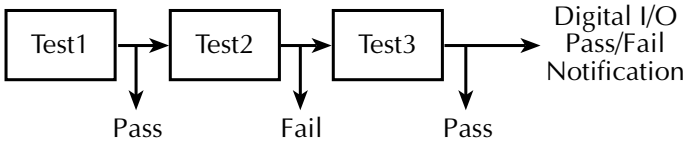
Binning control

The binning control selection determines when the testing process stops and the appropriate binning operation occurs. The results are communicated through the Digital I/O port based on limit test data. (See *Binning systems* later in this section.) There are two types of binning control for the grading mode: immediate and end.

Immediate binning — Use immediate binning when you want to stop all testing after the first failure occurs. Any pending tests will be cancelled, and the DUT will be placed in the bin assigned to that test failure. If no failures occur, all enabled tests will be performed, and the DUT will be placed in the assigned "pass" bin. This process is demonstrated in Figure 11-3.

Using a sweep with immediate binning lets you test different devices at different source levels. For example, assume a 3-point linear sweep at 1V, 2V, and 3V step levels. The first DUT is tested at 1V, the second DUT is tested at 2V, and the third DUT is tested at 3V.

Figure 11-3
Immediate binning

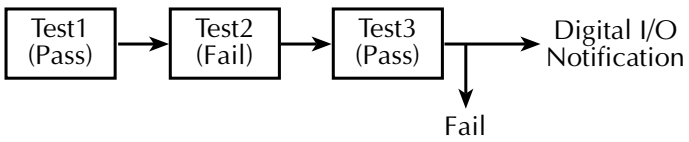


End binning — End binning allows a sweep to finish before performing the binning operation. In the event of a failure, the first test failure determines the bin assignment. (See Figure 11-4.)

Using a sweep with end binning lets you test a device at different source levels. For example, assume a 3-point list sweep at 1.1V, 2.2V, and 3.3V source levels. Limit testing will be performed at each source level. After the completion of the three test cycles, the DUT is placed in the appropriate bin.

Adding a scanner to the system lets you test each element of a multi-element device (i.e., resistor network). For example, the previous 3-point list sweep can be used to test a 3-element resistor network. The first test cycle (using the 1.1V source level) tests the first element of the network. The second test cycle (2.2V) tests the second element of the network, and last test cycle (3.3V) tests the third element. After the three test cycles are finished, the resistor network is placed in the appropriate bin.

Figure 11-4
End binning



Pass condition

For this discussion, assume that all grading mode limit tests pass. After the three limit tests pass, the “PASS” message is displayed, and operation drops down to the Binning Control decision block. (Note that the pass condition can also be determined with the :CALC2:LIM<n>FAIL? query via remote.)

Immediate binning — For immediate binning, the testing process stops. The SourceMeter outputs the pass pattern to the component handler to perform the binning operation.

End binning — For end binning, operation drops down to the Another Test Cycle? decision block. If programmed to perform additional tests (i.e., sweep) on the DUT package, operation loops back up to perform the next source-measure action. After all programmed test cycles are successfully completed, the SourceMeter outputs the pass pattern to the component handler to perform the binning operation.

If configured to test another DUT package, operation loops back to the top of the flowchart and waits for the SOT (start of test) pulse from the component handler.

Fail condition

When a failure occurs, the FAIL message is displayed (and also can be read via remote with :CALC2:LIM<n>FAIL?), and operation proceeds to the Binning Control decision block.

Immediate binning — For immediate binning, the testing process is terminated and the fail pattern for that particular failure is sent to the component handler to perform the binning operation.

End binning — For end binning, the fail pattern for the first failure is stored in memory and operation proceeds to the Another Test Cycle? decision block. If programmed to perform additional tests (i.e., sweep) on the DUT package, operation loops back up to perform the next source-measure action. Note that when a failure occurs, subsequent tests in the test cycle are not performed.

After all programmed test cycles are completed, the SourceMeter outputs the fail pattern stored in memory. This reflects the first failure that occurred in the testing process for the device package. The component handler places the DUT in the appropriate bin.

If configured to test another DUT package, operation loops back to the top of the flowchart and waits for the SOT (start-of-test) pulse from the component handler.

Sorting mode

Sorting mode limits operation is detailed by the flowchart in Figure 11-5. A test is only performed if it is enabled. If disabled, operation proceeds to the next test. The following assumes the digital output of the SourceMeter is connected to a component handler for DUT binning. See *Binning systems*. If a handler is not used, ignore digital input/output (handler interface) actions.

With the limit tests properly configured, turn the SourceMeter output on and press the LIMIT key. The testing process will start when the component handler sends the SOT (start-of-test) strobe pulse to the SourceMeter. Note that if a handler is not used, testing will start when LIMIT is pressed. Pressing LIMIT a second time terminates the testing process. As shown in the flowchart, limit tests are performed after a measurement conversion.

For Limit 1 test (compliance), a failure will display the “FAIL” message and terminate the testing process for that DUT. For the pass condition, operation will proceed to the next enabled limit test. If, however, there are no software limit tests (Limit 2, 3, 5-12) enabled, the testing process will terminate and the “PASS” message will be displayed.

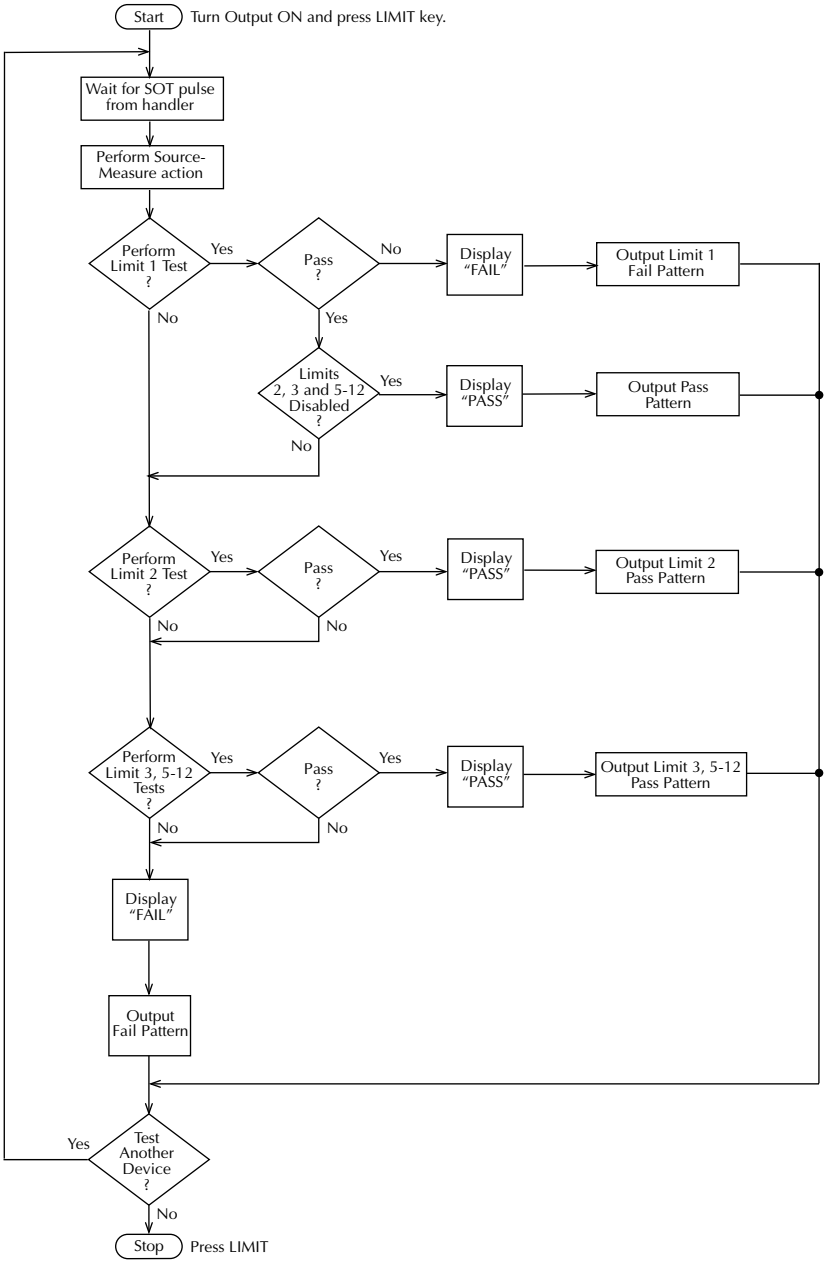
Assuming Limit 1 passes, each enabled software limit test will be performed until one of them passes. When a test passes, the “PASS” message is displayed and any pending limit tests for that DUT are cancelled. If all the limit tests fail, the “FAIL” message will be displayed.

Binning

For the sorting mode, only immediate binning can be performed. After the testing process is finished (“FAIL” or “PASS” displayed), the appropriate output bit pattern will be sent to the component handler which will place the DUT in the assigned bin. (The pass/fail condition can also be queried via remote with :CALC2:LIM<n>:FAIL?.)

Using a sweep with immediate binning lets you test different devices at different source levels. For example, assume a 3-point linear sweep at 1V, 2V, and 3V step levels. The first DUT is tested at 1V, the second DUT is tested at 2V, and the third DUT is tested at 3V.

Figure 11-5
Sorting mode limit testing



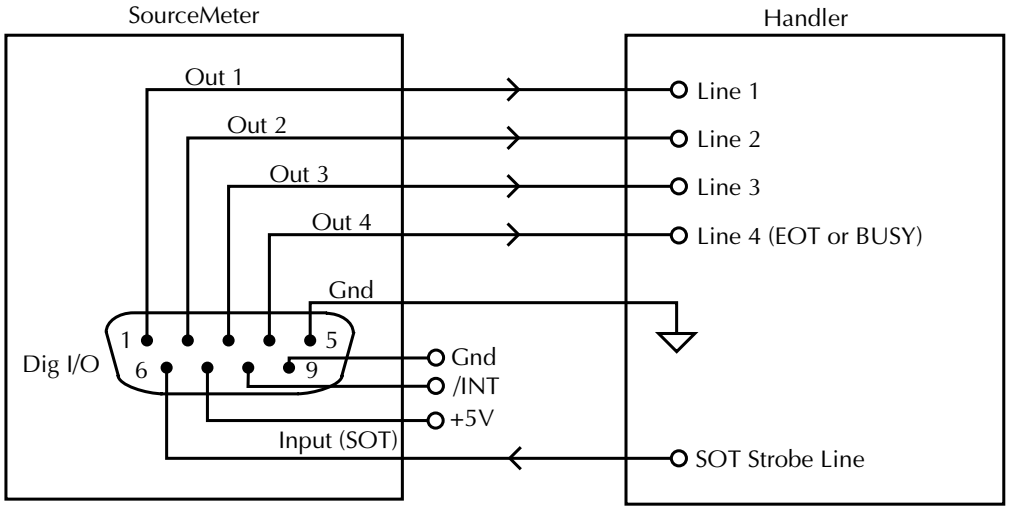
Binning systems

The SourceMeter can be used with a component handler to perform binning operations on DUT packages. With this system, you can test single-element devices (i.e., resistor). Adding a scanner to the system allows binning operations on multiple-element DUT packages. See *Limit test programming example* at the end of this section.

Handler interface

The SourceMeter is interfaced to a handler via the Digital I/O port as shown in Figure 11-6. The I/O port has four lines for output signals and one line for input signals. The output lines are used to send the test pass/fail signal(s) to the handler to perform the binning operation.

Figure 11-6
Handler interface connections



Digital I/O connector

These digital I/O lines are available at the DB-9 Digital I/O connector on the rear panel of the SourceMeter. A custom cable using a standard female DB-9 connector is required for connection to the SourceMeter. See *Digital I/O port* in Section 12 for more information.

Digital output lines

The four output lines output a specific bit pattern based on the pass/fail results of the various limit tests. (See *Types of limits* earlier in this section). In the 3-bit output mode, Line 4 can also be used either as an EOT (End of Test) or BUSY signal depending on the END OF TEST mode. (See *Configuring limit tests* later in this section.)

SOT line

The input line (SOT) of the Digital I/O is used to control the start of the testing process. When ↓STEST is the selected arm event of the trigger model, the testing process will start when the SOT line is pulsed low. When ↑STEST is the selected arm event, the testing process will start when the SOT line is pulsed high. When ↑↓STEST is the selected arm event, the testing process will start when the SOT line is pulsed either high or low. With the IMMEDIATE arm event selected, the testing process will start as soon as the LIMITS key is pressed (assuming the output is ON). See Section 10 for details on trigger model configuration.

When using the SOT line, the handler will not pulse the line while it is in a not ready condition. When the handler is ready (DUT properly positioned in the handler), it pulses the SOT line low or high to start the test.

/INT line

The /INT line of the Digital I/O can be used if the component handler is equipped with an interlock switch. With proper use of the interlock, power is removed from the DUT when the lid of the handler is opened. See Section 12, *Digital I/O port* and *Safety interlock* for operation details on the interlock.

Handler types

The SourceMeter can be used with either of the two basic types of handlers. When used with a Category Pulse Handler, the SourceMeter pulses one of the four handler lines. The handler then places the DUT into the bin assigned to the pulsed line.

When used with a Category Register Handler, the SourceMeter outputs a bit pattern to three handler lines. After the SourceMeter sends the end-of-test (EOT) strobe pulse to the fourth handler line, the handler places the DUT into the bin assigned to that bit pattern.

Category pulse component handler

When using this type of handler, the SourceMeter pulses one of the four handler lines when a pass or fail condition occurs. The handler then places the DUT in the bin assigned to that pulsed line. When interfacing to this type of handler, a maximum of four component handler bins are supported.

If the handler requires low-going pulses, then the four digital output lines of the SourceMeter must be initially set to high. This initial HI, HI, HI, HI clear pattern on the output lines represents a “no action” condition for the handler since it is waiting for one of the lines to go low. A line goes low when the defined fail or pass pattern sets it low. For example, if you want a particular test failure to pulse line #4 of the handler, the defined fail pattern has to be HI, HI, HI, LO. When the failure occurs, line #4 will be pulled low, and the DUT will be placed in the bin assigned to that pulsed line.

If the handler requires a high-going pulse, the four digital output lines of the SourceMeter must initially be set low. The LO, LO, LO, LO clear pattern represents the “no action” condition for the handler. When one of those lines are pulled high by a defined pass or fail bit pattern (i.e., LO, LO, LO, HI), the DUT will be placed in the bit assigned to that pulsed line.

Category register component handler

When using this type of handler, the SourceMeter sends a bit pattern to three handler lines when a pass or fail condition occurs. This bit pattern determines the bin assignment for the DUT. With the pass/fail pattern on the output, line #4 is then pulsed. This EOT (end-of-test) pulse latches the bit pattern into the register of the handler, which places the DUT in the assigned bin. When interfacing to this type of handler, a maximum of eight component handler bins are supported.

If the handler requires a high-going or low-going EOT pulse, program SourceMeter for 3-bit operation and appropriate EOT mode.

NOTE *The EOT and 3-bit modes are configured from the CONFIG LIMIT MENU. See "Configuring limit tests" later in this section.*

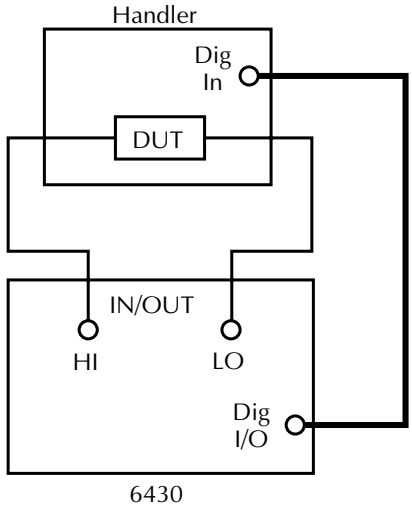
Basic binning systems

Two basic binning systems are shown in Figures 11-7 and 11-8. Both systems require a handler to physically place the device packages in the appropriate bins. The handler is controlled by the SourceMeter via the Digital I/O port.

Single-element device binning

Figure 11-7 shows a basic binning system for single-element devices (i.e., resistors). After all programmed testing on the DUT is completed, the appropriate digital output information is sent to the component handler, which then places the DUT in the appropriate bin. The component handler selects the next DUT, and the testing process is repeated.

Figure 11-7
Binning system - single element devices



Multiple-element device binning

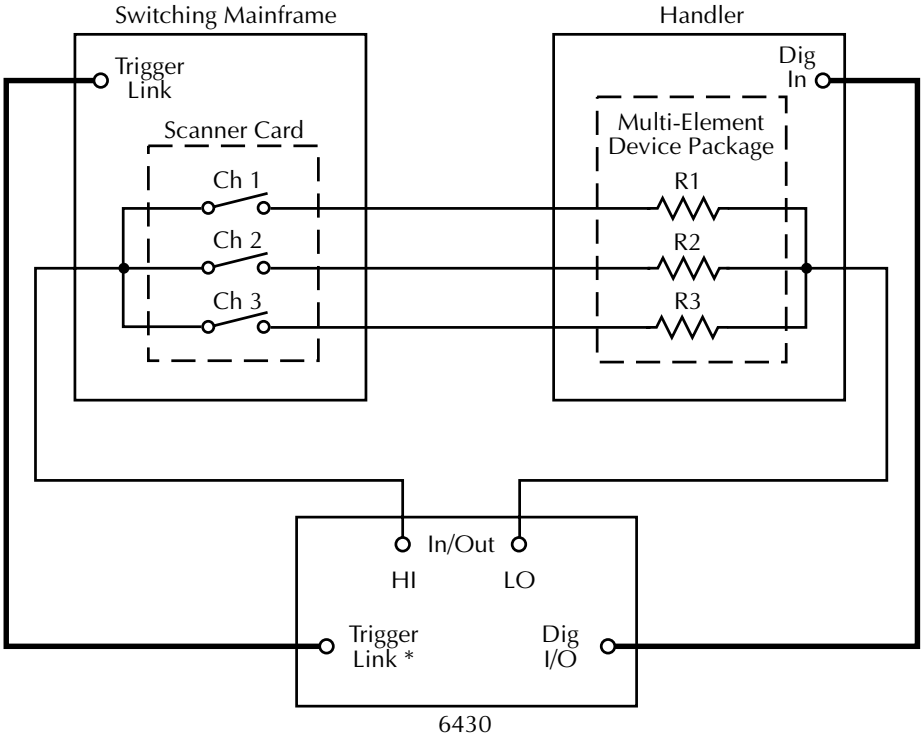
Figure 11-8 shows a basic binning system to test three-element resistor networks. Note that this system requires a scanner card that is installed in a switching mainframe. Scanner card switching is controlled through the Trigger Link. End binning control is required for this test system, therefore, the grading mode must be used.

Trigger operations for the scanner and SourceMeter must be configured appropriately for this test. In general, the scanner must be configured to scan three channels, and the SourceMeter must be configured to perform a 3-point sweep and output a trigger to the scanner after each measurement. See Section 10 for details.

When the testing process is started, Ch 1 of the scanner card closes, and R1 is measured. Two events occur concurrently after the measurement is completed: R1 is tested, and the SourceMeter sends a trigger pulse to the switching mainframe causing Ch 1 to open and Ch 2 to close. Assuming there is no failure, a measurement is then performed on R2. While R2 is being tested, Ch 2 opens and Ch 3 closes. Again assuming no failure, a measurement is performed on R3 and it is then tested. Assuming that all the tests on all three resistors passed, the device package is placed in the pass bin.

If any of the resistors in the network fails a test, the FAIL message is displayed, and the digital output information for the first failure is stored in memory (assuming that END binning control is selected). After the sweep is completed, the SourceMeter sends the output pattern stored in memory. This is the output pattern for the first test failure. The component handler places the DUT package into the bin assigned to that particular failure.

The handler selects the next resistor network, and the testing process is repeated.



* Trigger layer configured to output trigger pulse after each measurement.

Figure 11-8
Binning system - multiple element devices

Digital output clear pattern

After every binning operation, the digital output needs to be reset to a clear pattern, which serves as a “no action” condition for the component handler.

The SourceMeter can be programmed to automatically clear the digital output after the pass or fail pattern is sent. With auto-clear, you must specify the required pulse width (delay) for the pass or fail pattern. When not using auto-clear, you must return the digital output to its clear pattern from the DIGOUT AUTO CLEAR option of the CONFIG LIMIT menu. This option also sets the pass/fail pattern and pulse width.

Enabling auto-clear

To enable auto-clear:

1. Press CONFIG then LIMIT.
2. Select DIGOUT, then press ENTER.
3. Choose AUTO CLEAR, then press ENTER.
4. Select ENABLE, then press ENTER.
5. At the prompts, set the auto-clear pulse width (0s to 60s) and clear bit pattern (0 to 15, 4-bit; 0 to 7, 3-bit size). Use EXIT to return to normal display.

Auto-clear timing

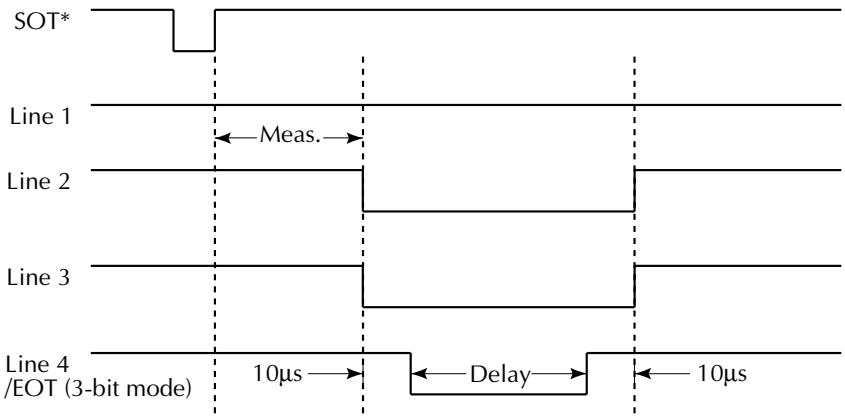
The following example timing diagram (Figure 11-9) and discussion explain the relationship between the digital output lines for auto-clear. This example uses the 3-bit digital output mode, and uses line 4 as /EOT. That is, line 4 will pulse low to signal “end of test.”

Initially, the four digital output lines are cleared (in this case, they are all set high). Limit tests start when the start-of-test (SOT) pulse is received from the component handler. When the testing process is finished, the pass or fail pattern is applied to the digital output. As shown in the diagram, lines 2, 3, and 4 go low while line 1 remains high.

The pulse width (delay) of the pas/fail pattern can be set from 0 to 60sec (100µsec resolution) as required by the component handler. Note that the delay specifies the pulse width of line 4. The pulse width of lines 1, 2, and 3 is actually 20µsec longer. Line 4 is skewed because it is used as the end-of-test (EOT) strobe by category register component handlers. Lines 1, 2, and 3 establish the bit pattern and then 10µsec later the SOT strobe “tells” the handler to read the bit pattern and perform the binning operation. This 10µsec offset is used to make sure the correct bit pattern is read by the handler.

After the pass/fail is read by the handler, the digital output returns to the clear pattern.

Figure 11-9
Digital output auto-clear timing example



* With the SOT line being pulsed low (as shown), ⇓STEST must be the selected arm event for the trigger model. If the SOT line is instead pulsed high by the handler, ⇑STEST must be the selected arm event.

Configuring and performing limit tests

Configuring limit tests

Press CONFIG and then LIMITS to display the CONFIG LIMITS MENU. The limits configuration menu is structured shown below and in Figure 11-10. The limits configuration menu is structured as follows. Note that bullets indicate the primary items of the limit menu and dashes indicate the options of each menu item. Refer to Section 1, *Rules to navigate menus* to configure the limit tests.

- **DIGOUT** — Use this menu item to control the following Digital I/O aspects:
  - **SIZE** — Use to select 3-BIT or 4-BIT Digital I/O bit size (or 16-BIT with 2499-DIGIO opion). In the 3-BIT mode, Digital I/O line 4 becomes the EOT, /EOT, BUSY, or /BUSY signal depending on the selected END OF TEST mode. In the 4-BITmode, Digital I/O line 4 is controlled manually if the END OF TEST mode is set to EOT.
  - **MODE** — Use to select GRADING or SORTING mode. In GRADING mode, a reading passes if it is within all of the HI/LO limit tolerances enabled, assuming that it has passed the Compliance tests first. The Digital I/O will be driven with the first pattern of the first Compliance, HI, or LO failure. Otherwise, the pass pattern will be output. In GRADING mode, you will also choose bin control modes. With IMMEDIATE, the testing process will stop after the first failure and place the fail pattern on the digital output. If none of the limit tests fail, the pass pattern will be placed on the output, and the testing process will stop. With END, the testing process will continue until the programmed sweep is completed, regardless of how many failures occur. This allows multi-element devices (i.e., resistor networks) to be tested. After testing is finished, the bit pattern for the first failure is placed on the output. If all tests pass, the pass pattern will instead be placed on the output.

In SORTING mode, a reading will fail if it fails the Compliance Test, or is not within any of the Digital I/O Bands. If the tests pass and only Limit 1 is enabled, the associated pass pattern will be output. Otherwise, the first limit test band that passes will output its lower limit pattern (upper limit patterns will be ignored). If Limit 1 fails, its failure patterns will be output. If no Limit 2, 3, or 5-12 passes, their failure pattern will be output. When SORTING is selected, the Digital I/O bit pattern can also be set (0 to 7, 3-bit; 0 to 15, 4-bit).

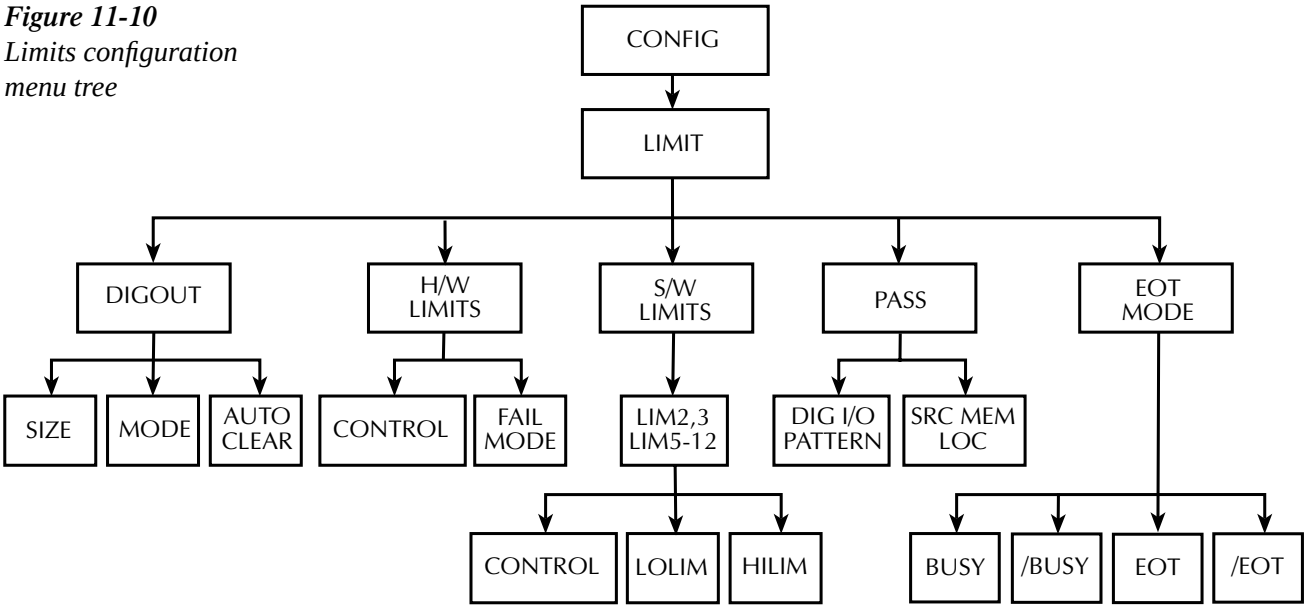
– AUTO CLEAR — Use this menu item to ENABLE or DISABLE auto-clear for the digital output. After enabling auto-clear, you will be prompted to set the pass/fail pattern pulse width (delay; 0 to 60.00000sec). You will then be prompted to set the digital output clear pattern (0 to 7, 3-bit; 0 to 15, 4-bit; 0 to 65535, 16-bit).

NOTE *16-bit digital output patterns are available only with the 2499-DIGIO option.*

- **H/W LIMITS** — Use this menu item to control and set the fail mode for the Limit 1 (Compliance) test:
  - **CONTROL** — Use to ENABLE or DISABLE the test.
  - **FAIL MODE** — Use to select the fail mode for Limit 1 test. With IN selected, the test will fail when the SourceMeter is in compliance. With OUT selected, the test will fail when not in compliance. Also use to specify the digital output bit pattern for Limit #1 IN or OUT test failure (0 to 7, 3-bit; 0 to 15, 4-bit; 0 to 65535, 16-bit).
- **S/W LIMITS** — Use this menu item to control, set limits for, and define output bit patterns for LIM2, LIM3, and LIM5 through LIM12 tests:
  - **CONTROL** — Use to ENABLE or DISABLE the test.
  - **LOLIM** — Use to set the low limit and, for the grading mode, specify the “fail” bit pattern (0-7; 3-bit; 0 to 15; 4-bit; 0 to 65535, 16-bit).
  - **HILIM** — Use to set the high limit and, for the grading mode, specify the “fail” bit pattern (0 to 7; 3-bit); 0 to 15; 4-bit; 0 to 65535, 16-bit).
  - **PASS** — Use to specify the “pass” bit pattern for the sorting mode software limit tests.
- **PASS** — Use this menu item to dictate actions upon a PASS condition:
  - **DIGIO PATTERN** — Use this option item to define the digital output bit pattern (0 to 7, 3-bit; 0 to 15, 4-bit; 0 to 65535, 16-bit). For the grading mode, it is the pass pattern for the “all tests pass” condition. For the sorting mode, it is the pass pattern for Limit 1 (compliance) when all other software limit tests are disabled (0 to 7, 3-bit; 0 to 15, 4-bit; 0 to 65535, 16-bit).
  - **SRC MEM LOC** — Use this option with a Source Memory Sweep to select the next memory location point in the sweep when the PASS condition occurs. If NEXT is selected, the next point in the sweep list will be selected. You can also branch to a different point in the sweep by specifying the memory LOCATION# (1 to 100).

- **EOT MODE** — Use this menu item to control the operation of Digital I/O line 4 to act as an EOT (End of Test) or BUSY signal:
  - **EOT** — In 3-bit mode, automatically output a HI pulse on Digital I/O line 4 at end of test. In 4-bit mode, EOT is not automatically controlled.
  - **/EOT** — In 3-bit mode, automatically output a LO pulse on Digital I/O line 4 at end of test. In 4-bit mode, this option is not available.
  - **BUSY** — Set Digital I/O line 4 HI while unit is busy. With BUSY selected, the unit behaves as if it is in 3-bit mode.
  - **/BUSY** — Set Digital I/O line 4 LO while unit is busy. With /BUSY selected, the unit behaves as if it is in 3-bit mode.

Figure 11-10
Limits configuration menu tree



Performing limit tests

Perform the following steps to run limit tests:

Step 1: Configure test system.

As previously explained in Section 2, your test system could be as simple as connecting a DUT to the SourceMeter or could employ the use of a handler for binning operations. Adding a scanner to the test system allows you to test multi-element devices (such as resistor networks). Make sure that the Digital I/O is configured appropriately for the handler you are using.

Step 2: Configure source-measure functions.

Configure the SourceMeter for the desired source-measure operations as follows:

1. Select the desired source function by pressing SOURCE V or SOURCE I.
2. Set the source level and compliance limit to the desired values.

3. Press MEAS V or MEAS I to select the desired measurement function, then choose the desired measurement range.

Refer to the *Basic source-measure* procedure in Section 3 for more information.

Step 3: Configure limit tests.

Select and configure the following limit tests parameters as explained in *Configuring limit tests*:

- Use DIGOUT to configure the Digital I/O port for SIZE, MODE, and AUTO CLEAR.
- Set your H/W LIMITS and S/W LIMITS parameters as desired.
- Set up PASS conditions for Digital I/O bit pattern and memory source location if using source memory sweep.
- If using 3-bit port size, program the Digital I/O Line 4 EOT MODE for EOT or BUSY, as appropriate.

Step 4: Turn output on.

Press the ON/OFF key to turn the output on (OUTPUT indicator turns on). The Source-Meter will output the programmed bias level.

Step 5: Start testing process.

To enable the limit tests, press the LIMIT key. If the /SOT line of the Digital I/O is being used by a handler, the testing process will not start until the handler sends a low-going pulse. Otherwise, the testing process will start when LIMIT is pressed.

NOTE *The "PASS" and "FAIL" messages indicate the status of each test cycle, with the following exceptions:*

- *When in the NORMAL or GUARD output-off state, the "OFF" message is displayed. The pass and fail conditions will be displayed as "P OFF" and "F OFF" respectively.*
- *When in the ZERO output-off state, the "ZER" message is displayed. The pass and fail conditions will be displayed as "P ZER" and "F ZER" respectively.*
- *If the source reaches the OVP (Over-Voltage Protection) limit, the "OVP" message will be displayed. The pass and fail conditions will be displayed as "P OVP" and "F OVP" respectively.*

Step 6: Stop testing process.

The testing process can be terminated at any time by again pressing LIMIT. When using a handler, the testing process will stop after the last DUT is tested.

Remote limit testing

Limit commands

Table 11-1 summarizes remote commands to control limit testing. See *CALCulate2* and *SOURce2* in Section 17 for more details on these commands.

Table 11-1
Limit commands

Command*	Description*
:CALCulate2:FEED <name>	Select limit test input path (name = CALCulate[1], VOLTage, CURRent, or RESistance).
:CALCulate2:DATA?	Acquire limit test data.
:CALCulate2:LIMit:COMPliance:FAIL <name>	Set Limit 1 fail condition. Name = IN (fail into compliance) or OUT (fail out of compliance).
:CALCulate2:LIMitX:LOWer <n>	Specify lower Limit X; X = 2, 3, 5-12 (n = limit).
:CALCulate2:LIMitX:UPPer <n>	Specify upper Limit X; X = 2, 3, 5-`2 2 (n = limit).
:CALCulate2:LIMit[1]:COMPliance:SOURce2 <NRf> | <NDN>	Specify limit 1 fail bit pattern. (NRf | NDN = pattern).
:CALCulate2:LIMitX:LOWer:SOURce2 <NRf> | <NDN>	Specify lower Limit X fail bit pattern for grading mode; X = 2, 3, 5-12 (NRf | NDN = bit pattern).
:CALCulate2:LIMitX:UPPer:SOURce2 <NRf> | <NDN>	Specify upper Limit X fail bit pattern for grading mode; X = 2, 3, 5-12 (NRf = bit pattern).
:CALCulate2:LIMitX:PASS:SOURce2 <NRf> | <NDN>	Specify pass pattern for sorting mode (NRf | NDN = bit pattern).
:CALCulate2:LIMit[1]:STATe <state>	Enable/disable Limit 1 test (state = ON or OFF).
:CALCulate2:LIMitX:STATe <state>	Enable/disable Limit X test; X = 2, 3, 5-12 (state = ON or OFF).
:CALCulate2:LIMit[1]:FAIL?	Query Limit 1 test result (0 = pass, 1 = fail).
:CALCulate2:LIMitX:FAIL?	Query Limit X test result; X = 2, 3, 5-12 (0 = pass, 1 = fail).
:CALCulate2:CLIMits:PASS:SOURce2 <NRf> | <NDN>	Specify pass bit pattern (NRf | NDN = pattern). Sorting mode only if limits 2, 3 and 5-12 disabled.
:CALCulate2:CLIMits:FAIL:SOURce2 <NRf> | <NDN>	Specify fail bit pattern for sorting mode (NRf | NDN = pattern).
:CALCulate2:CLIMits:PASS:SMLocation <location>	Specify pass source memory location. Location = NRf (memory #) or NEXT (next location).
:CALCulate2:CLIMits:FAIL:SMLocation <location>	Specify fail source memory location. (Location = NRf (memory #) or NEXT (next location).
:CALCulate2:CLIMits:BCONtrol <name>	Control I/O port pass/fail update. Name = IMMediate (at failure) or END (end of sweep).
:CALCulate2:CLIMits:CLEar	Clear test results, reset I/O port.
:CALCulate2:CLIMits:CLEar:AUTO <state>	Enable/disable auto-clear (state = ON or OFF).
:CALCulate2:CLIMits:MODE <name>	Select Digital I/O control mode (name = GRADing or SORTing).

Table 11-1 (cont.)
Limit commands

Command*	Description*
:SOURce2:BSIZe <n>	Set Digital I/O port bit size (n = 3 or 4).
:SOURce2:TTL <NRf> | <NDN>	Set I/O port bit pattern (NRf | NDN = pattern).
:SOURce2:TTL:ACTual?	Query bit pattern on digital output port.
:SOURce2:TTL4:MODE <name>	Set Digital I/O line 4 mode (name = EOTest or BUSY).
:SOURce2:TTL4:BSTate <state>	Set BUSY and EOT polarity (HI or LO).
:SOURce2:CLEar	Clear digital output lines.
:SOURce2:CLEar:AUTO <state>	Enable/disable I/O port auto clear (state = ON or OFF).
:SOURce2:CLEar:AUTO:DELay <n>	Set auto-clear delay (n = delay).

*LIMitX = LIMit2, LIMit3, LIMit5 through LIMit12.

Limit test programming example

Diode breakdown voltage test is an example that readily lends itself to pass/fail analysis. This test verifies the reverse and often the forward voltage at which the device begins to show a large deviation in current for a small deviation in voltage. The test is performed by sourcing a specified current level and then measuring the resulting voltage drop. The voltage drop is then compared with one set of limits to determine if the diode passes, or fails and should be discarded. Voltage measurements for failing diodes are also compared against a more restricted range of limits to determine if they should be routed to QA (Quality Assurance) for further analysis.

Test parameters for this test include:

- Source Function: current
- Sense Function: voltage
- Source Current: 100mA
- Source Delay: 100ms
- Limit 2 Upper Value: 0.85V
- Limit 2 Lower Value: 0.75V
- Limit 3 Upper Value: 0.82V
- Limit 3 Lower Value: 0.78V

Figure 11-11 demonstrates graphically how parts are sorted. Diodes with a voltage between 0.78V and 0.82V are considered good and will pass the limits test. Diodes that test with a slightly wider voltage range are routed to QA for analysis, while those with the largest voltage tolerance will be discarded.

Figure 11-11
Diode pass/fail limits

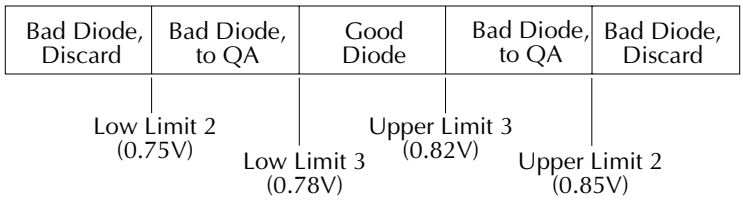


Table 11-2 summarizes the basic SCPI command sequence for performing a limit test for the diode breakdown and Table 11-3 summarizes pass/fail parameters.

NOTE *Additional programming steps will be necessary to test the values returned by the :CALC2:LIM2:FAIL? and :CALC:LIM3:FAIL? queries. A returned value of 1 indicated a failure of that limit test.*

Table 11-2
Limits test programming example

Command	**Description**
*RST	Restore GPIB default conditions.
:SENS:FUNC:CONC OFF	Turn off concurrent functions.
:SOUR:FUNC CURR	Current source function.
:SENS:FUNC 'VOLT:DC'	Volts sense function.
:SOUR:CURR:TRIG 0.1	Output 100mA when triggered.
:SOUR:DEL 0.1	100ms source delay.
:CALC2:FEED VOLT	Use voltage for limits comparison.
:CALC2:LIM2:UPP 0.85	Limit 2 upper value = 0.85V.
:CALC2:LIM2:LOW 0.75	Limit 2 lower value = 0.75V.
:CALC2:LIM3:UPP 0.82	Limit 3 upper value = 0.82V.
:CALC2:LIM3:LOW 0.78	Limit 3 lower value = 0.78V.
:CALC2:CLIM:PASS:SOUR2 1	Digital I/O port = 0001 (1) when test passes.
:CALC2:LIM2:UPP:SOUR2 2	Digital I/O port = 0010 (2) when upper Limit 2 fails.
:CALC2:LIM2:LOW:SOUR2 2	Digital I/O port = 0010 (2) when lower Limit 2 fails.
:CALC2:LIM3:UPP:SOUR2 3	Digital I/O port = 0011 (3) when upper Limit 3 fails.
:CALC2:LIM3:LOW:SOUR2 3	Digital I/O port = 0011 (3) when lower Limit 3 fails.
:CALC2:CLIM:BCON IMM	Update Digital I/O port immediately after test.
:CALC2:LIM1:STAT 0	Turn off Limit 1 test.
:CALC2:LIM2:STAT 1	Turn on Limit 2 test.
:CALC2:LIM3:STAT 1	Turn on Limit 3 test.
:OUTPUT ON	Turn on source output.
:INIT	Trigger reading and limits test.
:OUTP OFF	Turn off output.
:CALC2:LIM2:FAIL?	Query Limit 2 test results (1 = discard diode).
:CALC2:LIM3:FAIL?	Query Limit 3 test results (1 = send diode to QA).

Table 11-3
Limits test results summary

Diode voltage range	**Test result**	**Digital I/O port binary value**	**Handler bin number**
0.78 to 0.82V	Pass	0001	1
0.75 to 0.78V or 0.82 to 0.85V	Send to QA	0010	2
<0.75, >0.85V	Discard	0011	3

12
Digital I/O Port, Interlock, and Output Configuration

- **Digital I/O Port** — Discusses the various input/output lines on the Digital I/O Port as well as the +5V line that can be used to power external logic circuits.
- **Safety Interlock** — Describes how to use the Digital I/O Port as a safety interlock.
- **Front Panel Output Configuration** — Details configuration of the Digital I/O Port as an interlock as well as configuring main output off states.
- **Remote Output Configuration** — Summarizes the remote commands used to control the Digital I/O Port interlock and main output off states. A simple programming example is also provided.

Digital I/O port

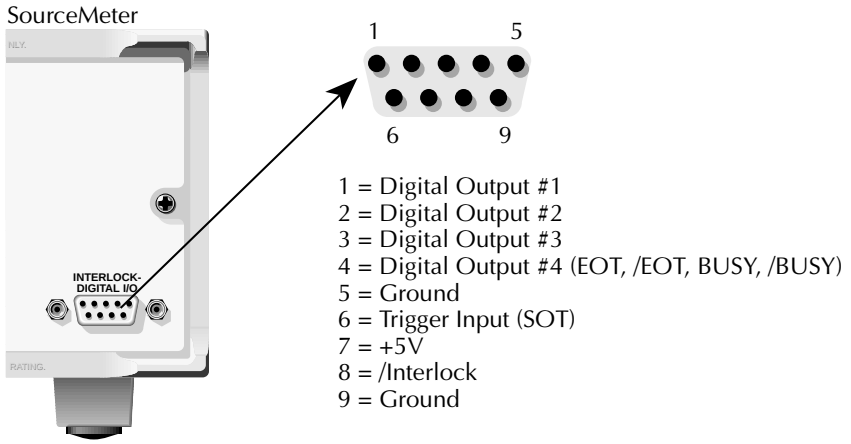
The SourceMeter has a digital input/output port that can be used to control external digital circuitry, such as a handler that is used to perform binning operations when testing limits.

Port configuration

The Digital I/O Port is located on the rear panel and is shown in Figure 12-1. Note that a standard male DB-9 connector is used for the Digital I/O port.

NOTE *The four digital output lines and the SOT line are primarily intended for limit testing with a device handler. See "Limit testing" in Section 11 for details on performing limit tests and interfacing to handlers and "Triggering" in Section 10 for information on programming the SourceMeter to respond to the SOT (start-of-test) pulse from a handler.*

Figure 12-1 *Interlock and digital I/O port*



Digital output lines

The port provides four output lines and one input line. Each open-collector output can be set high (+5V) or low (0V). Each output line can source up to 2mA or sink up to 500mA. When using a category register handler for limit testing, output line #4 is typically used for the EOT (End-of-Test) or BUSY pulse. This pulse from the SourceMeter signals the handler to perform the binning operation, or indicates a busy condition. (See Section 11, *Configuring limit tests*.)

SOT line

The input line (SOT) is used by the handler to start limit testing. With the ↓STEST arm event selected, the handler must pulse SOT low in order to provide event detection which starts the testing process. With the ↑STEST arm event selected, the handler must pulse SOT high in order to provide event detection and start the testing process. With the ↑↓STEST arm event selected, the handler must pulse SOT either high or low in order to provide event detection and start the testing process.

EOT/BUSY line

Line 4 can be used for a normal bit pattern, EOT (End-of-Test), or BUSY signal, depending on the selected END OF TEST mode.

NOTE *See Section 11 for details on performing limit tests and Section 10 for information on programming the SourceMeter to respond to the SOT (start-of-test) pulse from a handler.*

+5V output

The Digital I/O Port provides a +5V output that can be used to drive external logic circuitry. Maximum current output for this line is 300mA. This line is protected by a self-resetting fuse (one hour recovery time).

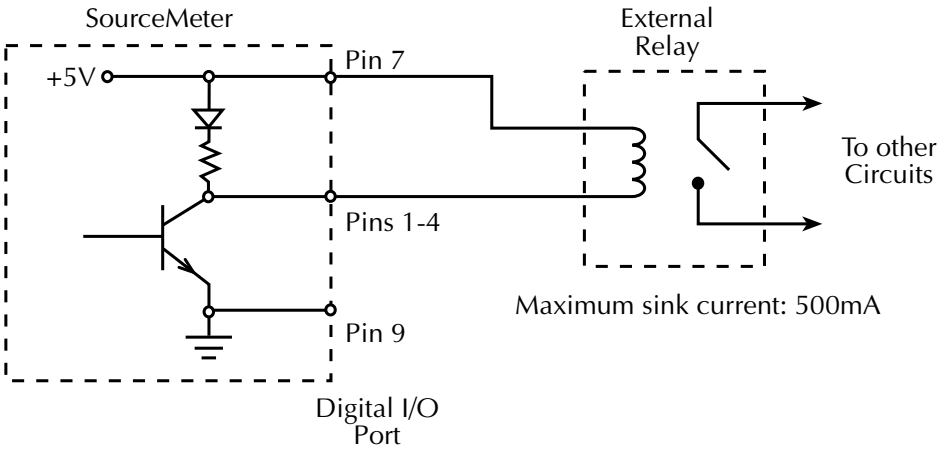
Digital output configuration

There are two basic methods to connect external components to the digital output lines, sink operation and source operation.

Sink operation

Figure 12-2 shows the basic output configuration for sink operation. Note that the external relay coil is connected between the digital output line (pins 1 to 4) and +5V (pin 7). With this configuration, the digital output line must be set LO to energize the relay, and the maximum sink current is 500mA.

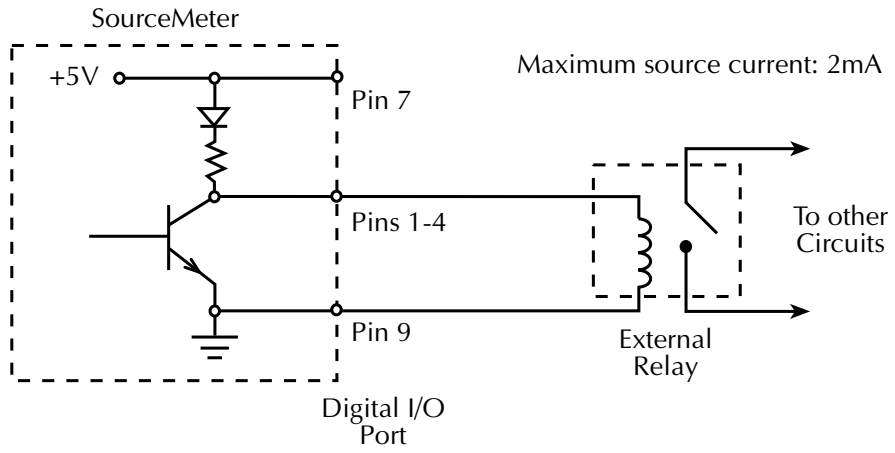
Figure 12-2
Sink operation



Source operation

Figure 12-3 shows the basic output configuration for source operation. In this case, the external relay coil is connected between the digital output line (pins 1 to 4) and ground (pin 9). With this configuration, the digital output line must be set HI to energize the relay, and the maximum source current is 2mA.

Figure 12-3
Source operation



Controlling digital output lines

Although the digital output lines are primarily intended for use with a device handler for limit testing, they can also be used for other purposes such as controlling external relays or indicator lights. You can control these lines either from the front panel or via remote as follows.

Front panel digital output control

Set digital output line logic levels from the front panel as follows:

1. Press the MENU key.
2. Select GENERAL, then press ENTER.
3. Select DIGOUT, then press ENTER.
4. Using the RANGE and cursor keys, set the digital output parameter to the desired decimal value (Table 12-1). For example, to set the output lines to L, H, H, H, set the digital output parameter value to 7.
5. Press EXIT to return to normal display.

Remote digital output control

Use the :SOURce:TTL <NRf> command to control the digital output line logic levels, where <NRf> is the decimal value shown in Table 12-1. For example, send the following command to set the output lines to L, H, L, H:

:SOUR:TTL 5

Table 12-1
Digital output line settings

OUT 4	OUT 3	OUT 2	OUT 1	Decimal value*
L	L	L	L	0
L	L	L	H	1
L	L	H	L	2
L	L	H	H	3
L	H	L	L	4
L	H	L	H	5
L	H	H	L	6
L	H	H	H	7
H	L	L	L	8
H	L	L	H	9
H	L	H	L	10
H	L	H	H	11
H	H	L	L	12
H	H	L	H	13
H	H	H	L	14
H	H	H	H	15

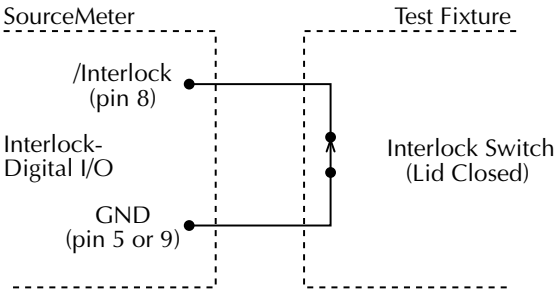
L = Low (Gnd)
H = High (>+3V)
*0-7 in 3-bit mode, which is controlled by CONFIG LIMIT menu. (See Section 11.)
0-65535 with 2499-DIGIO 16-bit option.

Safety interlock

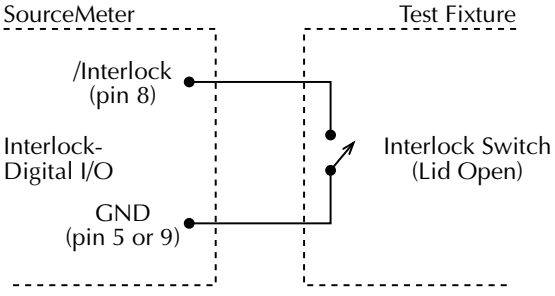
The Digital I/O Port provides an interlock line for use with a test fixture interlock switch. When properly used, the OUTPUT of the SourceMeter will turn OFF when the lid of the test fixture is opened. See *Connections* in Section 2 for important safety information when using the test fixture interlock.

When the interlock is enabled (see *Front panel output configuration* later in this section), the output of the SourceMeter cannot be turned on unless the interlock line is pulled low through a switch to ground as shown in Figure 12-4A. If the lid of the test fixture opens (Figure 12-4B), the switch opens, and the interlock line goes high turning the OUTPUT of the SourceMeter OFF (high impedance). The output can only be turned back on by first closing the lid of the test fixture and then pressing the OUTPUT ON/OFF key.

Figure 12-4
Using test fixture interlock



A. SourceMeter OUTPUT can be turned on.



B. SourceMeter OUTPUT turns off.

NOTE *Interlock can be driven by Digital I/O. Allow 100µs settling and response time. The Digital I/O lines are open-collector, edge-sensitive and signals should be de-bounced to avoid erratic operation.*

Front panel output configuration

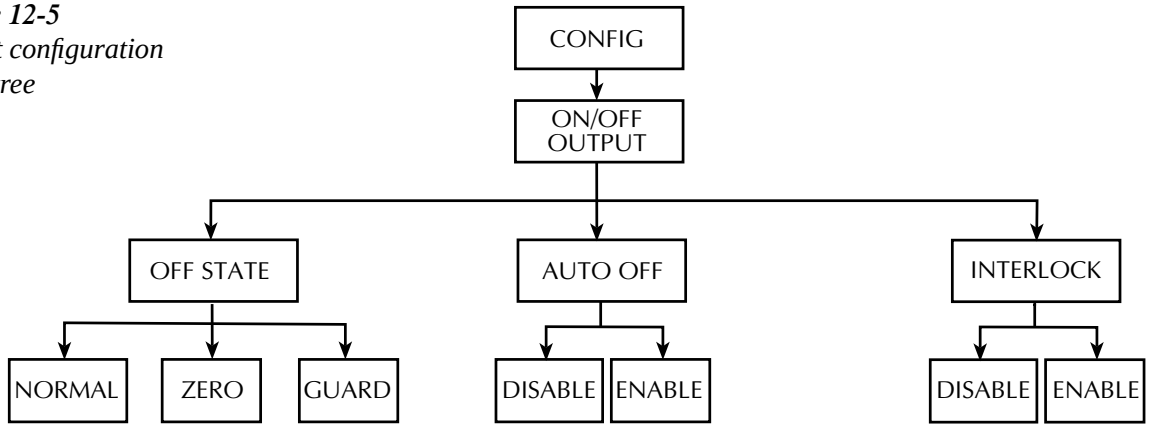
The output is configured from the CONFIGURE OUTPUT menu and is structured as follows. Note that bullets indicate the primary items of the sweep menu, while dashes indicate options. Use Section 1, *Rules to navigate menus* to check and/or change operate options.

Configure OUTPUT menu

Press CONFIG and then ON/OFF OUTPUT to display the menu, which is also shown in Figure 12-5.

- **OFF STATE** — Use to select the OFF state of the output. (See *Output-off states* for details.)
  - **NORMAL** — When the OUTPUT is turned off, the V-Source is selected and set to 0V. Current compliance is set to 0.5% full scale of the present current range. NORMAL is the default off-state.
  - **ZERO** — When the V-Source OUTPUT is turned off, the V-Source is set to 0V and current compliance is not changed. When the I-Source OUTPUT is turned off, the V-Source mode is selected and set to 0V. Current compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. Measurements are performed and displayed while the OUTPUT is off.
  - **GUARD** — When OUTPUT is turned OFF, the current source is selected and set to 0A. Voltage compliance is set to 0.5% full scale of the present voltage range.
- **AUTO OFF** — Use to ENABLE or DISABLE auto output off. When enabled, the OUTPUT will turn off after the measurement phase of every SDM cycle. The OUTPUT turns back on at the beginning of the next SDM cycle. When disabled, the OUTPUT stays on as long as the SourceMeter is operating within the trigger model (ARM annunciator on). With the OUTPUT enabled, pressing the ON/OFF key will disable the OUTPUT and disable auto output off.
- **INTERLOCK** — Use to ENABLE or DISABLE the interlock line of the Digital output. This line is used as an interlock for a test fixture. See *Safety interlock*.

Figure 12-5
Output configuration menu tree



Output-off states

NORMAL

When in this relatively high-impedance output-off state, the V-Source is selected and set to 0V. Current compliance is set to 0.5% full scale of the present current range. In theory, with the V-Source set to zero, the SourceMeter will not source or sink power. In practice, the source value may not be exactly at zero. Therefore, the SourceMeter may source or sink a very small amount of power. In most cases, this source or sink power level is not significant.

ZERO

When in this output-off state, the "ZER" message is displayed (instead of "OFF"), and the SourceMeter is configured as follows:

When the V-Source is the selected source:

- The programmed V-Source value remains on the display.
- Internally, the V-Source is set to 0V.
- The current compliance setting remains the same as the output-on value. "Real" and "range" compliance detection remains active.
- Measurements are performed and displayed.

When the I-Source is the selected source:

- The programmed I-Source value remains on the display.
- Internally, the V-Source is selected and set to 0V.
- Current compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater.
- Measurements are performed and displayed.

While in the ZERO output-off state, the SourceMeter can be used as an I-Meter.

The ZERO output-off state can also be used with the V-Source and Output Auto-Off to generate very quick pulsed voltage waveforms. For example, with Output Auto-Off enabled, you can generate 0 to +5V pulses. While in this relatively low-impedance output-off state, the Source-Meter will be able to quickly dissipate (sink) current caused by high input capacitance (i.e., cable capacitance) or an external source. This results in fast settling time. If you instead used the NORMAL output-off state for this application, current would dissipate very slowly (slow settling time) resulting in distorted pulses.

WARNING **Hazardous voltages (30V rms) can appear on the selected INPUT/OUTPUT LO terminal when generating quick, pulsed waveforms using the ZERO AUTO-OFF output state. To eliminate this shock hazard, connect the LO terminal to earth ground. If using the front panel terminals, ground the front panel LO terminal. If using the rear panel terminals, ground the rear panel LO terminal. The ground connection can be made at the chassis ground screw on the rear panel or to a known safety earth ground.**

GUARD

With this output-off state, the current source is selected and set to 0A. Voltage compliance is set to 0.5% full scale of the present voltage range. This output-off state should be used when performing 6-wire guarded ohms measurements or for any other load that uses an active source.

NOTE *When changing the output-off state with the output off, the selected output-off state will be entered immediately.*

Output off states and inductive loads

The output off state you select for inductive loads depends on how much energy the inductor holds. The Normal output off state is *not* recommended as it lowers the compliance setting. The Zero or the Guard state are better suited, as Zero does *not* change the compliance setting and the Guard output off state would change the voltage source to a current source with a voltage compliance. The Guard state is typically used only for guarded ohms measurements.

To protect the unit from inductive energy, the application may require a spark gap across the INPUT HI and LO terminals. The SourceMeter does not have internal spark gap protection, as some leakage current (nA) is associated with the protection circuits.

Remote output configuration

Output configuration commands

Table 12-2 summarizes output configuration commands. These commands include those to enable and disable the interlock as well as commands to control output off states. See Section 17, *OUTPut subsystem* and *SOURce subsystem* for more information.

Table 12-2
Output configuration commands

Command	Description
:OUTPut:INTerlock:STATe <state>	Enable/disable interlock (state = ON or OFF).
:OUTPut:INTerlock:TRIPped?	Query interlock tripped state (1 = tripped).
:OUTPut:SMODe <name>	Select output-off mode (state = NORMal, ZERO, or GUARd).
:SOURce:CLEar	Turn output source off when in idle state.
:SOURce:CLEar:AUTO <state>	Enable/disable auto output-off. State = ON (output off after measurement) or ON (output stays on).
:SOURce:CLEar:AUTO:MODE <name>	Auto clear mode. Name = ALWays (every reading; default) or TCOunt (ON when trigger layer entered; OFF when leaving trigger layer).

Output configuration programming example

Table 12-3 lists the command sequence for output configuration. These commands set up the SourceMeter as follows:

- Interlock: enabled
- Output-off mode: normal
- Auto-off mode: on

NOTE *Connect pins 8 and 9 of the Digital I/O Port together to simulate a closed interlock switch. Otherwise, the unit will not turn on its output when the measurement is made.*

Table 12-3
Output configuration programming example

Command	Description
*RST	Restore GPIB defaults.
:SOUR:VOLT 10	Output 10V.
:OUTP:INT:STAT ON	Enable interlock.*
:OUTP:SMOD NORM	Select normal output-off mode.
:SOUR:CLE:AUTO ON	Enable auto-off mode.
:READ?	Trigger and acquire readings.

*Connect pins 8 and 9 of Digital I/O Port to simulate closed interlock switch.

13
Remote Operations

- **Differences: Remote vs. Local Operation** — Summarizes remote operation enhancements and local-to-remote and remote-to-local transitions.
- **Selecting an Interface** — Describes how to select between the GPIB and RS-232 interfaces.
- **GPIB Operation** — Covers GPIB bus standards, bus connections, and primary address selection.
- **General Bus Commands** — Describes general bus commands used for fundamental GPIB control.
- **Front Panel GPIB Operation** — Summarizes GPIB error messages, status indicators, and using the LOCAL key.
- **Programming Syntax** — Describes the basic programming syntax for both common and SCPI commands.
- **RS-232 Interface Operation** — Outlines use of the RS-232 interface to control the SourceMeter via remote.

Differences: remote vs. local operation

Operation enhancements (remote operation)

There are some source-measure operations you can do over the IEEE-488 bus and RS-232 interface that you cannot do from the front panel; these are summarized below.

Math expressions

There are five math expressions available from the panel. All except the Percent Deviation are available as pre-defined math expressions for remote operation. However, remote operation allows you to create up to five user-defined math expressions for a total of nine expressions. An example program shows how to create Percent Deviation as a user-defined math expression.

Concurrent measurements

With the use of the TOGGLE key, you can measure (display) two functions concurrently. Using remote operation, you can perform concurrent measurements on all three functions (voltage, current, and resistance). See Section 17, *SENSe1 Subsystem* for details.

Local-to-remote transition

When changing from local to remote operation, the following actions occur:

- The SourceMeter stops performing source-measure operations and returns to the idle state (ARM annunciator off).
- All sweep operations are aborted.
- All menus are exited.
- All pending front panel commands are aborted.
- Source and compliance editing are disabled.
- Data in the sample buffer is lost (i.e., :FETCh?, :CALC1:DATA?, and :CALC2:DATA? will not return any data until readings are taken while in remote).
- Concurrent measurements are enabled.
- All other settings are not affected, including those for the :TRACe buffer (data store).

Remote-to-local transition

When changing from remote to local operation, the following actions occur.

- The SourceMeter stops performing source-measure operations and returns to the idle state (ARM annunciator off).
- All sweep operations are aborted.
- All user-defined display messages are cancelled.
- The display is turned on (if it was previously turned off).
- Source autoranging is disabled.
- Concurrent measurements are enabled.
- If resistance was enabled, source readback is enabled.
- The display is set to the default toggle state.
- Readings are continuously taken (if OUTPUT is on).

Selecting an interface

The SourceMeter supports two built-in remote interfaces:

- GPIB (General Purpose Interface Bus)
- RS-232 interface

You can use only one interface at a time. The factory interface selection is the GPIB bus. You can select the interface only from the front panel. The interface selection is stored in non-volatile memory; it does not change when power has been off or after a remote interface reset.

The GPIB bus is the IEEE-488 interface. You must select a unique address for the Source-Meter. The address is displayed when the instrument is turned on. At the factory, the address is set to 24.

The RS-232 interface is a serial interface. Programmable aspects of this interface include the following (factory default settings are shown in parentheses):

- Baud rate (9600)
- Data bits (8)
- Parity (none)
- Terminator (CR)
- Flow control (none)

An interface is selected and configured from the COMMUNICATIONS option of the Main Menu. See Section 1, *Main menu*. For details on the programmable aspects of the interfaces, see *Primary address* and *RS-232 interface operation* in this section.

NOTE *When changing interface selections, the SourceMeter performs a power-on reset. To check and/or change options of the selected interface, you must re-enter the menu structure.*

GPIB operation

This section contains information about GPIB standards, bus connections, and primary address selection.

GPIB standards

The GPIB 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 SourceMeter conforms to these standards:

- IEEE-488.1-1987
- IEEE-488.2-1992

The above standards define a syntax for sending data to and from instruments, how an instrument interprets this data, what registers should exist to record the state of the instrument, and a group of common commands. The SourceMeter also conforms to this standard:

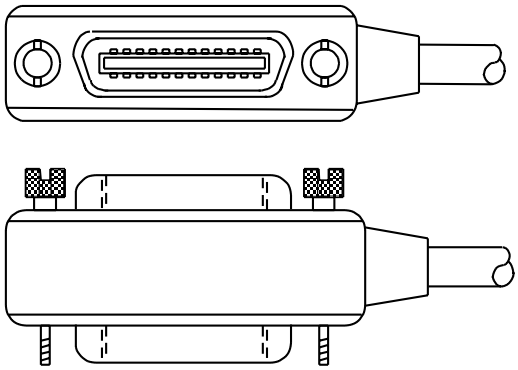
- SCPI 1996.0 (Standard Commands for Programmable Instruments)

This standard defines a command language protocol. It goes one step farther than IEEE-488.2-1992 and defines a standard set of commands to control every programmable aspect of an instrument.

GPIB connections

To connect the SourceMeter to the GPIB bus, use a cable equipped with standard IEEE-488 connectors as shown in Figure 13-1.

Figure 13-1
IEEE-488 connector



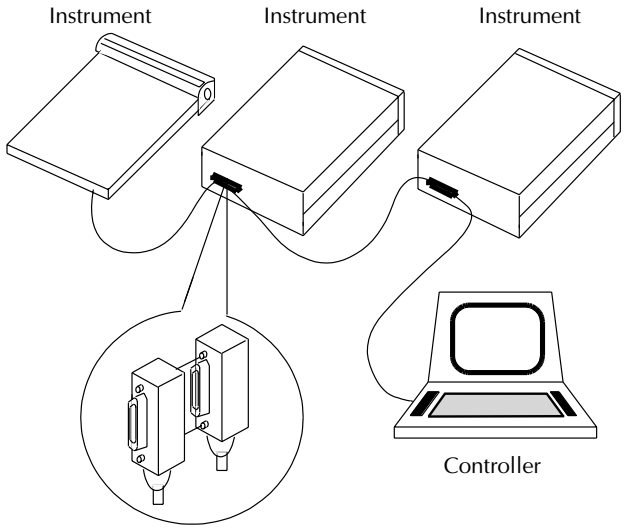
To allow many parallel connections to one instrument, stack the connectors. Two screws are located on each connector to ensure that connections remain secure. Present standards call for metric threads, which are identified with dark-colored screws. Earlier versions have different screws, which are silver-colored. Do not use these types of connectors on the SourceMeter; it is designed for metric threads.

Figure 13-2 shows a typical connecting scheme for a multi-unit test system.

To avoid possible mechanical damage, stack no more than three connectors on any one unit.

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.*

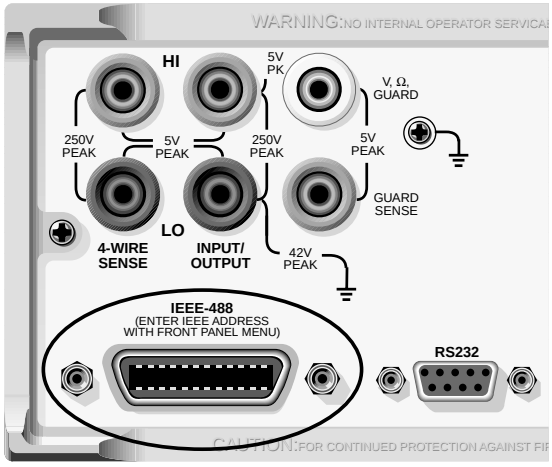
Figure 13-2
IEEE-488 connections



To connect the SourceMeter to the IEEE-488 bus, follow these steps:

1. Line up the cable connector with the connector located on the rear panel. The connector is designed so it will fit only one way. Figure 13-3 shows the location of the IEEE-488 connector.
2. Tighten the screws securely, making sure not to overtighten them.

Figure 13-3
IEEE-488 connector location



3. Connect any additional connectors from other instruments as required for your application.
4. Make sure the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. See your controller's instruction manual for information about properly connecting to the IEEE-488 bus.

NOTE *You can only have 15 devices connected to a IEEE-488 bus, including the controller. The maximum cable length is either 20 meters or two meters multiplied by the number of devices, whichever is less. Not observing these limits may cause erratic bus operation.*

Primary address

The SourceMeter ships from the factory with a GPIB primary address of 24. When the unit powers up, it momentarily displays the primary address. You can set the address to a value from 0 to 30, but do not assign the same address to another device or to a controller that is on the same GPIB bus (controller addresses are usually 0 or 21).

The primary address can be checked and/or changed from the COMMUNICATIONS/GPIB option of the Main Menu. See Section 1, *Main menu*. This menu option also allows you to select the 488.1 or SCPI protocol (see Appendix G).

General bus commands

General commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. Table 13-1 lists the general bus commands.

Table 13-1
General bus commands

Command	Effect on SourceMeter
REN	Goes into remote when next addressed to listen.
IFC	Goes into talker and listener idle states.
LLO	LOCAL key locked out.
GTL	Cancel remote; restore SourceMeter front panel operation.
DCL	Returns all devices to known conditions.
SDC	Returns SourceMeter to known conditions.
GET	Initiates a trigger.
SPE, SPD	Serial polls the SourceMeter.

REN (remote enable)

The remote enable command is sent to the SourceMeter 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. Setting REN true does not place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote.

The SourceMeter must be in remote in order to use the following commands to trigger and acquire readings:

- :INITiate and then :FETCh?
- :READ?
- :MEASure?

IFC (interface clear)

The IFC command is sent by the controller to place the SourceMeter in the local, talker, listener idle states. The unit responds to the IFC command by cancelling front panel TALK or LSTN lights, if the instrument was previously placed in one of these states.

Note that this command does not affect the status of the instrument. Settings, data, and event registers are not changed.

With auto output off enabled (:SOURce1:CLEar:AUTO ON), the output will remain on if operation is terminated before the output has a chance to automatically turn off.

To send the IFC command, the controller need only 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 of its front panel controls except OUTPUT OFF are inoperative. In this state, pressing LOCAL will not restore control to the front panel. The GTL command restores control to the front panel. Cycling power will also cancel local lockout.

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 SourceMeter 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 arm event to control operation. The SourceMeter reacts to this trigger if it is the programmed arm control source. The following command selects the GPIB arm control source:

:ARM:SOURce BUS

NOTE *With :ARM:SOURce BUS selected and an :INITiate command sent, do not send any commands (except GET, DCL, SDC, IFC, *TRG, and :ABORt) while performing source-measure operations (ARM annunciator on). If you do, erratic operation will occur.*

SPE, SPD (serial polling)

Use the serial polling sequence to obtain the SourceMeter serial poll byte. The serial poll byte contains important information about internal functions. See Section 14. 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 SourceMeter.

Front panel GPIB operation

This section describes aspects of the front panel that are part of GPIB operation, including messages, status indicators, and the LOCAL key.

Error and status messages

See Appendix B for a list of status and error 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.

GPIB status indicators

The REM (remote), TALK (talk), LSTN (listen), and SRQ (service request) annunciators show the GPIB bus status. Each of these indicators is described below.

REM

This indicator shows when the instrument is in the remote state. REM does not necessarily indicate the state of the bus REN line, as the instrument must be addressed to listen with REN true before the REM indicator turns on. When the instrument is in remote, all front panel keys, except for the LOCAL key, are locked out. When REM is turned off, the instrument is in the local state, and front panel operation is restored.

NOTE *If LLO is in effect, LOCAL will be locked out. OUTPUT ON/OFF is still operational in remote. If ARM:SOUR is set to manual, the TRIG key will be active in remote.*

TALK

This indicator is on when the instrument is in the talker active state. Place the unit in the talk state by addressing it to talk with the correct MTA (My Talk Address) command. TALK is off when the unit is in the talker idle state. Place the unit in the talker idle state by sending an UNT (Untalk) command, addressing it to listen, or sending the IFC (Interface Clear) command.

LSTN

This indicator is on when the SourceMeter is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LSTN is off when the unit is in the listener idle state. Place the unit in the listener idle state by sending UNL (Unlisten), addressing it to talk, or sending IFC (Interface Clear) command over the bus.

SRQ

You can program the instrument to generate a service request (SRQ) when one or more errors or conditions occur. When this indicator is on, a service request has been generated. This indicator stays on until the serial poll byte is read or all the conditions that caused SRQ have been cleared. See Section 14 for more information.

LOCAL key

The LOCAL key cancels the remote state and restores local operation of the instrument.

Pressing the LOCAL key also turns off the REM 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.

For safety reasons, the OUTPUT key can be used to turn the output off while in LLO.

Programming syntax

The information in this section covers syntax for both common commands and SCPI commands. For information not covered here, see the IEEE- 488.2 and SCPI standards. See Section 15 and Section 17 for more details on common and SCPI commands, respectively.

Command words

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

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
:CALCulate1:STATe <b>	Parameter <b> required
:SYSTem:PRESet	No parameter used

NOTE At least one space between the command word and the parameter is required.

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:

:INITiate[:IMMediate]

These brackets indicate that :IMMediate is implied (optional) and does not have to be used. Thus, the above command can be sent in one of two ways:

:INITiate

or

:INITiate:IMMediate

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:

:CALCulate1:STATe ON — Enable Calc 1 math expression

<name> **Name parameter** — Select a parameter name from a listed group. Example:

<name> = NEVer

= NEXt

:TRACe:FEED:CONTrol NEXt

<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:

:SYSTem:KEY 11 — Press EXIT key from over the bus

<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:

:ARM:TIMer 0.1	Sets timer to 100 msec.
:ARM:TIMer DEFault	Sets timer to 0.1 sec.
:ARM:TIMer MINimum	Sets timer to 1 msec.
:ARM:TIMer MAXimum	Sets timer to 99999.99 sec.

<numlist> **Numlist** — Specify one or more numbers for a list. Example:

:STATus:QUEue:ENABle (-110:-222) — Enable errors -110 through -222

<NDN> **Non-decimal numeric** — This parameter is used to send values in the binary, octal, or hexadecimal format. The prefix designates the format type:

#Bxx...x	#B specifies the binary format. xx...x is the binary number (using 0s and 1s).
#Qxx...x	#Q specifies the octal format. xx...x is the octal number (values 0 through 7).
#Hxx...x	#H specifies the hexadecimal format. xx...x is the hexadecimal number (values 0 through 9 and A through F).

Examples to send the decimal value 36 in the non-decimal formats:

*ESE #b100100	Binary format
*ESE #q44	Octal format
*ESE #h24	Hexadecimal format

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

:OUTPut <b>

The <b> indicates a Boolean-type parameter is required. Therefore, to enable the selected source, you must send the command with the ON or 1 parameter as follows:

:OUTPut ON

:OUTPut 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:

:ARM:TIMer?	Queries the timer interval.

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 are:

:ARM:TIMer? DEFault	Queries the *RST default value.
:ARM:TIMer? MINimum	Queries the lowest allowable value.
:ARM:TIMer? 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?
:SYSTem:PRESet = :system:preset

NOTE *Using all upper case will result in slightly faster command response times.*

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 17 provide the long-form version. However, the short-form version is indicated by upper case characters. Examples:

:SYSTem:PRESet	long-form
:SYST:PRES	short-form
:SYSTem:PRES	long-form and short-form combination

Note that each command word must be in long-form or short-form, and not something in between. For example, :SYSTe: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:

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

  :auto = :auto

These rules apply to command words that exceed four letters:

- If the fourth letter of the command word is a vowel (including “y”), delete it and all the letters after it. Example:

  :immediate = :imm
- 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:

  :delay? = :del?
- Command words or characters that are enclosed in brackets ([ ]) are optional and need not be included in the program message.

NOTE *For fastest response to commands, always use short forms.*

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 :STATus subsystem and are used to 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 above 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 (;). The following is an example showing two commands in one program message:

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

When the above 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., [:SENSe]). If the root is optional, simply treat a command word on the next level as the root. For fastest operation, do not send optional data.
- The colon (:) at the beginning of a program message is optional and need not be used. Note that eliminating the first colon will result in fastest operation. 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 command 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, of course, 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 SourceMeter 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 (*Multiple command messages*), the multiple response messages for all the queries are sent to the computer when the SourceMeter 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 SourceMeter 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 SourceMeter to talk.

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

RS-232 interface operation

NOTE *The programmable aspects of RS-232 operation (baud rate, data bits, parity, and terminator) are configured from the COMMUNICATION option of the Main Menu. See Section 1, "Main Menu."*

Sending and receiving data

The RS-232 interface transfers data using 8 data bits, 1 stop bit, and no parity. Make sure the device you connect to the SourceMeter also uses these settings.

You can break data transmissions by sending a ^C (decimal 3) or ^X (decimal 18) character string to the instrument, or by sending an RS-232 break condition (holding the transmit line low for >11 bits). This clears any pending operation, discards any pending output, and returns a "DCL."

Baud rate

The baud rate is the rate at which the SourceMeter and the programming terminal communicate. Choose one these available rates:

- 57600
- 38400
- 19200
- 9600
- 4800
- 2400
- 1200
- 600
- 300

The factory selected baud rate is 9600.

When you choose a baud rate, make sure the programming terminal or printer that you are connecting to the SourceMeter can support the baud rate you selected. Both the SourceMeter and the other device must be configured for the same baud rate.

Data bits and parity

The RS-232 interface can be configured to send/receive data that is 7 or 8 bits long using even, odd, or no parity. No parity is only valid when using 8 data bits.

Terminator

The SourceMeter can be configured to terminate each program message that it transmits to the controller with any of the following combinations of <CR> and <LF>:

<CR>	Carriage return
<CR+LF>	Carriage return and line feed
<LF>	Line feed
<LF+CR>	Line feed and carriage return

Flow control (signal handshaking)

Signal handshaking between the controller and the instrument lets the two devices communicate with each other about readiness to receive data. The SourceMeter does not support hardware handshaking (flow control).

Software flow control is in the form of XON and XOFF characters and is enabled when XON-XOFF is selected from the RS-232 FLOW CONTROL menu. When the input queue of the unit becomes more than 3/4 full, the instrument issues an XOFF command. The control program should respond to this and stop sending characters until the SourceMeter issues the XON, which it will do once its input buffer has dropped below half-full. The SourceMeter recognizes XON and XOFF sent from the controller. An XOFF will cause the instrument to stop outputting characters until it sees an XON. Incoming commands are processed after the <CR> character is received from the controller.

If NONE is the selected flow control, there will be no signal handshaking between the controller and the SourceMeter. Data will be lost if transmitted before the receiving device is ready.

RS-232 connections

The RS-232 serial port is connected to the serial port of a computer using a straight-through RS-232 cable terminated with DB-9 connectors. Do not use a null modem cable. The serial port uses the transmit (TXD), receive (RXD), and signal ground (GND) lines of the RS-232 standard. Figure 13-4 shows the rear panel connector for the RS-232 interface, and Table 13-2 shows the pinout for the connector.

If your computer uses a DB-25 connector for the RS-232 interface, you will need a cable or adapter with a DB-25 connector on one end and a DB-9 connector on the other, wired straight through (not null modem).

Figure 13-4
RS-232 interface connector

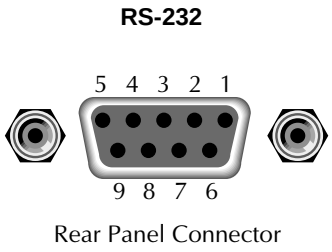


Table 13-2
RS-232 connector pinout

Pin number	Description
1	Not used
2	TXD, transmit data
3	RXD, receive data
4	Not used
5	GND, signal ground
6	Not used
7	RTS, ready to send
8	CTS, clear to send
9	Not used

Note: CTS and RTS are tied together.
Pins 1, 4, and 6 are tied together.

Table 13-3 provides pinout identification for the 9-pin (DB-9) or 25-pin (DB-25) serial port connector on the computer (PC).

Table 13-3
PC serial port pinout

Signal	DB-9 pin number	DB-25 pin number
DCD, data carrier detect	1	8
RXD, receive data	2	3
TXD, transmit data	3	2
DTR, data terminal ready	4	20
GND, signal ground	5	7
DSR, data set ready	6	6
RTS, request to send	7	4
CTS, clear to send	8	5
RI, ring indicator	9	22

Error messages

See Appendix B for RS-232 error messages.

Programming example

The following QuickBasic 4.5 programming example will control the SourceMeter via the RS-232 COM2 port. Place the SourceMeter into the RS-232 mode from the front panel main menu (press MENU, select COMMUNICATION, select RS-232). When the communication setting is changed, the SourceMeter will reset into that mode.

```
RD$ = SPACE$ (1500)              ‘ Set string space.
CLS                              ‘ Clear screen.
PRINT “Set COM2 baud rate to 9600”
PRINT “Set no flow control, and CR as terminator.”

‘ Configure serial port parameters.
‘ The following values are the default settings for the SourceMeter:
ComOpen$ = “COM2: 9600,N,8,1,ASC,CD0,CS0,DS0,LF,OP0,RS,TB8192,RB8192”
OPEN ComOpen$ FOR RANDOM AS #1

‘ SourceMeter setup commands:
PRINT #1,   “*RST”               ‘ Reset instrument to default parameters.
PRINT #1,   “:SENS:FUNC ‘RES’ “  ‘ Select ohms measurement function.
PRINT #1,   “:SENS:RES:NPLC 1”   ‘ Set measurement speed to 1 PLC.
PRINT #1,   “:SENS:RES:MODE MAN” ‘ Select manual ohms mode.
PRINT #1,   “:SOUR:FUNC CURR”    ‘ Select current source function.
PRINT #1,   “:SOUR:CURR 0.01”    ‘ Set source to output 10mA.
PRINT #1,   “:SOUR:CLE:AUTO ON”  ‘ Enable source auto output-off.
PRINT #1,   “:SENS:VOLT:PROT 10” ‘ Set 10V compliance limit.
PRINT #1,   “:TRIG:COUN 1”       ‘ Set to perform one measurement.
PRINT #1,   “:FORM:ELEM RES”     ‘ Set to output ohms reading to PC.

‘ Initiate a reading and print results:
PRINT #1,   “:READ?”             ‘ Trigger and acquire one reading.
LINE INPUT #1, RD$
RD$ = “Resistance:  “  +  RD$
PRINT RD$

‘ Clean up and quit:
finish:
CLOSE #1                         ‘ Close file.
CLEAR                            ‘ Interface clear.
END
```

14
Status Structure

- **Overview** — Provides an operational overview of the status structure for the SourceMeter.
- **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.

Overview

The SourceMeter 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 14-1. 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

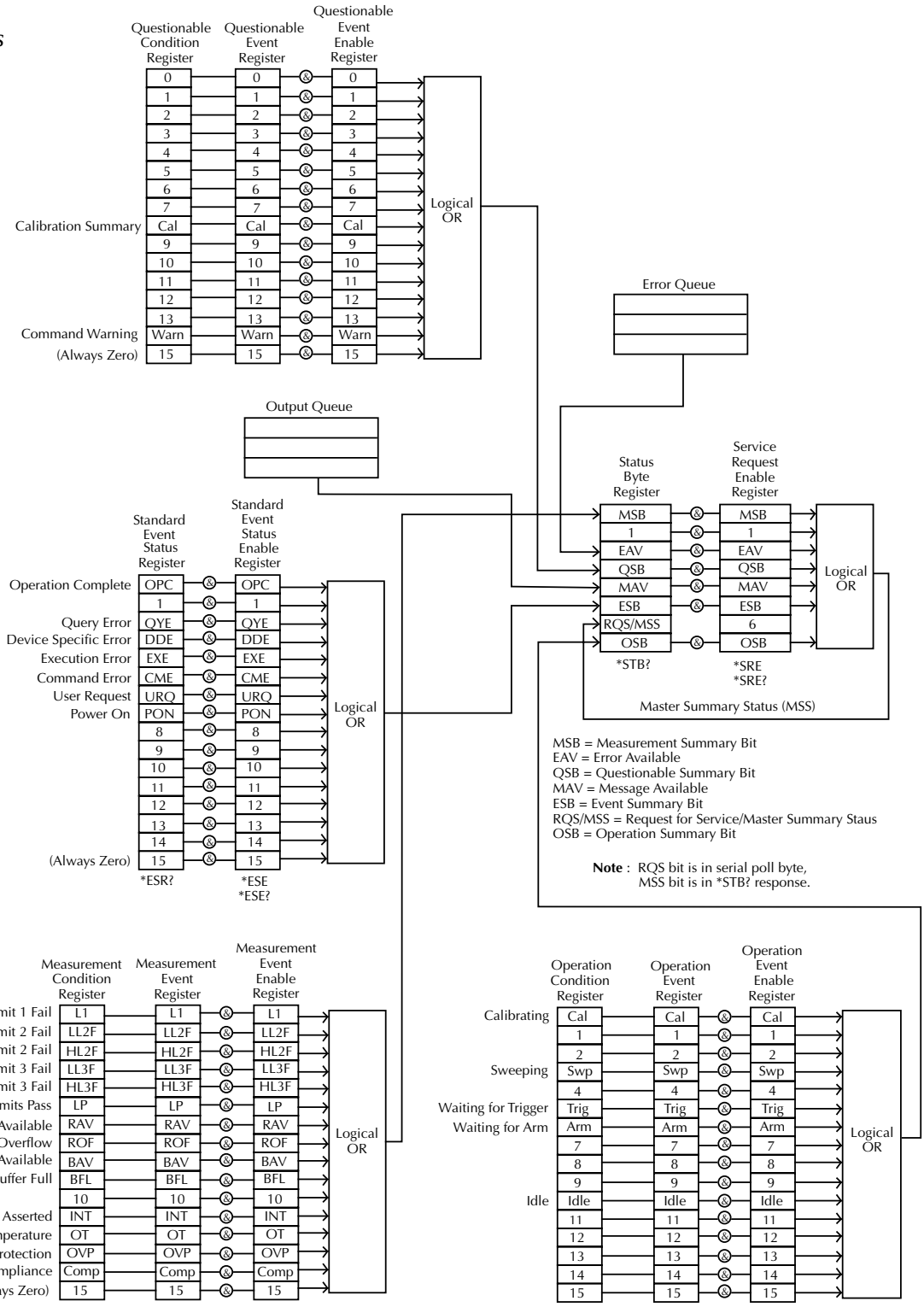
A typical status register set is made up of a condition register, an event register and an event enable register. A condition register is a read-only register that constantly updates to reflect the present operating conditions of the instrument.

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 SourceMeter 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 14-1
SourceMeter status register structure



Clearing registers and queues

When the SourceMeter is turned on, the bits of all registers in the status structure are cleared (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 14-1. 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 *SYSTem:PRESet and *RST have no effect on status structure registers and queues.*

Table 14-1
Common and SCPI commands to reset registers and clear queues

Commands	Description	Ref.
To Reset Registers:		
*CLS	Reset all bits of the following event registers to 0: Standard Event Register Operation Event Register Measurement Event Register Questionable Event Register	Note 1
:STATus:PRESet	Reset all bits of the following enable registers to 0: Operation Event Enable Register Measurement Event Enable Register Questionable Event Enable Register	Note 1
To Clear Error Queue:		
*CLS	Clear all messages from Error Queue	Note 2
:STATus:QUEue:CLEar	Clear messages from Error Queue	Note 3
:SYSTem:ERRor:CLEar	Clear 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.*
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 only registers that can be programmed by the user are the enable registers. All other registers in the status structure are read-only registers. The following explains how to ascertain the parameter values for the various commands used to program enable registers. The actual commands are covered later in this section (Tables 14-3 and 14-6).

A command to program an event enable register is sent with a parameter value that determines the desired state (0 or 1) of each bit in the appropriate register. An enable register can be programmed using any of the following data formats for the parameter value: binary, decimal, hexadecimal, or octal.

The bit positions of the register (Figure 14-2) indicate the binary parameter value. For example, if you wish to sets bits B4, B3, and B1, the binary value would be 11010 (where B4=1, B3=1, B1=1, and all other bits are 0). When you use one of the other formats, convert the binary number to its decimal, hexadecimal, or octal equivalent:

Binary 11010 = Decimal 26 = Hexadecimal 1A = Octal 32

Note that Figure 14-2 includes the decimal weight for each register bit. To set bits B4, B3, and B1, the decimal parameter value would be the sum of the decimal weights for those bits (16+8+2 = 26).

Figure 14-2
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)

The <NDN> (non-decimal numeric) parameter type is used to send non-decimal values. These values require a header (#B, #H, or #Q) to identify the data format being sent. The letter in the header can be upper or lower case. The <NRf> (numeric representation format) parameter type is used to send decimal values, and does not use a header. The following examples show the proper parameter syntax for setting Bits B5, B3, and B2:

#b101100	Binary format (<NDN> parameter type)
#h2C	Hexadecimal format (<NDN> parameter type)
#q54	Octal format (<NDN> parameter type)
44	Decimal format (<NRf> parameter type)

Valid characters for the non-decimal parameter values are shown as follows:

<NDN> format	**Valid characters**
Binary	1s and 0s
Hexadecimal	0 through 9 and A through F
Octal	0 through 7

Reading registers

Any register in the status structure can be read by using the appropriate query (?) command. The following explains how to interpret the returned value (response message). The actual query commands are covered later in this section (Tables 14-3 through 14-7).

The response message will be a value that indicates which bits in the register are set. That value (if not already binary) will have to be converted to its binary equivalent. For example, for a binary value of 100101, bits B5, B2, and B0 are set.

The returned value can be in the binary, decimal, hexadecimal, or octal format. The FORMat:SREGister command is used to select the data format for the returned value (Table 14-2).

For non-decimal formats, one of the following headers will accompany the returned value to indicate which format is selected:

#B = Header for binary values
#H = Header for hexadecimal values
#Q = Header for octal values

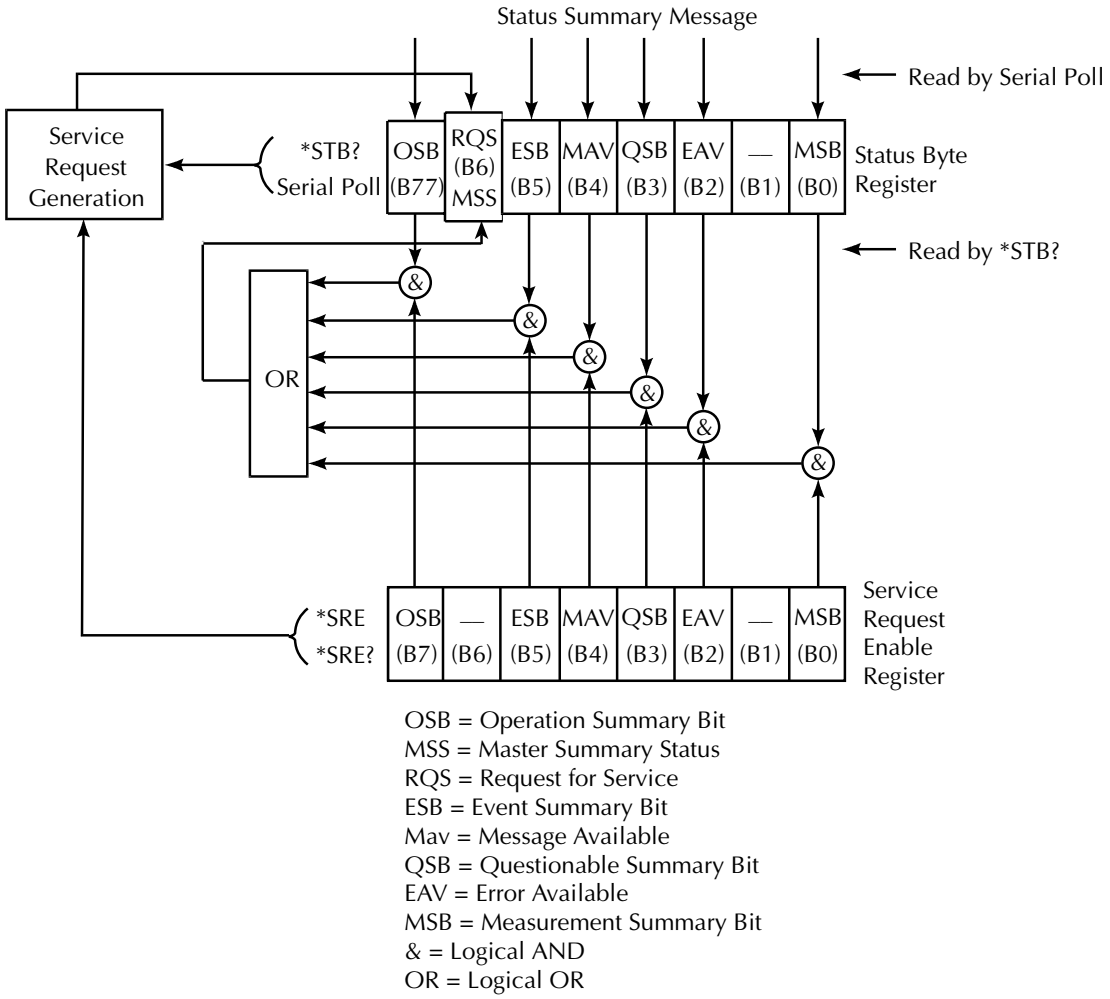
Table 14-2
Data format commands for reading status registers

Command	Description	Default
:FORMat:SREGister <name>	Select data format for reading status registers: <name> = ASCii Decimal format HEXadecimal Hexadecimal format OCTal Octal format BINary Binary format	ASCii

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 14-3 shows the structure of these registers.

Figure 14-3
Status byte and service request (SRQ)



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 Summary Bit (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 SourceMeter 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 (Table 14-3) 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 you 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 14-3, 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 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 14-3.

Serial polling and SRQ

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

Typically, SRQs are managed by the serial poll sequence of the SourceMeter. 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 sequence is used to serial poll the SourceMeter. 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 14-3. For details on programming and reading registers, see *Programming enable registers* and *Reading registers*.

NOTE *To reset the bits of the Service Request Enable Register to 0, use 0 as the parameter value for the *SRE command (i.e. *SRE 0).*

Table 14-3
Status Byte and Service Request Enable Register commands

Command	Description	Default
*STB?	Read Status Byte Register.	
*SRE <NDN> or <NRf>	Program the Service Request Enable Register: <NDN> = #Bxx…x Binary format (each x = 1 or 0) = #Hx Hexadecimal format (x = 0 to FF) = #Qx Octal format (x = 0 to 377) <NRf> = 0 to 255 Decimal format	Note
*SRE?	Read the Service Request Enable Register	

Note: *CLS and STATus:PRESet have no effect on the Service Request Enable Register.

Programming example - set MSS (B6) when error occurs

The first command of sequence in Table 14-4 enables EAV (error available). When an invalid command is sent (line 4), bits B2 (EAV) and B6 (MSS) of the Status Byte Register set to 1. The last command reads the Status Byte Register using the binary format (which directly indicates which bits are set). The command to select format (FORMat:SREGister) is documented in Table 14-2. To determine the exact nature of the error, you will have to read the Error Queue. Refer to *Queues*.

Table 14-4
Status byte programming example

Command	Description
*CLS	Clear Error Queue.
*SRE 4	Enable EAV.
FORM:SREG BIN	Select binary format.
*XYZ	Generate error.
*STB?	Read Status Byte Register.

Status register sets

As shown in Figure 14-1, there are four status register sets in the status structure of the SourceMeter: Standard Event Status, Operation Event Status, Measurement Event Status, and Questionable Event Status.

NOTE *See Appendix B for details on which register bits are set by specific error and status conditions.*

Register bit descriptions

Standard Event Register

The used bits of the Standard Event Register (shown in Figure 14-4) are described as follows:

- **Bit B0, Operation Complete** — Set bit indicates that all pending selected device operations are completed and the SourceMeter is ready to accept new commands. This bit only sets in response to the *OPC? query command. See Section 15 for details on *OPC and *OPC?.
- **Bit B1** — Not used.
- **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.

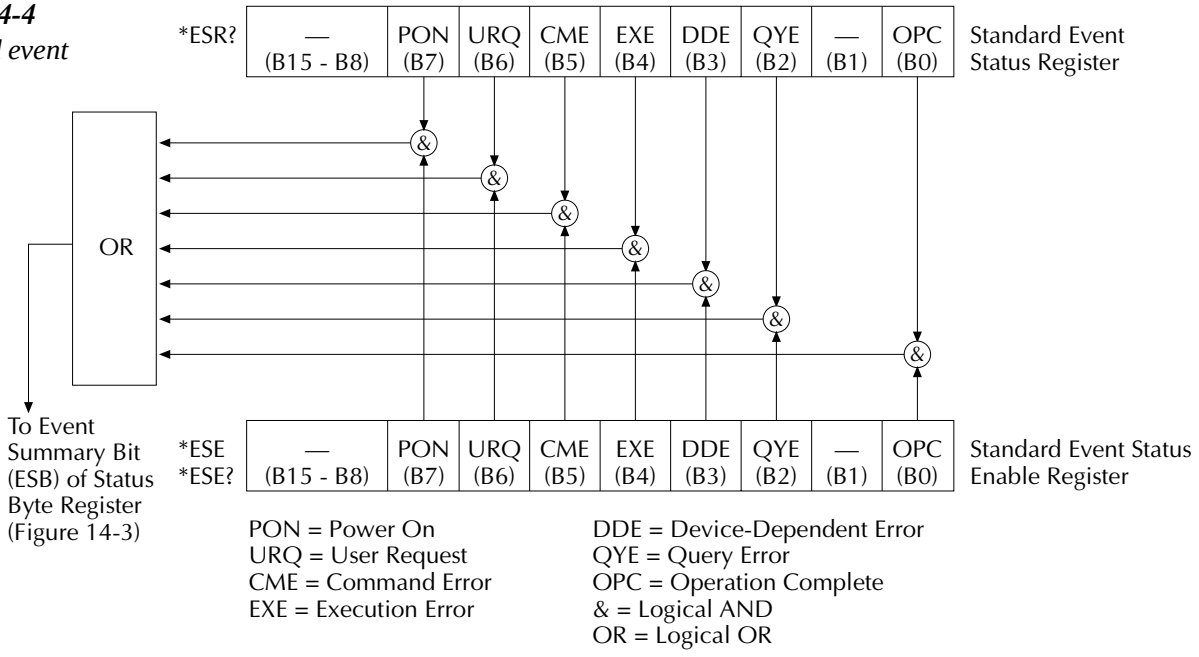


Figure 14-4
Standard event status

- **Bit B4, Execution Error (EXE)** — Set bit indicates that the SourceMeter detected an error while trying to execute a command.
- **Bit B5, Command Error (CME)** — Set bit indicates that a command error has occurred.

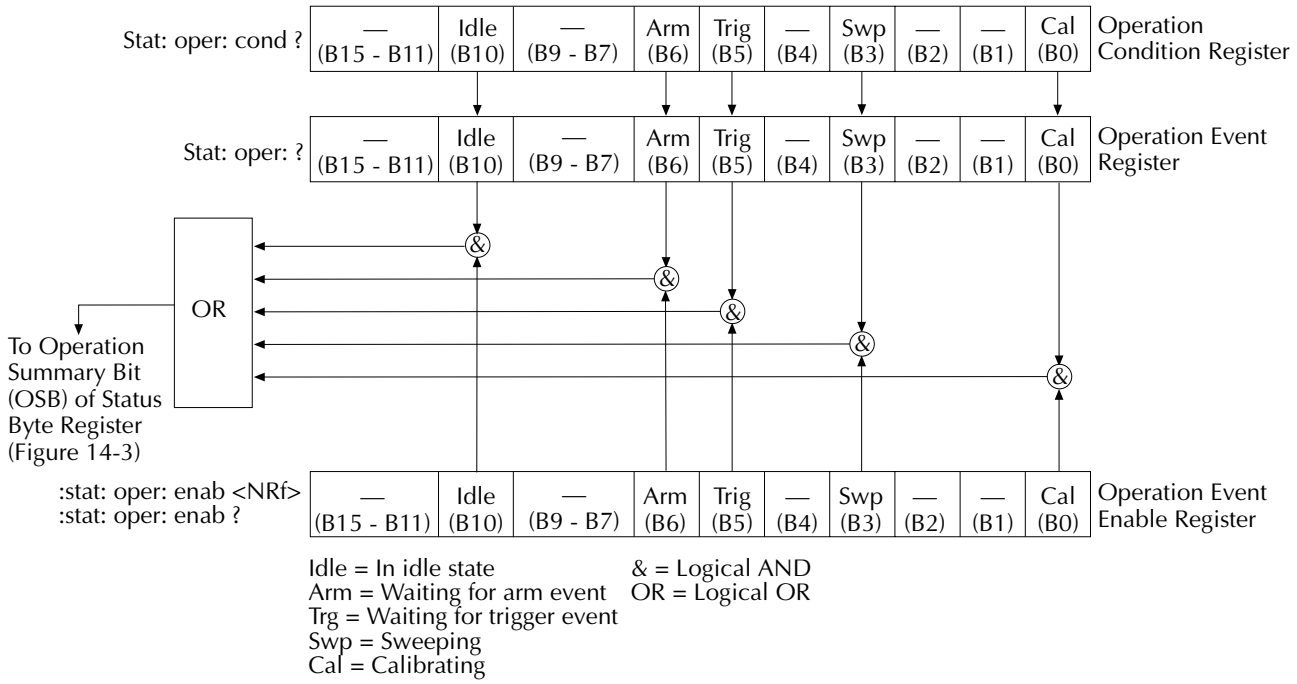
  Command errors include:
  - IEEE-488.2 syntax error — SourceMeter received a message that does not follow the defined syntax of the IEEE-488.2 standard.
  - Semantic error — SourceMeter received a command that was misspelled or received an optional IEEE-488.2 command that is not implemented.
  - The 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 SourceMeter front panel was pressed.
- **Bit B7, Power ON (PON)** — Set bit indicates that the SourceMeter has been turned off and turned back on since the last time this register has been read.

Operation Event Register

The used bits of the Operation Event Register (shown in Figure 14-5) are described as follows:

- **Bit B0, Calibrating (Cal)** — Set bit indicates that the SourceMeter is calibrating.
- **Bits B1 and B2** — Not used.
- **Bit B3, Sweeping (Swp)** — Set bit indicates the instrument is performing a sweep operation.
- **Bit B4** — Not used.
- **Bit B5, Waiting for Trigger Event (Trig)** — Set bit indicates that the SourceMeter is in the trigger layer waiting for a TLINK trigger event to occur.
- **Bit B6, Waiting for Arm Event (Arm)** — Set bit indicates that the SourceMeter is in the arm layer waiting for an arm event to occur.
- **Bits B7 through B9** — Not used.
- **Bit B10, Idle State (Idle)** — Set bit indicates the SourceMeter is in the idle state.
- **Bits B11 through B15** — Not used.

Figure 14-5
Operation event status

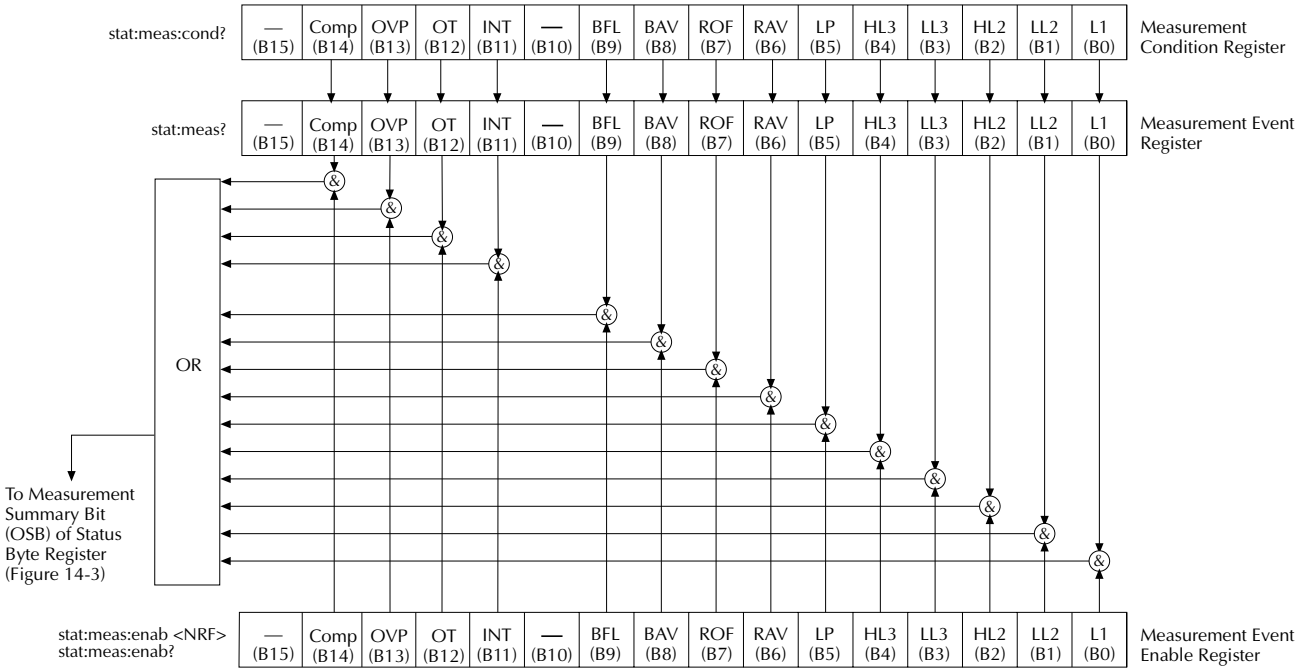


Measurement Event Register

The used bits of the Measurement Event Register (shown in Figure 14-6) are described as follows:

- **Bit B0, Limit 1 Fail (L1)** — Set bit indicates that the Limit 1 test has failed.
- **Bit B1, Low Limit 2 Fail (LL2)** — Set bit indicates that the Low Limit 2 test has failed.
- **Bit B2, High Limit 2 Fail (HL2)** — Set bit indicates that the High Limit 2 test has failed.
- **Bit B3, Low Limit 3 Fail (LL3)** — Set bit indicates that the Low Limit 3 test has failed.
- **Bit B4, High Limit 3 Fail (HL3)** — Set bit indicates that the High Limit 3 test has failed.
- **Bit B5, Limits Pass (LP)** — Set bit indicates that all limit tests passed.
- **Bit B6, Reading Available (RAV)** — Set bit indicates that a reading was taken and processed.
- **Bit B7, Reading Overflow (ROF)** — Set bit indicates that the volts or amps reading exceeds the selected measurement range of the SourceMeter.
- **Bit B8, Buffer Available (BAV)** — Set bit indicates that there are at least two readings in the buffer.
- **Bit B9, Buffer Full (BFL)** — Set bit indicates that the trace buffer is full.
- **Bit B10** — Not used.
- **Bit B11, Interlock Asserted (Int)** — Set bit indicates that the interlock line is at digital low (asserted). The source output can be turned on.
- **Bit B12, Over Temperature (OT)** — Set bit indicates that an over temperature condition exists. The source output cannot be turned on.
- **Bit B13, Over Voltage Protection (OVP)** — Set bit indicates that the source is being limited at the programmed limit level.
- **Bit B14, Compliance (Comp)** — Set bit indicates that the source is in compliance.
- **Bit B15** — Not used.

Figure 14-6
Measurement event status



Comp = In Compliance
OVP = Over Voltage Protection
OT = Over Temperature
INT = Interlock Asserted
BFL = Buffer Full
BAV = Buffer Available
ROF = Reading Overflow
RAV = Reading Available
LP = Limits Pass

HL3 = High Limit 3
LL3 = Low Limit 3
HL2 = High Limit 2
LL2 = Low Limit 2
L1 = Limit 1

& = Logical AND
OR = Logical OR

Questionable Event Register

The used bits of the Questionable Event Register (shown in Figure 14-7) are described as follows:

- **Bits B0 through B7** — Not used.
- **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 instrument.
- **Bits B9 through B13** — Not used.
- **Bit B14, Command Warning (Warn)** — Set bit indicates that a Signal Oriented Measurement Command parameter has been ignored.
- **Bit B15** — Not used.

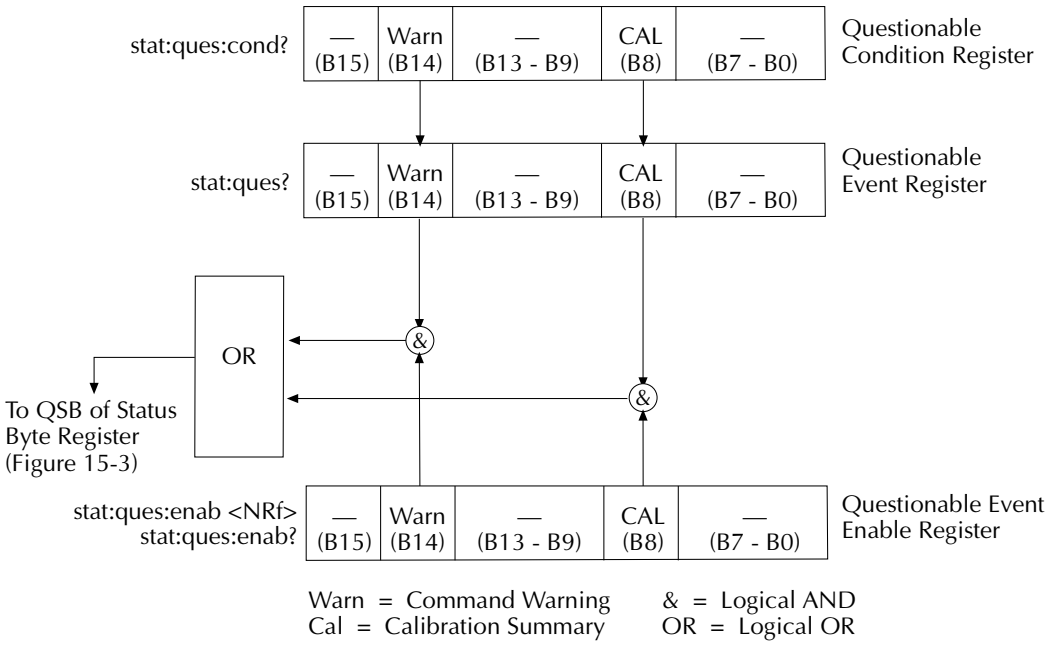


Figure 14-7 Questionable event status

Condition registers

As Figure 14-1 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, while the SourceMeter is in the idle state, bit B10 (Idle) of the Operation Condition Register will be set. When the instrument is taken out of idle, bit B10 clears.

The commands to read the condition registers are listed in Table 14-5. For details on reading registers, see *Reading registers*.

Table 14-5
Condition register commands

Command	Description
:STATus:OPERation:CONDition? :STATus:MEASurement:CONDition? :STATus:QUEStionable:CONDition?	Read Operation Condition Register. Read Measurement Condition Register. Read Questionable Condition Register.

Event registers

As Figure 14-1 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 14-6. For details on reading registers, see *Reading registers*.

Table 14-6
Event register commands

Command	Description	Default
*ESR? :STATus:OPERation:[:EVENt]? :STATus:MEASurement:[:EVENt]? :STATus:QUEStionable:[:EVENt]?	Read Standard Event Status Register. Read Operation Event Register. Read Measurement Event Register. Read Questionable Event Register.	Note

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

Event enable registers

As Figure 14-1 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 14-7. For details on programming and reading registers, see *Programming enable registers* and *Reading registers*.

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

Table 14-7
Event enable registers commands

Command	Description	Default
*ESE <NDN> or <NRf> *ESE? STATus :OPERation :ENABle <NDN> or <NRf> :ENABle? :MEASurement :ENABle <NDN> or <NRf> :ENABle? :QUEStionable :ENABle <NDN> or <NRf> :ENABle?	Program Standard Event Enable Register. See *Parameters*. Read Standard Event Enable Register. STATus Subsystem: Operation Event Enable Register: Program enable register. See *Parameters*. Read enable register. Measurement Event Enable Register: Program enable register. See *Parameters*. Read enable register. Questionable Event Enable Register: Program enable register. See *Parameters*. Read Measurement Event Enable Register:	Note
Parameters: <NDN> = #Bxx…x = #Hx = #Qx <NRf> = 0 to 65535	 Binary format (each x = 1 or 0) Hexadecimal format (x = 0 to FFFF) Octal format (x = 0 to 177777) Decimal format	

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

Programming example - program and read register set

The command sequence in Table 14-8 programs and reads the measurement register set. Registers are read using the binary format (which directly indicates which bits are set). The command to select format (FORMat:SREGister) is documented in Table 14-2.

Table 14-8
Program and read register programming example

Command	Description
FORM:SREG BIN STAT:MEAS:ENAB 512 STAT:MEAS:COND? STAT:MEAS?	Select binary format to read registers. Enable BFL (buffer full). Read Measurement Condition Register. Read Measurement Event Register.

Queues

The SourceMeter 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. (See Appendix B.)

The SourceMeter status model (Figure 14-1) 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 SourceMeter to talk after the appropriate query is sent.

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 14-9. 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. As shown in Table 14-7, there are commands to read the entire message (code and message) or the code only.

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 14-9, 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 14-9
Error queue commands

Command	Description	Default
STATus	STATus Subsystem:	
:QUEue	Read Error Queue:	Note 1
[:NEXT]?	Read and clear oldest error/status (code and 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
[:NEXT]?	Read and clear oldest error/status (code and message).	
:ALL?	Read and clear all errors/status (code and message).	
:COUNt?	Read the number of messages in queue.	
:CODE	Code numbers only:	
[:NEXT]?	Read and clear oldest error/status (code only).	
:ALL?	Read and clear all errors/status (codes only).	
: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

The following command reads the error queue:

```
STAT:QUE?
```

15
Common Commands

- **Command Summary** — Lists the IEEE-488.2 common commands used by the SourceMeter.
- **Command Reference** — Provides a detailed reference for all common commands except for those associated with the status structure, which are discussed in Section 14.

Command summary

Common commands (summarized in Table 15-1) are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard. Most of these commands are described in detail in this section.

NOTE *The following common commands associated with the status structure are covered in Section 14: *CLS, *ESE, *ESE?, *ESR?, *SRE, *SRE?, and *STB?.*

Table 15-1
IEEE-488.2 common commands and queries

Mnemonic	Name	Description
*CLS	Clear status	Clears all event registers and Error Queue.[1]
*ESE <NRf>	Event enable command	Program the Standard Event Enable Register.[1]
*ESE?	Event enable query	Read the Standard Event Enable Register.[1]
*ESR?	Event status register query	Read and clear the Standard Event Enable Register.[1]
*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 SourceMeter to the user-saved setup.
*RST	Reset command	Returns the SourceMeter 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.[1]
*SRE?	Service request enable query	Reads the Service Request Enable Register.[1]
*STB?	Status byte query	Reads the Status Byte Register.[1]
*TRG	Trigger command	Sends a bus trigger to the SourceMeter.
*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.

[1] Status commands are covered in Section 14.

Command reference

*IDN? — identification query

Reads identification code

The identification code includes the manufacturer, model number, serial number, and firmware revision levels and is sent in the following format:

KEITHLEY INSTRUMENTS INC., MODEL 6430, xxxxxxx, yyyyy/zzzzz /a/d

Where: xxxxxxx is the serial number.

yyyyy/zzzzz is the firmware revision levels of the digital board ROM and display board ROM, including date and time of build.

a is the analog board revision level.

d is the digital board revision level.

*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 the INITiate command. The INITiate command is used to take the instrument out of idle in order to perform measurements. While operating within the trigger model layers, all sent commands (except DCL, SDC, IFC, SYSTem:PRESet, *RST, *RCL, *TRG, GET, and ABORt) will not execute.

After all programmed operations are completed, the instrument returns to the idle state at which time all pending commands (including *OPC and/or *OPC?) are executed. After the last pending command is executed, the OPC bit and/or an ASCII "1" is placed in the Output Queue.

*OPC programming example

The command sequence in Table 15-2 will perform 10 measurements. After the measurements are completed (in approximately 10 seconds), an ASCII "1" will be placed in the Output Queue and displayed on the computer CRT. Note that additional codes must be added to query the instrument for the presence of the ASCII "1" in the Output Queue.

Table 15-2
**OPC programming example*

Command	Description
*RST	Return SourceMeter to GPIB defaults (idle).
:TRIG:DEL 1	Set trigger delay for 1 second.
:ARM:COUN 10	Program for 5 measurements and stop.
:OUTP ON	Turn on output.
:INIT	Start measurements.
*OPC?	Send *OPC? to query Output Queue.

*Additional code required to test for "1" in Output Queue.

*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.

The SourceMeter ships from the factory with SYSTem:PRESet defaults loaded into the available setup memory. If a recall error occurs, the setup memory defaults to the SYSTem:PRESet values.

*SAV, *RCL programming example

Table 15-3 summarizes the basic command sequence for saving and recalling a setup. The present setup is stored in memory location 2, GPIB defaults are restored, and the memory location 2 setup is recalled.

Table 15-3
**SAV, *RCL programming example*

Command	Description
*SAV 2	Save present setup in memory location 2.
*RST	Restore GPIB defaults.
*RCL 2	Recall location 2 setup.

*RST — reset

Return SourceMeter to GPIB defaults

When the *RST command is sent, the SourceMeter performs the following operations:

- Returns the SourceMeter to the GPIB default conditions. Refer to “Default parameters” column of SCPI tables in Section 17.
- Cancels all pending commands.
- Cancels response to any previously received *OPC and *OPC? commands.

*TRG — trigger

Send bus trigger to SourceMeter

Use the *TRG command to issue a GPIB trigger to the SourceMeter. It has the same effect as a group execute trigger (GET).

Use the *TRG command as an event to control operation. The SourceMeter reacts to this trigger if BUS is the programmed arm control source. The control source is programmed from the TRIGger subsystem.

NOTE Details on triggering are covered in Section 10.

*TRG programming example

The command sequence in Table 15-4 configures the SourceMeter to be controlled by bus triggers. The last command, which sends a bus trigger, triggers one measurement. Each subsequent bus trigger will also trigger a single measurement.

NOTE *With :ARM:SOURce BUS selected, do not send any commands (except *TRG, GET, DCL, SDC, IFC, and ABORt) while performing source-measure operations. Otherwise, erratic operation will occur.*

Table 15-4
**TRG programming example*

Command	Description
*RST	Restore GPIB defaults.
:ARM:SOUR BUS	Select BUS control source.
:ARM:COUN INF	Set arm layer count to infinite.
:OUTP ON	Turn on output.
:INIT	Take SourceMeter out of idle.
*TRG	Trigger one measurement.

*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 SourceMeter 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 SourceMeter and thus, 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.

16
SCPI Signal-Oriented Measurement Commands

- **Command Summary** — Summarizes those commands used to configure and acquire readings.
- **Configuring Measurement Function** — Provides detailed information on commands to configure the measurement function.
- **Acquiring Readings** — Describes commands to acquire post-processed readings, both trigger and acquire readings, and to perform a single measurement.

Command summary

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 16-1.

Table 16-1
Signal-oriented measurement command summary

Command	Description
:CONFigure:<function>	Configures SourceMeter for measurements on specified function. Output turns on.
:CONFigure?	Returns active function(s).
:FETCh?	Requests latest readings.
:READ?	Performs an :INITiate and a :FETCh?.
:MEASure[:<function>]?	One-shot measurement mode. Performs a :CONFigure and a :READ?.

Configuring measurement function

:CONFigure:<function>

Parameters <function> = CURRent[:DC] Amps function
VOLTage[:DC] Volts function
RESistance Ohms function

Query :CONFigure? Returns active function(s).

Description This command configures the instrument to a specific setup for measurements on the specified function. The :READ? command is then typically used to trigger a specified number of measurements. See *:READ?*.

When this command is sent, the SourceMeter will be configured as follows:

- Select specified function.
- All controls related to the selected function are defaulted to the *RST values.
- The event control source of the Trigger Model is set to Immediate.
- The count values of the Trigger Model are set to one.
- The Delay of the Trigger Model is set to zero.
- All math calculations are disabled.
- Buffer operation is disabled.
- Autozero is enabled.
- The source output will turn on.

WARNING **When :CONFigure is sent, the output will turn on. Beware of hazardous voltage that may be present on the output terminals.**

NOTE *This command is automatically asserted when the :MEASure? command is sent.*

Acquiring readings

:FETCh?

Description This query command requests the latest post-processed readings stored in the sample buffer. See Appendix C. After sending this command and addressing the SourceMeter to talk, the readings are sent to the computer. This command does not affect the instrument setup.

This command does not trigger source-measure operations; it simply requests the last available readings. Note that this command can repeatedly return the same readings. Until there are new readings, this command continues to return the old readings. For example, assume that the SourceMeter performed 20 source-measure operations. The :FETCh? command will request the readings for those 20 source-measure operations. If :FETCh? is sent while performing source-measure operations (ARM annunciator on), it will not be executed until the SourceMeter goes back into idle.

The readings that are acquired depend on which data elements are selected (Section 17, *FORMat subsystem*, *Data elements*), and what the instrument is presently programmed to source-measure. Measure readings take priority over source readings, and functions not sourced or measured are assigned the NAN (not a number) value of +9.91e37.

For example, assume that voltage, current and resistance readings are selected as data elements, and the instrument is programmed to Source V and Measure I. A reading string acquired by :FETch? will include the programmed
V-Source value and the I-Measure reading. The reading for resistance will be NAN since resistance was not measured.

If the SourceMeter is instead programmed to Source V and Measure V, the voltage reading will be the V-Measure reading (not the programmed V-Source value). Both current and resistance readings will be NANs (current is not measured or sourced).

NOTE *The :FETCh? command is automatically asserted when the :READ? or :MEASure? command is sent.*

NOTE *See Appendix C for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the types of readings that are acquired by the various commands to read data.*

[:SENSe[1]]:DATA[:LATest]?

Description This command works exactly like FETCh?, except that it returns only the most recent reading.

:READ?

Description This command is used to trigger and acquire readings. The number of readings depends on how the trigger model is configured. For example, if configured for 20 source-measure operations (arm count 1, trigger count 20), then 20 sets of readings will be acquired after the SourceMeter returns to the idle state.

When this command is sent, the following commands execute in the order that they are presented:

- :INITiate
- :FETCh?

The :INITiate command starts operation by taking the instrument out of idle.

After all source-measure operations are completed, the SourceMeter goes back into idle at which time the :FETCh? command is executed. The readings are sent to the computer and displayed when the SourceMeter is addressed to talk.

Note that if auto output-off is disabled (:SOURce1:CLEar:AUTO OFF), then the output must be turned on before you can perform a :READ?. The output will then remain on after all source-measure operations are completed.

If auto output-off is enabled (:SOURce1:CLEar:AUTO ON), then the output will automatically turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement.

NOTE *See Appendix C for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the type of readings that are acquired by the various commands to read data.*

:MEASure[:<function>]?

Parameters

<function> =	CURRent[:DC]	Amps function
	VOLTage[:DC]	Volts function
	RESistance	Ohms function

Description

This command combines other signal-oriented measurement commands to perform a "one-shot" measurement and acquire the reading. Note that if a function is not specified, the measurement will be done on the function that is presently selected.

When this command is sent, the following commands execute in the order that they are presented.

- :CONFigure:<function>
- :READ?

When :CONFigure is executed, the instrument goes into a "one-shot" measurement mode. See *:CONFigure<function>* for more details.

When :READ? is executed, its operations will then be performed. In general, another :ABORt is performed, then an :INITiate, and finally a FETCh? to acquire the readings. See *:READ?* for more details.

When :MEASure? is sent, the source turns on and a single measurement is performed. If auto output-off is enabled (:SOURce1:CLEar:AUTO ON), then the output will turn off after the measurement is completed. If auto output-off is disabled (:SOURce1:CLEar:AUTO OFF), then the output will remain on after the measurement is completed.

WARNING **With auto output-off disabled, the output will remain on after the one-shot source-measure operation is performed. Beware of hazardous voltage that may be present on the output terminals.**

17
SCPI Command Reference

- **Reference Tables** — Summarizes each SCPI command subsystem.
- **SCPI Subsystems** — Provides detailed information on all commands in each SCPI subsystem.

Reference tables

Tables 17-1 through 17-10 summarize the commands for each SCPI subsystem. The following list includes the SCPI subsystem commands, the table number where each command is summarized, and the reference page where detailed information begins.

Summary table	Subsystem	Reference page
17-1	CALCulate	17-22
17-2	DISPlay	17-41
17-3	FORMat	17-44
17-4	OUTPut	17-52
17-5	SENSe	17-54
17-6	SOURce	17-64
17-7	STATus	17-86
17-8	SYSTem	17-89
17-9	TRACe	17-99
17-10	TRIGger	17-102

General notes:

Brackets ([ ]) are used to denote optional character sets. These optional characters do not have to be included in the program message. Do not use brackets in the program message.

Angle brackets (< >) are used to indicate parameter type. Do not use angle brackets in the program message.

The Boolean parameter (<b>) is used to enable or disable an instrument operation. 1 or ON enables the operation, and 0 or OFF disables the operation.

Upper case characters indicate the short-form version for each command word.

Default Parameter — Listed parameters are both the *RST and :SYSTem:PRESet defaults, unless noted otherwise. Parameter notes are located at the end of each table.

SCPI — A checkmark (✓) indicates that the command and its parameters are SCPI confirmed. An unmarked command indicates that it is a SCPI command, but does not conform to the SCPI standard set of commands. It is not a recognized command by the SCPI consortium. SCPI confirmed commands that use one or more non-SCPI parameters are explained by notes.

Source Memory — A checkmark (✓) indicates that the parameters associated with the specified command are saved in any one of 100 memory locations by the :SOURce[1]:MEMory:SAVE command.

Table 17-1
CALCulate command summary

Command	Description	Default parameter	SCPI	Source memory
:CALCulate[1]	Subsystem to control CALC1:		✓	
:MATH	Path to configure and control math expressions:		✓	
[:EXPRession] <form>	Define math expression using standard math operator symbols.		✓	
[:EXPRession]?	Query math expression.		✓	
:CATalog?	Query list of math expression names.		✓	
:NAME <name>	Create name for new user-defined expression.	Power	✓	✓
:NAME?	Query created name.		✓	
[:DEFine] <form>	Same as :EXPRession <form> command.		✓	
:DELete	Path to delete user-defined expressions.		✓	
[:SELected] <name>	Delete specified expression.		✓	
:ALL	Delete all user-defined expressions.		✓	
:UNITs <name>	Define units name for math expression (3 ASCII characters).	"W"		✓
:UNITs?	Query math expression units name.			
:STATe <b>	Enable or disable math expression.	OFF	✓	✓
:STATe?	Query state of math expression.		✓	
:DATA	Path to CALC1 data.		✓	
:LATest?	Return only most recent math result.			
:DATA?	Read result of math expression.		✓	
:CALCulate2	Subsystem to control CALC2:		✓	
:FEED <name>	Select input path (CALCulate[1], CURRent, VOLTage, or RESistance).	VOLT	✓	✓
:FEED?	Query CALC2 feed.		✓	
:NULL	Path to configure and control REL:			
:OFFSet <NRf>	Specify REL value (-9.999999e20 to 9.999999e20).	0		✓
:OFFSet?	Query REL value.			
:STATe <b>	Enable or disable REL.	OFF		✓
:STATe?	Query state of REL.			
:ACQuire	Automatically acquire REL value.			
:DATA	Path to CALC2 data.		✓	
:LATest?	Return only most recent REL or LIMIT result.			
:DATA?	Read math result of CALC2.		✓	
:LIMit[1]	Path to control LIMIT 1 test:		✓	
:COMPliance	Configure Limit 1 test:			
:FAIL <name>	Specify "fail" condition (IN or OUT of compliance).	IN		✓
:FAIL?	Query "fail" condition.			

Table 17-1 (cont.)
CALCulate command summary

Command	Description	Default parameter	SCPI	Source memory
:CALCulate2				
:LIMit[1]				
:COMPliance				
:SOURce2 <NRf> | <NDN>	Specify output "fail" pattern (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query "fail" bit pattern.[1]			
:STATe <b>	Enable or disable Limit 1 test.	OFF	✓	✓
:STATe?	Query state of Limit 1 test.		✓	
:FAIL?	Returns result of Limit 1 test: 0 (pass) or 1 (fail).		✓	
:LIMit2	Path to control LIMIT 2 test:		✓	
:UPPer	Configure upper limit:		✓	
[:DATA] <n>	Specify upper limit (-9.999999e20 to 9.999999e20).	1	✓	✓
[:DATA]?	Query upper limit.		✓	
:SOURce2 <NRf> | <NDN>	Specify output "fail" pattern for grading mode (0 to 7, 3-bit;0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query "fail" bit pattern.[1]			
:LOWer	Configure lower limit:		✓	
[:DATA] <n>	Specify lower limit (-9.999999e20 to 9.999999e20).	-1	✓	✓
[:DATA]?	Query lower limit.		✓	
:SOURce2 <NRf> | <NDN>	Specify output "fail" pattern for grading mode (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query "fail" bit pattern.[1]			
:PASS	Path to specify "pass" pattern for sorting mode:			
:SOURce2 <NRf> | <NDN>	Specify output "pass" pattern (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7	✓	✓
:SOURce2?	Query "pass" bit pattern.[1]			
:STATe <b>	Enable or disable Limit 2 test.	OFF	✓	✓
:STATe?	Query state of Limit 2 test.		✓	
:FAIL?	Return result of Limit 2 test: 0 (pass) or 1 (fail).		✓	
:LIMit3	Path to control LIMIT 3 test:		✓	
:UPPer	Configure upper limit:		✓	
[:DATA] <n>	Specify upper limit (-9.999999e20 to 9.999999e20).	1	✓	✓
[:DATA]?	Query upper limit.		✓	
:SOURce2 <NRf> | <NDN>	Specify output "fail" pattern (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query "fail" bit pattern.[1]			

[1]The format (ASCII, hexadecimal, octal, or binary) for the returned value is set by FORMat:SOURce2 <name>.
[2]Default based on present digital output size (:SOURce2:BSIZe <n>). 3-bit default is 7. 4-bit default is 15. 16-bit default is 65535.

Table 17-1 (cont.)
CALCulate command summary

Command	Description	Default parameter	SCPI	Source memory
:CALCulate2				
:LIMit3				
:LOWer	Configure lower limit:		✓	
[:DATA] <n>	Specify lower limit (-9.999999e20 to 9.999999e20).	-1	✓	✓
[:DATA]?	Query lower limit.		✓	
:SOURce2 <NRf> | <NDN>	Specify output "fail" pattern for grading mode (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query "fail" bit pattern.[1]			
:PASS	Path to specify "pass" pattern for sorting mode:			
:SOURce2 <NRf> | <NDN>	Specify output "pass" pattern (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7	✓	✓
:SOURce2?	Query "pass" bit pattern.[1]			
:STATe <b>	Enable or disable Limit 3 test.	OFF	✓	✓
:STATe?	Query state of Limit 3 test.		✓	
:FAIL?	Return result of Limit 3 test: 0 (pass) or 1 (fail).		✓	
:LIMit5…12	Path to control LIMIT 5 to LIMIT 12 tests (see Note):		✓	
:UPPer	Configure upper limit:		✓	
[:DATA] <n>	Specify upper limit (-9.999999e20 to 9.999999e20).	1	✓	✓
[:DATA]?	Query upper limit.		✓	
:SOURce2 <NRf> | <NDN>	Specify output "fail" pattern for grading mode (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query "fail" bit pattern.[1]			

[1]The format (ASCII, hexadecimal, octal, or binary) for the returned value is set by FORMat:SOURce2 <name>.
[2]Default based on present digital output size (:SOURce2:BSIZe <n>). 3-bit default is 7. 4-bit default is 15. 16-bit default is 65535.
Note: Use LIMit5 through LIMit12 to control Limit 5 through Limit 12 tests respectively. For example, send :LIM5:STAT ON to enable Limit 5; send LIM10:FAIL? to return the result of Limit 10.

Table 17-1 (cont.)
CALCulate command summary

Command	Description	Default parameter	SCPI	Source memory
:CALCulate2				
:LIMit5…12				
:LOWer	Configure lower limit:		✓	
[:DATA] <n>	Specify lower limit (-9.999999e20 to 9.999999e20).	-1	✓	✓
[:DATA]?	Query lower limit.		✓	
:SOURce2 <NRf> | <NDN>	Specify output “fail” pattern for grading mode (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query “fail” bit pattern.[1]			
:PASS	Path to specify “pass” pattern for sorting mode:			
:SOURce2 <NRf> | <NDN>	Specify output “pass” pattern (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7	✓	✓
:SOURce2?	Query “pass” bit pattern.			
:STATe <b>	Enable or disable Limit 5 to 12 tests.	OFF	✓	✓
:STATe?	Query state of Limit 5 to 12 tests.		✓	
:FAIL?	Return result of Limit 5 to 12 tests: 0 (pass) or 1 (fail).		✓	
:CLIMits	Composite limits for Limit 1 through Limit 12:			
:BCONtrol <name>	Specify when to send binning info to handler. A limit test is performed (IMMediate) or after a sweep, list, or memory sequence (END).	IMM		
:BCONtrol?	Query binning control.			
:MODE <name>	Set how limit results control Digital I/O lines (GRADing or SORTing).	GRAD		
:MODE?	Query limit results control of Digital I/O lines.			
:CLEar	Clear test results:			
[:IMMediate]	Clear latest limit test result and reset Digital I/O port back to :SOURce2:TTL settings.			
:AUTO <b>	Enable or disable clearing of test results when :INITiate command is sent.	ON		
:AUTO?	Query state of auto clear.			
:PASS	Define “pass” digital output pattern. Sorting mode only if limits 2, 3, 5-12 disabled.			
:SOURce2 <NRf> | <NDN>	Specify output “pass” pattern: (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query “pass” bit pattern.[1]			
:SMLocation <NRf> | NEXT	Specify next “PASS” Source Memory Sweep location (NEXT location or 1 to 100).	NEXT		✓
:SMLocation?	Query “PASS” memory location.			

[1]The format (ASCII, hexadecimal, octal, or binary) for the returned value is set by FORMat:SOURce2 <name>.
[2]Default based on present digital output size (:SOURce2:BSIZe <n>). 3-bit default is 7. 4-bit default is 15. 16-bit default is 65535.

Table 17-1 (cont.)
CALCulate command summary

Command	Description	Default parameter	SCPI	Source memory
:CALCulate2				
:CLIMits				
:FAIL	Define “fail” digital output pattern:			
:SOURce2 <NRf> | <NDN>	Specify output “fail” pattern: (0 to 7, 3-bit; 0 to 15, 4-bit).[2]	15 or 7		✓
:SOURce2?	Query “fail” bit pattern.[1]			
:SMLocation <NRf> | NEXT	Specify next “FAIL” Source Memory Location (NEXT location or 1 to 100).	NEXT		
:SMLocation?	Query “FAIL” memory location.			
:CALCulate3	Subsystem to control CALC3:		✓	
:FORMat <name>	Specify math format (MEAN, SDEViation, MAXimum, MINimum, or PKPK).	MEAN	✓	
:FORMat?	Query math format.		✓	
:DATA?	Read math result of CALC3.		✓	

[1]The format (ASCII, hexadecimal, octal, or binary) for the returned value is set by FORMat:SOURce2 <name>.
[2]Default based on present digital output size (:SOURce2:BSIZe <n>). 3-bit default is 7. 4-bit default is 15. 16-bit default is 65535.

Table 17-2
DISPlay command summary

Command	Description	Default parameter	SCPI
:DISPlay			
:ENABle <b>	Turn on or turn off front panel display.	Note 1	✓
:ENABle?	Query state of display.		✓
:CNDisplay	Return to source-measure display state.		
[:WINDow[1]]	Path to locate message to top display:		✓
:TEXT	Control user test message:	Note 2	✓
:DATA <a>	Define ASCII message “a” (up to 20 characters).		✓
:DATA?	Query text message.		✓
:STATe <b>	Enable or disable message mode.	Note 3	✓
:STATe?	Query text message state.		✓
:DATA?	Query data on top portion of display.		
:ATTRibutes?	Query attributes of message characters: blinking (1) or not blinking (0).		
:WINDow2	Path to locate message to bottom display:		
:TEXT	Control user test message:		✓
:DATA <a>	Define ASCII message “a” (up to 32 characters).	Note 2	✓
:DATA?	Query text message.		✓
:STATe <b>	Enable or disable message mode.		✓
:STATe?	Query text message state.	Note 3	✓
:DATA?	Query data on bottom portion of display.		✓
:ATTRibutes?	Query attributes of message characters: blinking (1) or not blinking (0).		
:DIGits <n>	Specify display resolution (4 to 7).		
:DIGits?	Query display resolution.	6	

Notes:
1. *RST and :SYSTem:PRESet has no effect on the display circuitry. Pressing LOCAL or cycling power enables (ON) the display circuit.
2. *RST and :SYSTem:PRESet has no effect on a user-defined message. Pressing LOCAL or cycling power cancels all user-defined messages.
3. *RST and :SYSTem:PRESet has no effect on the state of the message mode. Pressing LOCAL or cycling power disables (OFF) the message mode.

Table 17-3
FORMat command summary

Command	Description	Default parameter	SCPI
:FORMat			
:SREGister <name>	Select data format for reading status event registers (ASCii, HEXadecimal, OCTal or BINary).	ASCii	✓
:SREGister?	Query format for reading status event registers.		
[:DATA] <type>[<,length>]	Specify data format (ASCii, REAL, 32 or SREal).	ASCii	✓
[:DATA]?	Query data format.		✓
:BORDer <name>	Specify byte order (NORMal or SWAPped).	Note	✓
:BORDer?	Query byte order.		✓
:ELEMents			
[:SENSe[1]] <item list>	Specify data elements (VOLTage, CURRent, RESistance, TIME, and STATus).	All	
[:SENSe[1]]?	Query data format elements.		
:CALCulate <item list>	Specify CALC data elements (CALC, TIME, or STATus).	CALC	
:CALCulate?	Query CALC data elements.		
:SOURce2 <name>	Specify SOURce2 data format (ASCii, HEXadecimal, OCTal, or BIN).	ASCii	
:SOURce2?	Query SOURce2 data format.		

Note: Byte order — *RST default is NORMal. :SYSTem:PRESet default is SWAPped.

Table 17-4
OUTPut command summary

Command	Description	Default parameter	SCPI	Source memory
:OUTPut[1]			✓	
:STATe <b>	Turn source on or off.	OFF	✓	
:STATe?	Query state of source.		✓	
:INTerlock	Path to control interlock:			
:STATe <b>	Enable or disable interlock.	OFF		
:STATe?	Query state of interlock.			
:TRIPped?	Interlock tripped?: 1 (yes) or 0 (no).			
:SMODe <name>	Select output off mode (NORMal, ZERO or GUARd).	NORMAL		✓
:SMODe?	Query output off mode.			

Table 17-5
SENSe command summary

Command	Description	Default parameter	SCPI	Source memory
[:SENSe[1]]	Sense 1 Subsystem:		✓	
:DATA	Path to SENSe[1] data.		✓	
[:LATest?]	Return only most recent reading.			
:FUNCtion	Select measurement function(s):		✓	
:CONCurrent <b>	Enable or disable ability to measure more than one function simultaneously. When disabled, volts function is enabled.	ON	✓	✓
:CONCurrent?	Query concurrent state.		✓	
[:ON] <function list>	Specify functions to enable (VOLTage[:DC], CURRent[:DC], or RESistance).	CURRent	✓	✓
:ALL	Enable all functions (concurrent enabled) or enable ohms function (concurrent disabled).		✓	
:COUNt?	Query number of functions that are enabled.		✓	
[:ON]?	Returns list of functions that are enabled.		✓	
:OFF <function list>	Specify functions to disable: (VOLTage[:DC], CURRent[:DC], or RESistance).	VOLTage, RESis-tance	✓	✓
:ALL	Disable all measurement functions.		✓	
:COUNt?	Query number of functions that are disabled.		✓	
:OFF?	Returns list of functions that are disabled.		✓	
:STATe? <name>	Query state of specified function: 1 (on) or 0 (off).		✓	
:CURRent[:DC]	Path to configure current:		✓	
:RANGe	Configure measurement range:		✓	
[:UPPer]	Select range by specifying the expected		✓	✓[1]
<n>|UP|DOWN	current reading; 0 to ±105e-3.	1.05e-4		
[:UPPer]?	Query range.		✓	
:AUTO <b>	Enable or disable auto range.		✓	✓[1]
:AUTO?	Query auto range.	ON	✓	
:ULIMit?	Returns I compliance range.		✓	
:LLIMit <n>	Set auto ranging lower limit (-105e-3 to 105e-3).	1e-6	✓	
:LLIMit?	Query auto ranging lower limit.		✓	

[1]If source V is active.

Table 17-5 (cont.)
SENSe command summary

Command	Description	Default parameter	SCPI	Source memory
[:SENSe[1]]				
:CURRent[:DC]				
:NPLCycles <n>	Specify integration rate (in line cycles): 0.01 to 10.	10	✓	✓[1]
:NPLCycles?	Query integration rate.		✓	
:PROTection	Path to configure current compliance:		✓	
[:LEVel] <n>	Specify current limit for V-Source; -105e-3 to 105e-3.	1.05e-4	✓	✓[1]
[:LEVel]?	Query current compliance limit.		✓	
:TRIPped?	In current compliance: 1 (yes), 0 (no).		✓	
:VOLTage[:DC]	Path to configure volts:		✓	
:RANGe	Configure measurement range:		✓	
[:UPPer] <n>|UP|DOWN	Select range by specifying the expected voltage reading; 0 to ±210.	21	✓	✓[2]
[:UPPer]?	Query range.		✓	
:AUTO <b>	Enable or disable auto range.	ON	✓	✓[2]
:AUTO?	Query auto range.		✓	
:ULIMit?	Returns V compliance range.		✓	
:LLIMit <n>	Set auto range lower limit (-21 to 21).	0.21	✓	
:LLIMit?	Query auto range lower limit.		✓	
:NPLCycles <n>	Specify integration rate (in line cycles): 0.01 to 10.	10	✓	✓[2]
:NPLCycles?	Query integration rate.		✓	
:PROTection	Path to configure voltage compliance:		✓	
[:LEVel] <n>	Specify voltage limit for I-Source; -210 to 210.	21	✓	✓[2]
[:LEVel]?	Query voltage compliance limit.		✓	
:TRIPped?	In voltage compliance?: 1 (yes), 0 (no).		✓	
:RESistance	Path to configure resistance:		✓	
:MODE <name>	Select ohms mode (MANual or AUTO).	MANual		✓
:MODE?	Query ohms mode.			
:OCOMpensated <b>	Enable or disable offset-compensated ohms.	OFF	✓	✓
:OCOMpensated?	Query state of offset-compensated ohms.		✓	

[1]If source V is active.
[2]If source I is active and auto ohms is disabled.

Table 17-5 (cont.)
SENSe command summary

Command	Description	Default parameter	SCPI	Source memory
[:SENSe[1]]				
:RESistance				
:RANGe	Configure measurement range:		✓	
[:UPPer]	Select range by specifying the expected	2.1e5	✓	✓[3]
<n>|UP|DOWN	resistance reading.[1]		✓	
[:UPPer]?	Query range.			
:AUTO <b>	Enable or disable auto range.	ON	✓	✓
:AUTO?	Query auto range.		✓	
ULIMit <n>	Set upper limit.[1]	Note 2	✓	
ULIMit?	Query auto range upper limit.		✓	
LLIMit <n>	Set lower limit.[1]	2.1e1	✓	
LLIMit?	Query auto range lower limit.		✓	
:NPLCycles <n>	Specify integration rate (in line cycles): 0.01 to 10.	1.0	✓	✓
:NPLCycles?	Query integration rate.		✓	
:AVERage	Path to configure moving and repeat filters:		✓	
:AUTO <b>	Enable or disable auto filter.	ON	✓	✓
:AUTO?	Query state of auto filter.		✓	
:COUNt <n>	Specify moving filter count; 1 to 100.	1	✓	✓
:COUNt?	Query moving filter count.		✓	
[:STATe] <b>	Enable or disable moving filter.	ON	✓	✓
[:STATe]?	Query state of moving filter.		✓	
:ADVanced	Configure the advanced filter:		✓	
:NTOLerance <NRf>	Set filter noise window (in %); 0 to 105.	5	✓	✓
:NTOLerance?	Query filter noise window setting.		✓	
[:STATe] <b>	Enable or disable advanced filter.	OFF	✓	✓
[:STATe]?	Query state of advanced filter.		✓	
:REPeat	Confifgure the repeat filter:		✓	
:COUNt <n>	Specify repeat filter count; 1 to 100.	1	✓	✓
:COUNt?	Query repeat filter count.		✓	
[:STATe] <b>	Enable or disable repeat filter.	ON	✓	✓
[:STATE]:	Query state of repeat filter.		✓	
:MEDian	Configure and control the median filter:			
:RANK <NRf>	Specify median filter rank; 0 to 5.	0		✓
:RANK ?	Query median filter rank.			
[:STATe] <b>	Enable or disable median filter.	ON		✓
[:STATe]?	Query state of median filter.			

Notes:
1. 0 to 2.1e13 with PreAmp. 0 to 2.1e7 without PreAmp.
2. 1e13 with PreAmp. 2.1e7 without PreAmp.
3. If auto ohms is enabled.

Table 17-6
SOURce command summary

Command	Description	Default parameter	SCPI	Source memory
:SOURce[1]	Path to control sourcing:		✓	
:CLEar	Path to clear source:			
[:IMMediate]	Turn selected source off.			
:AUTO <b>	Enable or disable auto clear for source.			
:AUTO?	Query state of auto clear.	OFF		
:MODE <name>	Specify auto clear mode (ALWays or TCOunt).	ALWays		
:MODE?	Query auto clear mode.			
:FUNCtion	Source selection:		✓	
[:MODE] <name>	Select source mode (VOLTage, CURRent or MEMory).	VOLTage	✓	✓
[:MODE]?	Query source selection.		✓	
:DELay <n>	Specify settling time (in sec): 0 to 9999.999.	0.003		✓
:AUTO <b>	Enable or disable auto settling time.	OFF		✓
:AUTO?	Query state of auto settling time.			
:DELay?	Query source settling time.			
:CURRent	Path to configure I-Source:		✓	
:MODE <n>	Select I-Source mode (FIXed, SWEep, or LIST).	FIXed	✓	
:MODE?	Query I-Source mode.		✓	
:RANGe <n>|UP|DOWN|	Select fixed I-Source range; 0 to 0.105.	1.05e-4	✓	✓[1]
:AUTO <b>	Enable or disable autoranging.	ON	✓	
:AUTO?	Query state of autoranging.		✓	
:RANGe?	Query I-Source range setting.		✓	
[:LEVel]	Set I-Source level (in amps):		✓	
[:IMMediate]	Set level immediately:		✓	
[:AMPLitude] <n>	Specify current level; -0.105 to 0.105.	0	✓	✓[1]
[:AMPLitude]?	Query current level.		✓	
:TRIGgered	Set level when triggered:		✓	
[:AMPLitude] <n>	Specify current level; -0.105 to 0.105.	0	✓	
[:AMPLitude]?	Query current level.		✓	
:SFACtor <n>	Set current scaling factor (-999.9999e+18 to +999.999e+18).	1.0		✓[1]
:STATe <b>	Enable/disable current scaling factor.	OFF		✓[1]
:STATe?	Query current scaling factor state.			
:SFACtor?	Query current scaling factor.			
:STARt <n>	Specify start level for I-sweep; -105e-3 to 105e-3.	0	✓ ✓	

[1]If source V is active.

Table 17-6 (cont.)
SOURce command summary

Command	Description	Default parameter	SCPI	Source memory
:SOURce[1]				
:CURRent				
:STARt?	Query start level for current sweep.			
:STOP <n>	Specify stop level for I-sweep; -105e-3 to 105e-3.	0	✓ ✓	
:STOP?	Query stop level for current sweep.			
:STEP <n>	Specify step value for I-sweep; -210e-3 to 210e-3.	0		
:STEP?	Query step value for current sweep.			
:SPAN <n>	Specify span; -210e-3 to 210e-3.	0	✓	
:SPAN?	Query span.		✓	
:CENTer <n>	Specify center point; -210e-3 to 210e-3.	0	✓	
:CENTer?	Query center point.		✓	
:VOLTage	Path to configure V-Source:		✓	
:MODE <n>	Select V-Source mode (FIXed, SWEep, or LIST).	FIXed	✓	
:MODE?	Query V-Source mode.		✓	
:RANGe <n>|UP|DOWN|	Select fixed V-Source range; 0 to 210.	21	✓	✓[1]
AUTO <b>	Enable or disable autoranging.	ON	✓	✓[1]
:AUTO?	Query state of autoranging.		✓	
:RANGe?	Query V-Source range setting.		✓	
[:LEVel]	Set V-Source level (in volts):		✓	
[:IMMediate]	Set specified level immediately:		✓	
[:AMPLitude] <n>	Specify voltage level; -210 to 210.	0	✓	✓[1]
[:AMPLitude]?	Query voltage level.		✓	
:TRIGgered	Set specified level when triggered:		✓	
[:AMPLitude] <n>	Specify voltage level; -210 to 210.	0	✓	
[:AMPLitude]?	Query voltage level.		✓	
:SFACtor <n>	Set voltage scaling factor (-999.9999e+18 to +999.9999e+18).	0		✓[1]
:STATe <b>	Enable/disable voltage scaling factor.	OFF		✓[1]
:STATe?	Query voltage scaling factor state.			
:SFACtor?	Query voltage scaling factor.			
:PROTection	Path to limit output voltage:		✓	
[:LEVel] <NRf>	Specify voltage limit level; -210 to 210.	210	✓	
[:LEVel]?	Query voltage limit.		✓	
:TRIPped?	Voltage limit detected: 1 (yes), 0 (no).		✓	

[1]If source V is active.

Table 17-6 (cont.)
SOURce command summary

Command	Description	Default parameter	SCPI	Source memory
:SOURce[1]				
:VOLTage				
:STARt <n>	Specify start level for V-sweep; -210 to 210.	0	✓	
:STARt?	Query start level for voltage sweep.		✓	
:STOP <n>	Specify stop level for V-sweep; -210 to 210.	0	✓	
:STOP?	Query stop level for voltage sweep.		✓	
:STEP <n>	Specify step value for V-sweep; -420 to 420.	0		
:STEP?	Query step value for voltage sweep.			
:SPAN <n>	Specify span; -420 to 420.	0	✓	
:SPAN?	Query span.		✓	
:CENTer <n>	Specify center point; -420 to 420.	0	✓	
:CENTer?	Query center point.		✓	
:SOAK <NRf>	Set first sweep point soak time (0.00000 to 9999.999s).	0.00000	✓ ✓	
:SOAK?	Query soak time.		✓	
:SWEep	Configure SWEep source mode:		✓	
:SPACing <name>	Select sweep spacing type (LINear or LOGarithmic).	LINear	✓	
:SPACing?	Query sweep spacing.		✓	
:POINts <n>	Specify number of sweep points (2 to 2500).	2500		
:POINts?	Query number of points in sweep.			
:DIRection <name>	Sweep from start to stop (UP) or from stop to start (DOWN).	UP		
:DIRection?	Query sweep direction.			
:RANGing <name>	Select source ranging mode (BEST, AUTO, or FIXed).	BEST		
:RANGing?	Query source ranging mode.			
:LIST	Configure LIST source mode:			
:CURRent <NRf>	Create list of I-Source values; -0.105 to 0.105.			
:APPend <NRf>	Add I-Source values to end of list.			
:POINts?	Query number of source values in list.			
:CURRent?	Query I-Source list.			
:VOLTage <NRf>	Create list of V-Source values; -210 to 210.			
:APPend <NRf>	Add V-Source values to end of list.			
:POINts?	Query number of source values in list.			
:VOLTage?	Query V-Source list.			

Table 17-6 (cont.)
SOURce command summary

Command	Description	Default parameter	SCPI	Source memory
:SOURce[1]				
:MEMory	Configure Source Memory Sweep:			
:SAVE <n>	Save settings at memory location (1 to 100).			
:RECall <n>	Recall settings from memory (1 to 100).	1		
:POINts <n>	Specify number of sweep points (1 to 100).			
:POINts?	Query number of sweep points.			
:STARt <NRf>	Specify start location for Source Memory Sweep (1 to 100).	1		
:STARt?	Query start location.			
:SOURce2	Path to control digital output lines:			
:BSIZe <n>	Set Digital I/O bit size (3, or 4).[3]	No effect		
:BSIZe?	Query Digital I/O bit size.			
:TTL				
[:LEVel]				
[:DEFault] <NRf>, <NDN>	Specify digital output pattern.[4]	15 or 7		
:ACTual?	Query actual pattern on digital output port.			
[:DEFault]?	Query the programmed output pattern value			
:TTL4				
:MODE <name>	Set Digital I/O mode (EOTest or BUSY).	EOTest		
:MODE?	Query Digital I/O line 4 mode.			
:BSTate <b>	Set BUSY and EOT polarity (HI or LO).	LO		
:BSTate?	Query BUSY and EOT polarity.			
:CLEar	Clear digital output:			
[:IMMediate]	Restore (clear) to :TTL output pattern.			
:AUTO <b>	Enable or disable auto-clear.	OFF		
:AUTO?	Query state of auto-clear.			
:DELay <n>	Specify pulse-width of pass/fail pattern (0.0000 to 60 sec).	0.00010		
:DELay?	Query delay.			

[3]16-bit size available with 2499-DIGIO option.
[4]Bit range set by :BSIZe. Default for 3-bit is 7. Default for 4-bit is 15. Default for 16-bit is 65535.

Table 17-7
STATus command summary

Command	Description	Default parameter	SCPI
:STATus		Note 1	✓
:MEASurement	Control measurement event registers:		
[:EVENt]?	Read the event register.[6]	Note 2	✓
:ENABle <NDN> or <NRf>	Program the enable register.	Note 3	✓
:ENABle?	Read the enable register.[6]		✓
:CONDition?	Read the condition register.[6]		✓
:OPERation	Control operation status registers:		✓
[:EVENt]?	Read the event register.[6]	Note 2	✓
:ENABle <NDN> or <NRf>	Program the enable register.	Note 3	✓
:ENABle?	Read the enable register.[6]		✓
:CONDition?	Read the condition register.[6]		✓
:QUEStionable	Control questionable status registers:		✓
[:EVENt]?	Read the event register.[6]	Note 2	✓
:ENABle <NDN> or <NRf>	Program the enable register.	Note 3	✓
:ENABle?	Read the enable register.[6]		✓
:CONDition?	Read the condition register.[6]		✓
:PRESet	Return status registers to default states.		✓
:QUEue	Path to access error queue:		
[:NEXT]?	Read the most recent error message.	Note 4	✓
:ENABle <list>	Specify error and status messages for error queue.	Note 5	✓
:ENABle?	Read the enabled messages.		✓
:DISable <list>	Specify messages not to be placed in error queue.	Note 5	
:DISable?	Read the disabled messages.		
:CLEar	Clears all messages from error queue.		

Notes:
1. Commands in this subsystem are not affected by *RST and :SYSTem:PREset. The effects of cycling power, *CLS and :STATus:PRESet, are explained by the following notes.
2. Event Registers — Power-up and *CLS clears all bits.:STATus:PRESet has no effect.
3. Enable Registers — Power-up and :STATus:PRESet clears all bits. *CLS has no effect. Accepts the SCPI 1995.0 mandated (non-decimal numeric) format (#H, #Q, or #B).
4. Error Queue — Power-up and *CLS clears all bits of the registers.
5. Error Queue Messages — Power-up clears list of messages. *CLS and :STATus:PRESet have no effect.
6. Register Query Commands — The format for the response messages (ASCII, hexadecimal, octal, or binary) depends on which data format is presently selected. See the :FORMat:SREGister command.

Table 17-8
SYSTem command summary

Command	Description	Default parameter	SCPI	Memory
:SYSTem				
:PRESet	Return to :SYSTem:PRESet defaults.		✓	
:POSetup <name>	Select power-on setup (RST, PRESet or SAV 0-4).			
:POSetup?	Query power-on setup.			
:VERSion?	Query revision level of SCPI.		✓	
:ERRor	Path to read messages in error queue. [1]		✓	
[:NEXT]?	Return and clear oldest error (code and message).			
:ALL?	Return and clear all errors (codes and messages).			
:COUNt?	Return the number of errors.			
:CODE	Path to return error code numbers only:			
[:NEXT]?	Return and clear oldest error (code only).			
ALL?	Return and clear all errors (codes only).			
:CLEar	Clears messages from error queue.			
:KEY <n>	Simulate key-press (1 to 31). See Figure 17-3.		✓	
:KEY?	Query the last “pressed” key.		✓	
:GUARd <name>	Select guard type (OHMS or CABLe).	CABLe		
:GUARd?	Query guard type.			
:BEEPer	Control beeper:			
[:IMMediate]	Beep at specified frequency (65 to 2e6 Hz) for			
<freq, time>	specified time period (0 to 7.9 seconds).			
:STATe <b>	Enable or disable beeper.	ON	✓	
:STATe?	Query state of beeper.		✓	
:AZERo	Control auto zero and NPLC caching:			
[:STATe] <name>	Control auto zero (ON, OFF, or ONCE).	ON	✓	✓
[:STATe]?	Query state of auto zero.		✓	
:CACHing	Control NPLC caching.			
[:STATe] <b>	Enable or disable NPLC caching.	OFF		
[:STATe]?	Query NPLC caching state.			
:REFResh	Force immediate update of NPLC cache values.			
:RESet	Clear cache of all NPLC values.			
:NPLCycles?	Return list of NPLC values in cache.			
:LFRequency <freq>	Select line frequency: 50 or 60 (Hz):			
:AUTO <b>	Enable or disable auto frequency.	Note 2		
:AUTO?	Query state of auto frequency.			
:LFRequency?	Query line frequency.			

Notes:
1. Clearing Error Queue — Power-up and *CLS clears the error queue. *RST, :SYSTem:PRESet, and :STATus:PRESet have no effect.
2. The auto line frequency setting is not affected by *RST and :SYSTem:PRESet.

Table 17-8 (cont.)
SYSTem command summary

Command	Description	Default parameter	SCPI	Memory
:SYSTem				
:TIME	Timestamp:			
:RESet	Reset timestamp to zero seconds.			
:AUTO <b>	Enable/disable timestamp reset on exiting idle.	OFF		
:TIME?	Query timestamp.			
:MEMory	Initialize memory:		✓	
:INITialize	Initialize battery backed RAM.		✓	
:LOCal	Take unit out of remote (RS-232 only).			
:REMote	Put unit in remote (RS-232 only).			
:RWLock <b>	Enable or disable local lockout (RS-232 only).			
:RCMode <name>	Set auto range on compliance mode (SINGle or MULTiple).	SINGle		
:RCMode?	Query auto range on compliance mode.			
:MEP	Path to 488.1 protocol (Appendix G).			
[:STATe]?	Query protocol (1 = SCPI, 0 = 488.1).			
:HOLDoff <b>	Enable/disable NDAC hold-off.	OFF		

Table 17-9
TRACe command summary

Command	Description	Default parameter	SCPI
:TRACe|:DATA	Use :TRACe or :DATA as root command:	Note	✓
:DATA?	Read the contents of the buffer (data store).		✓
:CLEar	Clear readings from buffer.		
:FREE?	Query bytes available and bytes in use.		✓
:POINts <NRf>	Specify size of buffer (1 to 2500).		✓
:ACTual?	Queries number of readings stored in the buffer.		
:POINts?	Query buffer size.		✓
:FEED <name>	Select source of readings (SENSe[1], CALCulate[1], or CALCulate2).		✓
:CONTrol <name>	Specify buffer control mode (NEVER or NEXT).		✓
:CONTrol?	Query buffer control mode.		✓
:TSTamp	Path to set timestamp format:		
:FORMat <name>	Select format (ABSolute or DELTa).		
:FORMat?	Query timestamp format.		

Note: :SYSTem:PRESet and *RST have no effect on the commands in this subsystem.

Table 17-10
TRIGger command summary

Command	Description	Default parameter	SCPI
:INITiate[:IMMediate]	Initiate source-measure cycle(s).		✓
:ABORt	Reset trigger system. Goes to idle state.		✓
:ARM	Path to program Arm Layer:		✓
[:SEQuence[1]]			✓
[:LAYer[1]]			✓
:COUNt <n>	Specify arm count (1 to 2500 or INFinite).	1	✓
:COUNt?	Query arm count (INFinite = +9.9e37).		✓
:SOURce <name>	Specify control source (IMMediate, TIMer, MANual, BUS, TLINk, NSTest, PSTest, BSTest).	IMMediate	✓
:SOURce?	Query control source.		✓
:TIMer <n>	Set timer interval in seconds (0.001 to 99999.99).	0.1	✓
:TIMer?	Query timer interval.		✓
[:TCONfigure]			✓
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.	ACCeptor	✓
:DIRection?	Query state of bypass.		✓
[:ASYNchronous]	Configure output triggers:		✓
:ILINe <n>	Select input trigger line (1, 2, 3, or 4).	1	
:ILINe?	Query input trigger line.		
:OLINe <n>	Select output trigger line (1, 2, 3, or 4).	2	
:OLINe?	Query output trigger line.		
:OUTPut <name>	Output TENTer, TEXit, or NONE.	NONE	
:OUTPut?	Query arm output trigger status.		
:TRIGger	Path to program Trigger Layer:		✓
:CLEar	Clear any pending input triggers immediately.		✓
[:SEQuence[1]]			✓
:COUNt <n>	Specify trigger count (1 to 2500).	1	✓
:COUNt?	Query trigger count.		✓
:DELay <n>	Specify trigger delay: 0 to 999.9999 (sec).	0	✓
:DELay?	Query source delay.		✓
:SOURce <name>	Specify control source (IMMediate or TLINk).	IMMediate	✓
:SOURce?	Query control source.		✓

Table 17-10 (cont.)
TRIGger command summary

Command	Description	Default parameter	SCPI
:TRIGger			
[:SEQuence[1]]			
[:TCONfigure]			✓
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.		✓
:DIRection	Query state of bypass.		✓
[:ASYNchronous]	Configure output triggers:		✓
:ILINe <n>	Select input trigger line (1, 2, 3, or 4).	1	
:ILINe?	Query input trigger line.		
:INPut <event list>	Enable input event detectors (SOURce, DELay, SENSe, or NONE).	NONE	
:INPut?	Query enabled input event detectors.		
:OLINe <n>	Select output trigger line (1, 2, 3, or 4).	2	
:OLINe?	Query output trigger line.		
:OUTPut <event list>	Output trigger after SOURce, DELay, SENSe or not (NONE) at all.	NONE	
:OUTPut?	Query when output trigger is going to occur.		

Calculate subsystems

There are three Calculate Subsystems. The CALC1 Subsystem is used for math expressions, CALC2 is used for limit tests, and CALC3 provides statistical data on readings stored in the buffer. The commands in these subsystems are summarized in Table 17-1.

CALCulate[1]

Configure and control math expressions

NOTE *Percent deviation (%DEV) is included in the catalog as a built-in math expression but is only available from the front panel. However, percent deviation can be added as a user-defined math expression for remote operation. See "Program examples."*

Select (create) math expression name

:CATalog?

:CALCulate[1]:MATH[:EXPression]:CATalog? Query list of expression names

Description This query command is used to list the math expression names. This list includes the built-in expression names as well as the names of expressions defined by the user. The names for the built-in expressions are as follows:

"POWER", "OFFCOMPOHM", "VOLTCOEF", "VARALPHA", "%DEV"

Thus, the :CATalog? command will return the above names as well as the names of any user-defined expressions. See :NAME to assign names to user-defined expressions.

:NAME <name>

:CALCulate[1]:MATH[:EXPression]:NAME <name> Select math expression

Parameters

<name>	=	"POWER"	Instantaneous power equation
		"OFFCOMPOHM"	Offset compensated ohms equation
		"VOLTCOEF"	Resistor voltage coefficient equation
		"VARALPHA"	Varistor alpha equation
		"user-name"	Assigned name for user-defined expression where the user name is made up of ASCII characters (up to 10).

Query :NAME? Query selected math expression

Description This command can be used to select a math expression that already exists (built-in or user-defined). Math expression names that already exist can be listed using the :CATalog? command. The actual math expression can be read using the :MATH? command. The built-in math expressions (except POWER) require a two-point sweep in order to perform the calculation. The "Program fragments" show how to configure the SourceMeter for these math expressions.

When you want to create a new user-defined math expression, perform the following steps in order:

1. If desired, assign units to the calculation result. See :UNITs. Units is stored for the calculation.
2. Assign a name to the expression (using up to 10 ASCII characters) using this command.
3. Define the expression using the: DEFine or EXPRession command. The new expression is the one that will be presently selected.

Math expression errors:

+801 "Insufficient vector data" — Returned to idle before acquiring enough data to fully populate the vector. A CALC1 result is not built.

+804 "Expression list full" — Attempted to create a new expression name when the list (catalog) is full. The maximum number of user-defined expression names is five.

+805 "Undefined expression exists" — Attempted to create a new expression name while a previous expression name remains undefined. Remember, after creating a name, you have to define the expression.

+806 "Expression not found" — Attempted to delete a named math expression that cannot be found.

+807 "Definition not allowed" — Attempted to define an expression that has not been previously named.

+808 "Expression cannot be deleted" — Attempted to delete one of the built-in math expressions. See :DELete.

+809 "Source memory location revised" — Occurs when a :SOURce:MEMory sweep location references an expression that no longer exists.

+811 "Not an operator or number" — Defined a null math expression by not using a valid operator or number.

+812 "Mismatched parenthesis" — Number of open parentheses must be the same as the number of closed parentheses. For example, CALC1:MATH:EXPR (2*sin(VOLT) generates this error.

+813 "Not a number of data handle" — An invalid floating point number or symbol other than VOLT, CURR, RES, or TIME appears in the math expression.

+814 "Mismatched brackets" — Improper use of brackets for vectored math expression indices. For example, CALC1:MATH:EXPR (VOLT[0*CURR[0]) generates this error.

+815 "Too many parenthesis" — Too many closed parentheses were detected. For example, CALC1:MATH:EXPR (In(VOLT)) generates this error.

+816 "Entire expression not parsed" — Occurs when the input expression does not produce a function for the SourceMeter to calculate.

+817 “Unknown token” — Attempted to define an expression using an invalid function name.

+818 “Error parsing mantissa” — Occurs when a floating point number has an invalid mantissa.

+819 “Error parsing exponent” — Occurs when a floating point number has an invalid exponent.

+820 “Error parsing value” — Occurs when an invalid floating point number is entered.

+821 “Invalid data handle index” — An invalid array index value was assigned to a vectored expression. Array indices start at 0 and can be as high as 2499.

Notes:

- Up to five user-defined math expressions can be created.
- A selected math expression can only be performed if CALC1 is enabled. See :STATe.
- When the math expression is vectored, the math result will not be generated until all source-measure operations for the vector array are performed.
- Initializing memory (:SYSTem:MEMory:INITialize) deletes all user-defined math expressions and selects the POWER expression.

Program examples

OFFCOMPOHM, VOLTCOEF, and VARALPHA require two source-measure sweep points in order to perform the math expressions. Shown below are code fragments that will properly configure the SourceMeter to perform the built-in math expressions:

Power:

```
*RST
:SENS:FUNC:OFF:ALL
:SENS:FUNC                  “VOLT”,“CURR”
:CALC:MATH:EXPR:NAME        “POWER”
:CALC:STAT                  ON
:OUTPUT                     ON
:INIT
:CALC:DATA?
```

Offset compensated ohms:

```
*RST
:SENS:FUNC:OFF:ALL
:SENS:FUNC                  “VOLT”,“CURR”
:SOUR:FUNC                  VOLT or CURR
if :SOUR:FUNC VOLT then     :SOUR:VOLT:STAR <n>;
                            STOP <n>; MODE SWE
if :SOUR:FUNC CURR then     :SOUR:CURR:STAR <n>;
                            STOP <n>; MODE SWE
```

:SOUR:SWE:POIN	2
:TRIG:COUN	2
:CALC:MATH:EXPR:NAME	“OFFCOMPOHM”
:CALC:STAT	ON
:OUTPUT	ON
:INIT	
:CALC:DATA?	

Resistor voltage coefficient

*RST	
:SENS:FUNC:ON:ALL	
:SENS:RES:MODE	MAN
:SOUR:FUNC:ON	VOLT or CURR
if :SOUR:FUNC VOLT then	:SOUR:VOLT:STAR <n>; STOP <n>; MODE SWE
if :SOUR:FUNC CURR then	:SOUR:CURR:STAR <n>; STOP <n>; MODE SWE
:SOUR:SWE:POIN	2
:TRIG:COUN	2
:CALC:MATH:EXPR:NAME	“VOLTCOEF”
:CALC:STAT	ON
:OUTPUT	ON
:INIT	
:CALC:DATA?	

Varistor alpha

*RST	
:SENS:FUNC:OFF:ALL	
:SENS:FUNC:ON	“VOLT”,“CURR”
:SOUR:FUNC:MODE	CURR
:SOUR:CURR:STAR	<n>;STOP <n>;MODE SWE
:TRIG:COUN	2
:CALC:MATH:EXPR:NAME	“VARALPHA”
:CALC:STAT	ON
:OUTPUT	ON
:INIT	
:CALC:DATA?	

Percent Deviation

NOTE *Percent deviation is not a built-in math expression for remote operation. This program example creates the following percent deviation (PER_DEV) calculation to test 10kΩ resistors. This user-defined math expression is added to the catalog.*

$$\text{PER_DEV} = \frac{(\text{RES} - 10\text{k}\Omega)}{10\text{k}\Omega} \times 100$$

Where: RES is the actual measured resistance of the DUT.
10kΩ is the reference value.

```
*RST
:SENS:FUNC:OFF:ALL
:SENS:FUNC:ON or “RES”
:CALC:MATH:UNIT “%”
:CALC:MATH:EXPR:NAME “PER_DEV”
:CALC:MATH:EXPR ((RES - 10e3) / 10e3) * 100
:CALC:MATH:EXPR:NAME “PER_DEV” (optional command)
:CALC:STAT ON
:OUTPUT ON
:INIT
:CALC:DATA?
```

NOTE *Parameter <n> referenced in the :SOUR:VOLT and :SOUR:CURR commands above represent the actual numbers that the user would program. All other commands should be entered as shown.*

:DELete[:SELected] <name>

:CALCulate[1]:MATH[:EXPRession]:DELete[:SELected] <name> Delete user-defined math expression

Parameters <name> = “user-name” Name of user-defined math expression

Description This command is used to remove (delete) the specified user-defined math expression from the catalog. Once removed, that math expression can no longer be selected. You can use the :CATalog? command to verify that the math expression is gone.

For example, if you wish to delete a user-defined math expression that is named “math1”, you would send the following command:

:DELete “math1”

You cannot delete built-in math expressions. This will result in error +808, “Expression cannot be deleted”.

:DELete:ALL

:CALCulate[1]:MATH[:EXPRession]:DELete:ALL Delete all user-defined math expression

Description This action command will remove (delete) all user-defined math expressions from the catalog. Built-in math expressions are not affected.

Assign unit suffix

:UNITs <name>

:CALCulate[1]:MATH:UNITs <name> Specify units for user-defined calculation

Parameters <name> = Three ASCII characters enclosed in single or double quotes

Query :UNITs? Query units for user-defined calculation

Description This command is used to specify the units suffix name for a user-defined math calculation. Use three ASCII characters for the units suffix name. If using fewer than three characters, add spaces to the right of the units name in the string. For example, if the units name is "Z", send it as follows:

:calc:math:unit "Z "

The units name can also be enclosed in single quotes as follows:

:calc:math:unit 'Z'

Define math expression

[:EXPRession] <form> or [:DEFine] <form>

:CALCulate[1]:MATH[:EXPRession] <form> Define math formula
:CALCulate[1]:MATH[:EXPRession][:DEFine] <form> Define math formula

Parameters <form> = mathematical formula using instrument readings, numbers and standard math operator symbols. See *Description* for details.

Query :MATH? Query user-defined math expression

Description Use either of these two commands to define a math formula using measure and source readings, numeric constants, and standard math operator symbols. After the math expression is defined, it will be assigned to the name that was created using the :NAME command and will become the selected math expression. See :NAME for more details.

Valid parameter names for measure and source readings include:

VOLTage	Use V-Measure or V-Source reading
CURRent	Use I-Measure or I-Source reading
RESistance	Use ohms reading
TIME	Use timestamp reading

Valid math operators and their operations are listed as follows:

+	Add
-	Subtract
*	Multiply
/	Divide
^	Exponent
log	Logarithmic, base 10
ln	Natural log
sin	Sine
cos	Cosine
tan	Tangent
exp	e^x
abs	Absolute value

NOTE *The log and ln operations are performed on the absolute value of the specified number. For example, log (100) = 2 and log (-100) = 2.*

Expressions are evaluated according to the following precedence rules:

1. Enclosed by parentheses
2. Unary operators (+ and -)
3. ^ (exponentiation)
4. * (multiplication) and / (division)
5. + (addition) and - (subtraction)
6. Left to right.

The readings used for the calculation depend on how the SourceMeter is configured. If configured to Source V Measure I, the voltage reading for the calculation will be the source value, and the current reading will be the current measurement. Conversely, if configured to Source I Measure V, the current reading will be the source value, and the voltage reading will be the voltage measurement.

Measure readings take priority over source readings. Thus, if configured to Source V Measure V, the voltage reading for the calculation will be the voltage measurement (not the programmed V-Source value). Conversely, if configured to Source I Measure I, the current reading for the calculation will be the current measurement.

The result of a calculation using a reading that is not sourced or measured will be the invalid NAN (not a number) value of +9.91e37. For example, using a current reading in a calculation for Source V Measure V will cause a NAN result.

Example using Source I Measure V configuration:

:calc:math (volt * curr)	Calculate power using voltage measurement and I-Source value.

After a calculation is configured and enabled, the results are displayed when source-measure operations are performed. See :STATe. Use the :data? command to send the results to the computer.

Vectored math

By incorporating vectors, you select which readings to use for the math calculation. After all programmed source-measure operations are completed, the math calculation(s) are performed using readings indicated by the specified vectors.

Vector numbers are enclosed in brackets ([]), and start at 0. Thus, vector 0 is the first reading in the array, vector 1 is the second reading in the array, and so on. The largest vector number in the expression defines the vector array size.

For example, assume the SourceMeter is programmed to perform 10 source-measure operations, and the following vectored math calculation is used:

(volt[3] - volt[9])

The above expression defines a vector array that is made up of 10 readings. Since the SourceMeter is programmed to perform 10 source-measure opera-

tions, the calculation will yield one result every 10 SDM cycles. The fourth voltage reading (vector 3) and the 10th voltage reading (vector 9) are used for the calculation.

Now assume that the SourceMeter is configured to perform 20 source-measure operations. Since the vector size is still 10, two 10-reading arrays will be created. The calculation will now yield two results, one for each array.

The first result, as before, is based on the fourth and 10th readings of the first array. The second result is based on the 14th and 20th readings. These are the fourth (vector 3) and 10th (vector 9) readings of the second array.

Note that you need complete vector arrays to acquire valid calculation results. If, in the preceding example, the SourceMeter is changed to perform 25 source-measure operations, then the third array will be incomplete (first array is 10 readings, second array is 10 readings, third array is only 5 readings). After the SourceMeter goes back into idle, the "Insufficient vector data" error message will be displayed, and the third result will be NAN (+9.91e37).

To avoid incomplete vector arrays, make sure the programmed number of source-measure operations (arm count × trigger count) is a multiple of the vector array size. In the preceding example, vector array size is 10. Thus, in order to avoid "Insufficient vector data" errors, the programmed number of source-measure operations has to be a multiple of 10 (10, 20, 30, 40, and so on).

The following vector math expression to calculate offset compensated ohms demonstrates proper syntax:

:calc:math ((volt[1] - volt[0]) / (curr[1] - curr[0]))

Notes:

1. Use nested parentheses to force math operations that are imbedded in the calculation. See the vector math example.
2. A calculation expression can be up to 256 characters in length, including parentheses and white spaces.
3. When using the filter, the measured readings used in the calculation are filtered - NOT the result of the calculation.
4. For vector math, it is recommended that only the REPEAT filter be used. For the repeat filter, the calculations use only the filtered readings of the vector points. If you instead use the MOVING filter, each vector point will reflect the filtered average of all the previous readings in the vector array.
5. The data format (ASCII or binary) for calculation results is selected using the :FORMat:DATA? command. See *FORMat Subsystem*. The *RST and :SYSTem:PRESet default is ASCII.
6. When brackets ([]) are left out of an expression, it is assumed that it is referencing the first vector point in the array (i.e., VOLT is the same as VOLT[0]).

Enable and read math expression result

:STATe <b>

:CALCulate[1]:STATe <b> Control CALC1

Parameters <b> = 0 or OFF Disable CALC1 calculation
1 or ON Enable CALC1 calculation

Query :STATe? Query state (on or off) of CALC1

Description This command is used to enable or disable the CALC1 calculation. When enabled, the selected math expression will be performed when the SourceMeter is triggered to perform the programmed source-measure operations.

After the SourceMeter returns to idle, you can read the result of the selected math expression using the :CALC1:DATA? command. See the next command.

When disabled, the :CALC1:DATA? command will return the NAN (not a number) value of +9.91e37.

:DATA?

:CALCulate[1]:DATA? Read CALC1 result

Description This query command is used to read the result of the CALC1 calculation. The largest valid calculation result can be ±9.9e37, which (defined by SCPI) is infinity.

For scalar math (non-vectored math), this command is used to return calculation results for all the programmed source-measure points. For example, if 20 source-measure operations were performed, this command will return 20 calculation results.

For vector math, this command will only return the calculation results for the specified vector points.

An invalid NAN (not a number) result of +9.91e37 indicates that one of the following conditions exist:

- Error in the expression.
- The required measurement function is disabled.
- CALC1 is disabled. See :STATe.

NOTE *See Appendix C for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the type of readings that are acquired by the various commands to read data.*

:LATest?

:CALCulate[1]:DATA:LATest? Read latest CALC1 result

Description This command works exactly like CALC1:DATA? except that it returns only the latest CALC1 result.

CALCulate2

Configure and control limit tests

The following commands are used to configure and control the three limit tests for DUT. When used with a handler to provide binning operations, communication between the SourceMeter and the handler is provided via the Digital I/O port. Many control aspects of the digital output lines are performed from the SOURce2 Subsystem. These control aspects include setting and clearing the digital output lines, and setting pulse width. See *SOURce2* for details.

Select input path

:FEED <name>

:CALCulate2:FEED <name> — Select input path for limit tests

Parameters

<name> =	CALCulate[1]	Use result of CALC1
	VOLTage	Use measured voltage reading
	CURRent	Use measured current reading
	RESistance	Use measured resistance reading

Query :FEED? — Query input path for limit tests

Description This command is used to select the input path for the limit tests. With CALCulate[1] selected, the specified limits will be compared to the result of CALC1. With VOLTage selected, limits will be compared to the voltage measurement. With CURRent or RESistance selected, limits will be compared with the respective current or resistance measurement.

Null feed reading

:OFFSet <n>

:CALCulate2:NULL:OFFSet <n> — Specify null offset (REL) for feed

Parameters

<n> =	-9.999999e20 to 9.999999e20	Specify null offset value

Query :OFFSet? — Query null offset value

Description This command lets you establish a null offset (REL) for the selected feed. When Null Offset is enabled (see :Ingolstadt), the result is the algebraic difference between the feed reading and the offset value:

CALC2 reading = feed reading - null offset

:ACQuire

:CALCulate2:NULL:ACQuire — Automatically acquire REL value

Description This command automatically acquires the null offset value. The next available reading will become the offset value.

:STATe <b>

:CALCulate2:NULL:STATe <b> — Control null offset

Parameters <b> = 1 or ON — Enable null offset
0 or OFF — Disable null offset

Query :STATe? — Query state of null offset

Description This command is used to enable or disable null offset. When enabled, the CALC2 reading will include the null offset value. See :OFFSet. When disabled, CALC2 will not include the null offset.

Read CALC2

:DATA?

:CALCulate2:DATA? — Read CALC2

Description This command is used to acquire all the readings used for the CALC2 limit tests. Note that if null offset is enabled, then the CALC2 readings will include the null offset value. See *Null Feed Reading*.

At least one of the limit tests have to be enabled to a acquire limit test readings. See *Configure and control limit tests*; :STATe.

NOTE *See Appendix C for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the type of readings that are acquired by the various commands to read data.*

:LATest?

:CALCulate2:DATA:LATest? — Read latest CALC2 data

Description This command works exactly like CALC2:DATA, except it returns only the latest null offset or limit result.

Configure and control limit tests

:COMPliance:FAIL <name>

:CALCulate2:LIMit[1]:COMPliance:FAIL <name>

Parameters

<name> =	IN	Fail Limit 1 test when unit goes into compliance
	OUT	Fail Limit 1 test when unit comes out of compliance

Query

:FAIL?	Query when Limit 1 test failure occurs

Description

This command is used to specify the condition that will cause Limit 1 test to fail. With IN specified, the test will fail when the SourceMeter goes into compliance. With OUT specified, the test will fail when the SourceMeter comes out of compliance.

[:DATA] <n>

:CALCulate2:LIMitx:LOWer[:DATA] <n>	Specify lower LIMIT x (x = 2, 3, 5-12)
:CALCulate2:LIMitx:UPPer[:DATA] <n>	Specify upper LIMIT x (x = 2, 3, 5-12)

Parameters

<n> =	-9.999999e20 to 9.999999e20	Specify limit value
	DEFault	Set specified lower limit to -1 Set specified upper limit to 1
	MINimum	Set specified limit to -9.999999e20
	MAXimum	Set specified limit to +9.999999e20

Query

:UPPer?	Query specified upper limit
:UPPer? DEFault	Query *RST default upper limit
:UPPer? MINimum	Query lowest allowable upper limit
:UPPer? MAXimum	Query largest allowable upper limit
:LOWer?	Query specified lower limit
:LOWer? DEFault	Query *RST default lower limit
:LOWer? MINimum	Query lowest allowable lower limit
:LOWer? MAXimum	Query largest allowable lower limit

Description

These commands are used to set the upper and lower limits for LIMIT 2, LIMIT 3, and LIMIT 5 through LIMIT 12 tests. The actual limit depends on which measurement function is currently selected. For example, a limit value of 1µ is 1µA for the amps function and 1µV for the v olts function. A limit value is not range sensitive. A limit of 2 for volts is 2V on all measurement ranges.

:SOURce2 <NRf> |<NDN>

:CALCulate2:LIMit[1]:COMPliance:SOURce2 <NRf> |<NDN> Specify pattern; LIMIT 1 failure
:CALCulate2:LIMitx:LOWer:SOURce2 <NRf>|<NDN> Specify pattern for grading mode; lower LIMIT x failure (x = 2, 3, 5-12)
:CALCulate2:LIMitx:UPPer:SOURce2 <NRf>|<NDN> Specify pattern for grading mode; upper LIMIT x failure (x = 2, 3, 5-12)

Parameters

<NRf> =	0 to 7 (3-bit)	Decimal value
	0 to 15 (4-bit)	Decimal value
<NDN> =	0 to #b111 (3-bit)	Binary value
	0 to #b1111 (4-bit)	Binary value
	0 to #q7 (3-bit)	Octal value
	0 to #q17 (4-bit)	Octal value
	0 to #h7 (3-bit)	Hexadecimal value
	0 to #hF (4-bit)	Hexadecimal value

Query :SOURce2? Query source value for specified limit

Description These commands are used to define the digital output "fail" patterns for the specified tests (0 to 7, 3-bit; 0 to 15, 4-bit). Note that the "fail" patterns for Limits 2, 3, and 5-12 apply only to the grading mode.

Tests are performed in the following order:

1. Limit Test 1
2. Limit Test 2
   A. Lower Limit 2
   B. Upper Limit 2
3. Limit Test x, where x = 3, 5-12 in ascending numerical order.
   A. Lower Limit x
   B. Upper Limit x

The first failure in the test sequence determines the bit pattern for the digital output port. Subsequent failures in the test sequence will not change the defined digital output pattern. Note that the output value can be specified as a binary, octal, decimal, or hexadecimal value.

NOTE *16-bit I/O is available with the 2499-DIGIO option. The maximum 16-bit output value is 65535.*

Use the following table to determine the parameter value for the desired decimal digital output pattern. For non-decimal parameters, convert the decimal value to its binary, octal, or hexadecimal equivalent.

OUT 4*	OUT 3	OUT 2	OUT 1	Decimal value*
L	L	L	L	0
L	L	L	H	1
L	L	H	L	2
L	L	H	H	3
L	H	L	L	4
L	H	L	H	5
L	H	H	L	6
L	H	H	H	7
H	L	L	L	8
H	L	L	H	9
H	L	H	L	10
H	L	H	H	11
H	H	L	L	12
H	H	L	H	13
H	H	H	L	14
H	H	H	H	15

L = Low (Gnd)
H = High (>+3V)
*OUT 4 not used in 3-bit mode (values = 0 to 7)

The SourceMeter can be configured to place the defined "fail" bit pattern on the digital output immediately when a "fail" condition occurs, or it can wait until all testing on a device package is completed (operation leaves trigger layer). See *Composite testing*; :BCONtrol for details.

PASS:SOURce2 <NRf> | NDN

:CALCulate2:LIMitx:PASS:SOURce2 <NRf> | <NDN> — Set sorting mode "pass" pattern (x = 2, 3, 5-12)

Parameters

<NRf> =	0 to 7 (3-bit)	Decimal value
	0 to 15 (4-bit)	Decimal value
<NDN> =	0 to #b111 (3-bit)	Binary value
	0 to #b1111 (4-bit)	Binary value
	0 to #q7 (3-bit)	Octal value
	0 to #q17 (4-bit)	Octal value
	0 to #h7 (3-bit)	Hexadecimal value
	0 to #hF (4-bit)	Hexadecimal value

Query :SOURce2? Query programmed source value

Description This command is used to define the 3-bit or 4-bit output pattern for the Digital I/O Port when a test (limit 2, 3, 5-12) for the sorting mode passes. Note that the output value can be specified in binary, octal, decimal, or hexadecimal format. Use the table provided in *:SOURce2<NRf> | <NDN>, Description* to determine the parameter value for the desired decimal digital output pattern.

NOTE *16-bit I/O is available with the 2499-DIGIO option. The maximum 16-bit output value is 65535.*

:STATe <b>

:CALCulate2:LIMit[1]:STATe <b> Control LIMIT 1 test
:CALCulate2:LIMitx:STATe <b> Control LIMIT x test (x = 2, 3, 5-12)

Parameters <b> = 1 or ON Enable specified limit test
0 or OFF Disable specified limit test

Query :STATe? Query state of specified limit test

Description These commands are used to enable or disable LIMIT 1, LIMIT 2, LIMIT 3, and LIMIT 5 to LIMIT 12 tests. Any limit test not enabled is simply not performed.

When a limit test is enabled, the Digital I/O port comes under control of limit tests. That is, the result of the testing process updates the output pattern on the I/O port.

:FAIL?

:CALCulate2:LIMit[1]:FAIL? Read LIMIT 1 test result
:CALCulate2:LIMitx:FAIL? Read LIMIT x test result (x = 2, 3, 5-12)

Description These commands are used to read the results of LIMIT 1, LIMIT 2, LIMIT 3, and LIMIT 5 to LIMIT 12 tests:

0 = Limit test passed
1 = Limit test failed

The response message (0 or 1) only tells you if a limit test has passed or failed. For Limit 2, Limit 3, and Limit 5-12, it does not tell you which limit (upper or lower) has failed. To determine which limit has failed, you will have to read the Measurement Event Register. See *STATus subsystem*.

Reading the results of a limit test does not clear the fail indication of the test. A failure can be cleared by using a :CLEar command.

Composite testing

PASS:SOURce2 <NRf> | NDN

:CALCulate2:CLIMits:PASS:SOURce2 <NRf> | <NDN> Specify composite "pass" pattern

Parameters

<NRf> =	0 to 7 (3-bit)	Decimal value
	0 to 15 (4-bit)	Decimal value
<NDN> =	0 to #b111 (3-bit)	Binary value
	0 to #b1111 (4-bit)	Binary value
	0 to #q7 (3-bit)	Octal value
	0 to #q17 (4-bit)	Octal value
	0 to #h7 (3-bit)	Hexadecimal value
	0 to #hF (4-bit)	Hexadecimal value

Query :SOURce2? Query programmed source value

Description This command is used to define the 3-bit or 4-bit output pattern for the Digital I/O Port when there are no failures. Note that the output value can be specified in binary, octal, decimal, or hexadecimal format. Use the table provided in *:SOURce2<NRf> | <NDN>, Description* to determine the parameter value for the desired decimal digital output pattern.

The SourceMeter can be configured to place the defined "pass" bit pattern on the digital output immediately when the "pass" condition occurs, or it can wait until all testing on a device package is completed (operation leaves trigger layer). See :BCONtrol for details.

For the sorting mode, this command defines the 3-bit or 4-bit output "pass" pattern for the Limit 1 test (compliance) when Limits 2, 3, and 5-12 are disabled.

NOTE *16-bit I/O is available with the 2499-DIGIO option. The maximum 16-bit output value is 65535.*

FAIL:SOURce2 <NRf> | <NDN>

:CALCulate2:CLIMits:FAIL:SOURce2 <NRf> | <NDN> Specify "fail" pattern

Parameters

<NRf> =	0 to 7 (3-bit)	Decimal value
	0 to 15 (4-bit)	Decimal value
<NDN> =	0 to #b111 (3-bit)	Binary value
	0 to #b1111 (4-bit)	Binary value
	0 to #q7 (3-bit)	Octal value
	0 to #q17 (4-bit)	Octal value
	0 to #h7 (3-bit)	Hexadecimal value
	0 to #hF (4-bit)	Hexadecimal value

Query :SOURce2? Query programmed source value

Description For the sorting mode, this command is used to define the 3-bit or 4-bit output pattern for the Digital I/O Port when there are failures. Note that the output value can be specified using binary, octal, decimal, or hexadecimal format. Use the table provided in *:SOURce2<NRf> | <NDN>, Description* to determine the decimal parameter value for the desired digital output pattern.

FAIL:SMLocation <NRf> | NEXT
PASS:SMLocation <NRf> | NEXT

:CALCulate2:CLIMits:FAIL:SMLocation <NRf> | Next — Specify "fail" source memory location
:CALCulate2:CLIMits:PASS:SMLocation <NRf> | Next — Specify "pass" source memory location

Parameters

<NRf> = 1 to 100		Specify memory location point
NEXT		Next memory location point in list (present location + 1)

Query :SMLocation? — Query "pass" or "fail" source memory location

Description

While using a Source Memory Sweep when performing limit tests, the sweep can branch to a specified memory location point or proceed to the next memory location in the list.

When a memory location is specified with PASS, the sweep will branch to that memory location if the test is successful (PASS condition). If not successful (FAIL condition), the sweep proceeds to the next memory location in the list. With NEXT selected (the default), the sweep proceeds to the next memory location (present location + 1) in the list regardless of the outcome of the test (PASS or FAIL condition).

When a memory location is specified with FAIL, the sweep will branch to that location on a failure. If not (PASS condition), the sweep proceeds to the next memory location in the list. With NEXT selected (the default), the sweep proceeds to the next memory location (present location + 1) in the list regardless of the outcome of the test (FAIL or PASS condition). Note that branch on FAIL is available only via remote.

See Section 9, *Source memory sweep* for more information.

:BCONtrol <name>

:CALCulate2:CLIMits:BCONtrol <name> — Control Digital I/O port pass/fail update

Parameters

<name> =	IMMediate	Update output when first failure occurs
	END	Update output after sweep is completed

Query :BCONtrol? — Query when digital output will update

Description

This command is used to control when the digital output will update to the "pass" or "fail" bit pattern. The "pass" or "fail" bit pattern tells the handler to stop the testing process and place the DUT in the appropriate bin.

With IMMediate selected, the digital output will update immediately to the bit pattern for the first failure in the testing process. If all the tests pass, the output will update to the "pass" bit pattern.

With END selected, the digital output will not update to the "pass" or "fail" bit pattern until the SourceMeter completes the sweep or list operation. This allows multiple test cycles to be performed on DUT. With the use of a scanner card, multi-element devices (i.e. resistor network) can be tested. If, for example, you didn't use END and the first element in the device package passed, the "pass" bit pattern will be output. The testing process will stop and the DUT will be binned. As a consequence, the other elements in the device package are not tested.

:MODE <name>

:CALCulate2:CLIMits:MODE <name> — Control Digital I/O port pass/fail output

Parameters <name> = GRADing — Output graded "pass/fail" pattern
SORTing — Output sorted "pass/fail" pattern

Query :MODE? — Query Digital I/O pass/fail mode

Description This command controls how limit calculations drive the Digital I/O lines. In GRADing mode, a reading passes if it is within all of the hi/low limit tolerances enabled, assuming that it has passed LIMIT 1 compliance test first. The Digital I/O lines will be driven with the first pattern of the first compliance, hi, or low failure. Otherwise, the CALC2:CLIM:PASS:SOUR2 pattern will be output.

In SORTing mode, a reading will fail if it fails the compliance test, or is not within any of the Digital I/O Bands. If the tests pass and only LIMIT 1 is enabled, the CALC2:CLIM:PASS:SOUR2 pattern will be output. Otherwise, the first limit test band that passes will output its LOW:SOUR2 pattern (UPP:SOUR2 patterns will be ignored). If LIMIT1 fails, its SOUR2 pattern will be output. If no LIMIT2, 3, 5-12 limit passes, the CALC2:CLIM:FAIL:SOUR2 pattern will be output.

Clear test results

[:IMMediate]

:CALCulate2:CLIMits:CLEar[:IMMediate] — Clears test results and resets Digital I/O Port

Description This command clears the test results (pass or fail) of the limit tests and resets the output lines of the Digital I/O port back to the :SOURce2:TTL settings. See *SOURce2*.

:AUTO <b>

:CALCulate2:CLIMits:CLEar:AUTO <b> — Control auto-clear for test results

Parameters <b> = 1 or ON — Enable auto-clear
0 or OFF — Disable auto-clear

Query :AUTO? — Query state of auto-clear

Description With auto-clear enabled, test results will clear and the output lines of the Digital I/O port will reset when the :INITiate command is sent to start a new test sequence.

When disabled, you must use :IMMediate to perform the clear actions.

CALCulate3

Provides statistical data on buffer readings

Select statistic

:FORMat <name>

:CALCulate3:FORMat <name> — Specify CALC3 format

Parameters <name> =

MEAN	Mean value of readings in buffer
SDEViation	Standard deviation of readings in buffer
MAXimum	Largest reading in buffer
MINimum	Lowest reading in buffer
PKPK	MAXimum - MINimum

Query :FORMat? — Query programmed math format

Description This command is used to select the desired statistic on readings stored in the buffer. See Section 8 for details on these statistics.

Readings stored in the buffer can be "raw" measured readings, the results of the CALC1 calculation, or CALC2 readings. The :TRACe:FEED command in the :TRACe Subsystem is used to select the type of readings to store.

Acquire statistic

:DATA?

:CALCulate3:DATA? — Read CALC3 result

Description This query command is used to perform the selected statistic operation and read the result(s). The result(s) is always returned in ASCII format.

If the buffer is configured to store "raw" measured readings (:TRACe:FEED SENSe1) and multiple functions were measured, the selected statistic operation will be performed on all the measured readings. For example, if voltage and current measurements were stored in the buffer, then the selected statistic operation will be performed on both readings. Statistics for multiple measurement functions are returned in the following order:

voltage statistic, current statistic, resistance statistic

Statistic operations are not performed on TIME and STATus data elements that are stored in the buffer.

If the buffer is configured to store the result of CALC1 or CALC2 (:TRACe:FEED CALC1 or CALC2), only one result will be returned by this query command.

Notes:

1. If there is no data in the buffer, the NAN (not a number) value +9.91e37 will be returned.

2. If there are a lot of readings stored in the buffer, some statistic operations may take too long and cause a bus time-out error. To avoid this, send the :calc3:data? command and then wait for the MAV (message available) bit in the Status Byte Register to set before addressing the SourceMeter to talk. See Section 14.
3. See Appendix C for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the types of readings that are acquired by the various commands to read data.

:DISPlay subsystem

The display subsystem controls the display of the SourceMeter and is summarized in Table 17-2.

Control display

:DIGits <n>

:DISPlay:DIGits <n> — Set display resolution

Parameters

<n> =	4	3.5 digit resolution
	5	4.5 digit resolution
	6	5.5 digit resolution
	7	6.5 digit resolution
	DEFault	5.5 digit resolution
	MINimum	3.5 digit resolution
	MAXimum	6.5 digit resolution

Query

:DIGits?	Query display resolution
:DIGits? DEFault	Query *RST default resolution
:DIGits? MINimum	Query lowest allowable display resolution
:DIGits? MAXimum	Query largest allowable display resolution

Description This command is used to set the display resolution. Note that you can instead use rational numbers. For example, to select 4.5 digit resolution, you can send a parameter value of 4.5 (instead of 5). The SourceMeter rounds the rational number to an integer.

:ENABle <b>

:DISPlay:ENABle <b> Control display circuitry

Parameters <b> = 0 or OFF Disable display circuitry
1 or ON Enable display circuitry

Query :ENABle? Query state of display

Description 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 frozen with the following message:

FRONT PANEL DISABLED
Press LOCAL to resume.

As reported by the message, all front panel controls (except LOCAL and OUTPUT OFF) are disabled. Normal display operation can be resumed by using the :ENABle command to enable the display or by putting the SourceMeter into local.

:ATTRibutes?

:DISPlay[:WINDow[1]]:ATTRibutes? Query attributes; top display
:DISPlay:WINDow2:ATTRibutes? Query attributes; bottom display

Description This query command is used to determine which characters on the display are blinking and which are not. The response message provides that status of each character position for the specified display. The primary display consists of 20 characters and the secondary display consists of 32 characters.

1 = Character is blinking
0 = Character is not blinking

For example, assume the following menu is displayed with the SAVESETUP option blinking:

MAIN MENU
SAVESETUP COMMUNICATION CAL >

The response message for :disp:attr? (top display) will result in 20 zeroes as follows:

00000000000000000000

The response message for :disp:wind2:attr? (bottom display) will display ones at the character positions for SAVESETUP as follows:

11111111100000000000000000000000

:CNDisplay

:DISPlay:CNDisplay Return to source-measure display state

Description This action command is used to return the instrument to the source-measure display state (source, measure, and compliance readings displayed). For example, if a menu structure is presently being displayed, this command will exit the menu and return to the source-measure display state.

Read display

:DATA?

:DISPlay[:WINDow[1]]:DATA?	Read top display
:DISPlay:WINDow2:DATA?	Read bottom display

Description These query commands are used to read what is currently being displayed on the top and bottom displays. After sending one of these commands and addressing the SourceMeter to talk, the displayed data (message or reading) will be sent to the computer.

Define :TEXT messages

:DATA <a>

:DISPlay[:WINDow[1]]:TEXT:DATA <a>	Define message; top display
:DISPlay:WINDow2:TEXT:DATA <a>	Define message; bottom display

Parameters

<a> = ASCII characters for message

Types:	String	'aa...a' or "aa...a"
	Indefinite Block	#0aa...a
	Definite Block	#XYaa...a
where	Y = number of characters in message:	
	Up to 20 for top display	
	Up to 32 for bottom display	
	X = number of digits that make up Y (1 or 2)	

Query :DATA? Query the defined text message

Description These commands define text messages for the display. A message can be as long as 20 characters for the top display, and up to 32 characters for the bottom display. A space is counted as a character. Excess message characters result in an error.

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.

:STATe <b>

:DISPlay[:WINDow[1]]:TEXT:STATe <b> Control message; top display
:DISPlay:WINDow2:TEXT:STATe <b> Control message; bottom display

Parameters <b> = 0 or OFF Disable text message for specified display
1 or ON Enable text message for specified display

Query :STATe? Query state of message mode for specified display

Description These commands enable and disable the text message modes. When enabled, a defined message is displayed. When disabled, the message is removed from the display.

GPIB Operation — A user defined 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 LOCAL 27) cancels the message and disables the text message mode.

RS-232 Operation — A user defined test message can be cancelled by sending the :SYSTem:LOCal command or pressing the LOCAL key.

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 17-3.

Data format

[:DATA] <type>[,length]

:FORMat[:DATA] <type>[,<length>] Select data format

Parameters <type>[,<length>] = ASCii ASCII format
REAL,32 IEEE754 single precision format
SREal IEEE754 single precision format

NOTE *<length> is not used for the ASCii or SREal parameters. It is optional for the REAL parameter. If you do not use <length> with the REAL parameter, the <length> defaults to 32 (single precision format).*

Query [:DATA]? Query data format

Description This command is used to select the data format for transferring readings over the bus. Only the ASCII format is allowed over the RS-232 interface. This command only affects the output of READ?, FETCh?, MEASure?, TRACe:DATA?, CALC1:DATA? and CALC2:DATA? over the GPIB. All other queries are returned in the ASCII format.

NOTE *Regardless of which data format for output strings is selected, the SourceMeter will only respond to input commands using the ASCII format.*

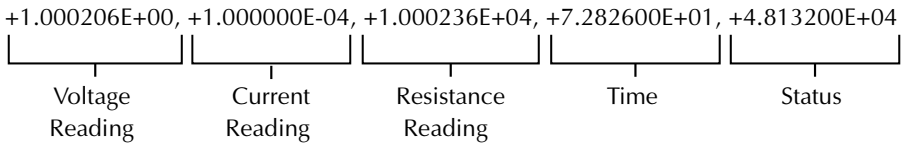
ASCII format

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. Figure 17-1 shows an example ASCII string that includes all the data elements. See :ELEMents.

Figure 17-1 also shows the byte order of the data string. Data elements not specified by the :ELEMents command are simply not included in the string.

Keep in mind that the byte order can only be reversed for the binary format. See :BORDer.

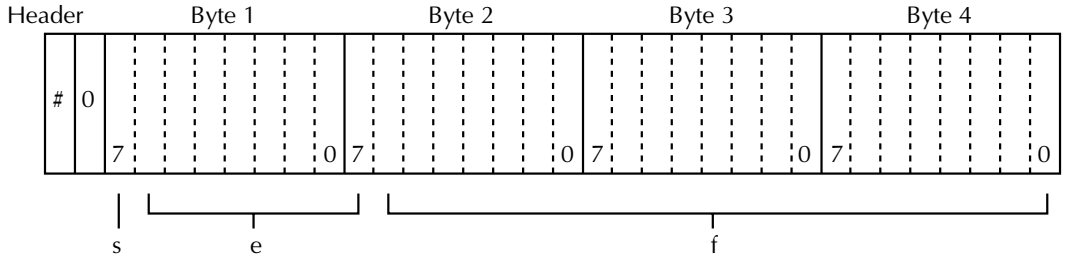
Figure 17-1 *ASCII data format*



IEEE-754 single precision format

REAL,32, or SREal will select the binary IEEE-754 single precision data format. Figure 17-2 shows the normal byte order format for each data element. For example, if three valid elements are specified, the data string for each reading conversion is made up of three 4-byte data blocks. 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. Figure 17-2 does not show the byte for the terminator that is attached to the end of each data string.

Figure 17-2 *IEEE-754 single precision data format (32 data bits)*



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 and terminator are sent only once for each READ?

During binary transfers, never un-talk the SourceMeter 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

where 2 is the number of bytes for the header (#0).
Rdgs is the product of the number of selected data elements, arm count, and trigger count.
4 is the number of bytes for each reading.
is the byte for the terminator.

For example, assume the SourceMeter is configured to perform 10 source-measure operations and send the 10 current measurements to the computer using the binary format.

Bytes = 2 + (10 × 4) + 1
= 43

Data elements

:ELEMents <item list>

:FORMat:ELEMents [SENSe[1]] <item list> Specify data elements for data string

Parameters

<item list> =	VOLTage	Includes voltage reading
	CURRent	Includes current reading
	RESistance	Includes resistance reading
	TIME	Includes timestamp
	STATus	Includes status information

NOTE *Each item in the list must be separated by a comma (i.e., :ELEMents, VOLTage, CURRent, RESistance).*

Query :ELEMents? Query elements in data string

Description This command is used to specify the elements to be included in the data string in response to the following queries:

:FETCh?
:READ?
:MEASure?
:TRACe:DATA?

You can specify from one to all five elements. Each element in the list must be separated by a comma (,). These elements (shown in Figure 17-1) are explained as follows:

NOTE *An overflow reading reads as +9.9E37.*

VOLTage — This element provides the voltage measurement or the programmed voltage source reading. If sourcing voltage and measuring voltage, this element will provide the voltage measurement (measure reading takes priority over source reading). If voltage is not sourced or measured, the NAN (not a number) value of +9.91e37 is used.

CURRent — This element provides the current measurement or the programmed current source reading. If sourcing current and measuring current, this element will provide the current measurement (measure reading takes priority over source reading). If current is not sourced or measured, the NAN (not a number) value of +9.91e37 is used.

RESistance — This element provides the resistance measurement. If resistance is not measured, the NAN (not a number) value of +9.91e37 is used.

TIME — A timestamp is available to reference each group of readings to a point in time. The relative timestamp operates as a timer that starts at zero seconds when the instrument is turned on or when the relative timestamp is reset (:SYSTem:TIME:RESet). The timestamp for each reading sent over the bus is referenced, in seconds, to the start time. After 99,999.999 seconds, the timer resets back to zero and starts over.

Timestamp is also available for buffer readings. Timestamp can be referenced to the first reading stored in the buffer (absolute format) which is timestamped at 0 seconds, or can provide the time between each reading (delta format). The :TRACe:TSTamp:FORMat command is used to select the absolute or delta format.

NOTE *Timestamp values are approximate. See Section 8 for details.*

STATus — A status word is available to provide status information concerning SourceMeter operation. The 24-bit status word is sent in a decimal form and has to be converted by the user to the binary equivalent to determine the state of each bit in the word. For example, if the status value is 65, the binary equivalent is 0000000000001000001. Bits 0 and 6 are set.

The significance of each status bit is explained as follows:

Bit 0 (OFLO) — Set to 1 if measurement was made while in over-range.
Bit 1 (Filter) — Set to 1 if measurement was made with the filter enabled.
Bit 2 — Not used.
Bit 3 (Compliance) — Set to 1 if in “real” compliance.
Bit 4 (OVP) — Set to 1 if the over voltage protection limit was reached.
Bit 5 (Math) — Set to 1 if math expression (calc1) is enabled.
Bit 6 (Null) — Set to 1 if Null is enabled.
Bit 7 (Limits) — Set to 1 if a limit test (calc2) is enabled.
Bits 8 and 9 (Limit Results) — Provides limit test results. See grading and sorting modes in the following paragraph, *Limit test bits*.
Bit 10 (Auto-ohms) — Set to 1 if auto-ohms enabled.
Bit 11 (V-Meas) — Set to 1 if V-Measure is enabled.
Bit 12 (I-Meas) — Set to 1 if I-Measure is enabled.

Bit 13 (Ω-Meas) — Set to 1 if Ω-Measure is enabled.
Bit 14 (V-Sour) — Set to 1 if V-Source used.
Bit 15 (I-Sour) — Set to 1 if I-Source used.
Bit 16 (Range Compliance) — Set to 1 if in "range" compliance.
Bit 17 (Offset Compensation) — Set to 1 if Offset Compensated Ohms is enabled.
Bit 18 — Not used.
Bits 19, 20 and 21 (Limit Results) — Provides limit test results. See grading and sorting modes in the following paragraph, *Limit test bits*.
Bit 22 — Not used.
Bit 23 — Not used.

Limit test bits Bits 8, 9, and 19-21 flag pass/fail conditions for the various limits tests. The bit values for the grading and sorting modes are covered below. See :CALC2:CLIM:MODE and associated commands in *Calculate subsystems*.

Sorting mode status bit values:

Result **Bit #:**	**21**	**20**	**19**	**9**	**8**	**Meas. Event Status[1]**
Limit 1 pass and 2, 3, and 5-12 disabled	0	0	0	0	0	Bit 5 (LP)
Limit test 1 fail	0	0	0	0	1	Bit 0 (L1)
Limit test 2 pass	0	0	0	1	0	Bit 5 (LP)
Limit test 3 pass	0	0	0	1	1	Bit 4 (HL3)
Limit test 5 pass	0	0	1	0	0	Bit 5 (LP)
Limit test 6 pass	0	0	1	1	0	Bit 5 (LP)
Limit test 7 pass	0	0	1	1	1	Bit 5 (LP)
Limit test 8 pass	0	1	0	0	0	Bit 5 (LP)
Limit test 9 pass	0	1	0	0	0	Bit 5 (LP)
Limit test 10 pass	0	1	0	1	0	Bit 5 (LP)
Limit test 11 pass	0	1	0	1	1	Bit 5 (LP)
Limit test 12 pass	0	1	1	0	0	Bit 5 (LP)
Limit 1 pass and 2, 3, and 5-12 fail	1	1	1	1	1	-

[1]See Section 14, *Measurement Event Register* and Figure 14-6 for details.

Grading mode status bit values:

Result Bit #:	21	20	19	9	8	Meas. Event Status[1]
All limits pass	0	0	0	0	0	Bit 5 (LP)
Limit test 1 fail	0	0	0	0	1	Bit 0 (L1)
Hi Limit test 2 fail	1	0	0	1	0	Bit 2 (HL2)
Lo Limit test 2 fail	0	0	0	1	0	Bit 1 (LL2)
Hi Limit test 3 fail	1	0	0	1	1	Bit 4 (HL3)
Lo Limit test 3 fail	0	0	0	1	1	Bit 3 (LL3)
Hi Limit test 5 fail	1	0	1	0	0	-
Lo Limit test 5 fail	0	0	1	0	0	-
Hi Limit test 6 fail	1	0	1	1	0	-
Lo Limit test 6 fail	0	0	1	1	0	-
Hi Limit test 7 fail	1	0	1	1	1	-
Lo Limit test 7 fail	0	0	1	1	1	-
Hi Limit test 8 fail	1	1	0	0	0	-
Lo Limit test 8 fail	0	1	0	0	0	-
Hi Limit test 9 fail	1	1	0	0	1	-
Lo Limit test 9 fail	0	1	0	0	1	-
Hi Limit test 10 fail	1	1	0	1	0	-
Lo Limit test 10 fail	0	1	0	1	0	-
Hi Limit test 11 fail	1	1	0	1	1	-
Lo Limit test 11 fail	0	1	0	1	1	-
Hi Limit test 12 fail	1	1	1	0	0	-
Lo Limit test 12 fail	0	1	1	0	0	-

[1]See Section 14, *Measurement Event Register* and Figure 14-6 for details.

Example reading string

The example ASCII reading string shown in Figure 17-1 shows a measurement of a 10kΩ resistor, with the SourceMeter configured to Source I Measure V. The voltage reading is the voltage measurement (1.000236V), the current reading is the current source value (100Ω), and the operation was performed 72.826 seconds after the SourceMeter was turned on (or after timestamp was reset). The status reading of 48,132 indicates that bits 2, 10, 11, 12, 13, and 15 of the status word are set.

:SOURce2 <name>

:FORMat:SOURce2 <name> Set SOUR2 and TTL response formats

Parameters <name> =

ASCii	ASCII format
HEXadecimal	Hexadecimal format
OCTal	Octal format
BINary	Binary format

Query :SOURce2? Query response format

Description This command controls the response format for all CALC2:XXXX:SOUR2 and SOUR2:TTL queries in a manner similar to formats set by the FORM:SREG command. See *Calculate subsystems* and *SOURce subsystem* topics for details.

CALC data elements

:CALCulate <item list>

:FORMat:ELEMents:CALCulate <item list> Set CALC data elements

Parameters <item list> =

CALC	Include CALC1 or CALC2 data
TIME	Include timestamp
STATus	Include status information

NOTE *Each item in the list must be separated by a comma (for example, :CALCulate CALC,TIME,STAT).*

Query :CALCulate? Query CALC data element list

Description This command allows you to retrieve timestamp and status information with the CALC1:DATA? And CALC2:DATA? queries. It also allows you to retrieve timestamp and status information from the buffer when TRACe:FEED is set to CALC1 or CALC2. See *Calculate subsystems* for a complete description of CALC1 and CALC2. See also *Data elements* for a description of TIME and STATus information.

Byte order

:BORDer <name>

:FORMat:BORDer <name> — Specify binary byte order

Parameters <name> =

NORMal	Normal byte order for binary formats
SWAPped	Reverse byte order for binary formats

Query :BORDer? — Query byte order

Description 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)

For reverse byte order, the data format for each element is sent as follows:

Byte 4 Byte 3 Byte 2 Byte 1 (Single 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 simply ignored when the ASCII format is selected.

NOTE *The SWAPped byte order must be used when transmitting binary data to any IBM PC compatible computer.*

Status register format

:SREGister <name>

:FORMat:SREGister <name> — Set data format for reading status registers

Parameters <name> =

ASCii	Decimal format
Hexadecimal	Hexadecimal format
OCTal	Octal format
BINary	Binary format

Query :SREGister? — Query format for reading status registers

Description Query commands are used to read the contents of the status event registers. This command is used to set the response message format for those query commands.

When a status register is queried, the response message is a value that indicates which bits in the register are set. For example, if bits B5, B4, B2, B1, and B0 of a register are set (110111), the following values will be returned for the selected data format:

ASCii	55	(decimal value)
Hexadecimal	#H37	(hexadecimal value)
OCTal	#Q67	(octal value)
BINary	#B110111	(binary value)

See Section 15 and *STATus subsystem* in this section for more information.

OUTPut subsystem

This subsystem is used to control the output of the selected source, and the interlock. These commands are summarized in Table 17-4.

Turn source on or off

[:STATe] <b>

:OUTPut[1][:STATe] <b> — Turn source on or off

Parameters <b> = 0 or OFF — Turn source off (standby)
1 or ON — Turn source on (operate)

Query :OUTPut? — Query state of source

Description This command is used to turn the source output on or off. Measurements cannot be made while the source is off.

Turning the source off places the SourceMeter in the idle state. The only exception to this is when source auto clear is enabled. In this mode, the source turns on during each source phase of the SDM cycle and then turns off after each measurement. See :SOURce[1]:CLEar:AUTO in *SOURce subsystem*.

NOTE *The :SOURce:CLEar command will also turn the source off.*

Interlock control

:STATe <b>
:OUTPut[1]:INTerlock:STATe <b> — Control hardware interlock

Parameters <b> = 0 or OFF — Disable interlock
1 or ON — Enable interlock

Query :STATe? — Query state of interlock

Description This command is used to enable or disable the hardware interlock. When enabled, the source cannot be turned on unless the interlock line (pin 8 of the rear panel Interlock - Digital I/O connector) is pulled to a logic low state. When the interlock line goes to a logic high state, the source turns off. See Section 12, *Digital I/O port* and *Safety interlock* for details using interlock with a test fixture.

When disabled, the logic level on the interlock line has no effect on the output state of the source.

:TRIPped?

:OUTPut[1]:INTerlock:TRIPped?

Description This query command is used to determine if the enabled interlock has been tripped. The tripped condition ("1") means that the source can be turned on (interlock line at logic low level).

A "0" will be returned if the source cannot be turned on (interlock line at logic high level).

Output-off states

:SMODe

:OUTPut[1]:SMODe <name> Select output-off mode

Parameters	<name> =	NORMal	Normal output-off state
		ZERO	Zero output-off state
		GUARd	Guard output-off state

Query :SMODe? Query output off mode

Description This command is used to select the output-off state of the SourceMeter.

With NORMal selected (which is the default), the V-Source is selected and set to 0V when the output is turned off. Compliance is set to 0.5% full scale of the present current range.

In the ZERO output-off state when the V-Source OUTPUT is turned off, the V-Source is set to 0V and current compliance is not changed. When the I-Source OUTPUT is turned off, the V-Source mode is selected and set to 0V. Current compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater.

The ZERO output-off state is typically used with the V-Source and Output Auto-On (see the :SOURce1:CLEar:AUTO command) to generate voltage waveforms that alternate between 0V and the programmed output-on voltage.

With GUARd selected, the I-Source is selected and set to 0A. Voltage compliance is set to 0.5% full scale of the present voltage range. This output-off state should be used when performing 6-wire guarded ohms measurements or for any other load that uses an active source.

NOTE *For more information on output-off states, see Section 12, "Output configuration."*

SENSe1 subsystem

The Sense1 subsystem is used to configure and control the measurement functions of the SourceMeter. Many of the commands are global, where a single command affects all functions. Some commands are unique to a specific function. For example, you can program a unique range setting for each basic function (amps, volts, and ohms).

A function does not have to be selected before you can program its various configurations. Whenever a programmed function is selected, it assumes the programmed states.

The commands for this subsystem are summarized in Table 17-5.

Select measurement functions

:CONCurrent <b>

[:SENSe[1]]:FUNCtion:CONCurrent <b> Control concurrent measurements

Parameters <b> = 0 or OFF Disable concurrent measurements
1 or ON Enable concurrent measurements

Query :CONCurrent? Query state of concurrent measurements

Description This command is used to enable or disable the ability of the instrument to measure more than one function simultaneously. When enabled, the instrument will measure the functions that are selected. See [:ON], :OFF and :ALL.

When disabled, only one measurement function can be enabled. When making the transition from :CONCurrent ON to :CONCurrent OFF, the voltage (VOLT:DC) measurement function will be selected. All other measurement functions will be disabled. Use the :FUNCTion[:ON] command to select one of the other measurement functions.

[:ON] <function list>
:OFF <function list>

[:SENSe[1]]:FUNCtion[:ON] <function list> Specify functions to be enabled
[:SENSe[1]]:FUNCtion:OFF <function list> Specify functions to be disabled

Parameters <function list> = "CURRent[:DC]" Amps measurement function
"VOLTage[:DC]" Volts measurement function
"RESistance" Ohms measurement function

NOTE *Each function in the list must be enclosed in quotes (double or single) and separated by a comma (i.e., :func:on "volt", "curr").*

Query

[:ON]?	Query functions that are enabled
:OFF?	Query functions that are disabled

Description When concurrent measurements are enabled, these commands are used to enable or disable functions to be measured. The [:ON] command is used to include (enable) one or more measurement functions in the list, and the :OFF command is used to remove (disable) one or more functions from the list.

Note that each function specified in the list must be enclosed in single or double quotes, and functions must be separated by commas (,). Examples:

:FUNCtion “VOLTage”, “CURRent”	Enable volts and amps functions
:FUNCtion:OFF ‘VOLTage’, ‘CURRent’	Disable volts and amps functions

Note that there is a stand-alone command that can be used to enable or disable all three measurement functions. See :ALL.

If concurrent measurements (:CONCurrent) are disabled, the :ON command can only turn on one function at a time.

:ALL

[:SENSe[1]]:FUNCtion[:ON]:ALL	Enable all measurement functions
[:SENSe[1]]:FUNCtion:OFF:ALL	Disable all measurement functions

Description This command is used to enable or disable all measurement functions.

When enabled (:ON:ALL), amps, volts, and ohms measurements will be performed simultaneously if concurrent measurements are enabled. See :CONCurrent. If concurrent measurements are disabled, only the ohms function will be enabled.

The :OFF:ALL command disables all measurements.

:COUNt?

[:SENSe[1]]:FUNCtion[:ON]:COUNt?	Query number of functions enabled
[:SENSe[1]]:FUNCtion:OFF:COUNt?	Query number of functions disabled

Description This query command is used to determine the number of functions that are enabled or disabled.

When :ON:COUNt? is sent, the response message will indicate the number of functions that are enabled.

When :OFF:COUNt? is sent, the response message will indicate the number of functions that are disabled.

:STATe? <name>

[:SENSe[1]]:FUNCtion:STATe <name> Query state of specified function

Parameters

<name> =	“CURRent[:DC]”	Amps measurement function
	“VOLTage[:DC]”	Volts measurement function
	“RESistance”	Ohms measurement function

NOTE *The function name must be enclosed in double or single quotes (i.e., :func:stat? "volt").*

Description This command is used to query the state of the specified measurement function. A returned response message of "0" indicates that the specified function is disabled, while a "1" indicates that the function is enabled.

:RESistance:MODE <name>

[:SENSe[1]]:RESistance:MODE <name> Select ohms measurement mode

Parameters <name> = MANual Manual ohms mode
AUTO Auto ohms mode

Query :MODE? Query ohms mode

Description This command is used to select the ohms measurement mode. With MANual ohms selected, the user must configure the source and measure aspects of the operation. When the ohms function is selected, the ohms reading is simply the result of the V/I calculation.

Range changes cannot be made in manual ohms.

With AUTO ohms selected, the SourceMeter will be configured to Source I Measure V when the ohms function is selected. The current source value and voltage measurement range used depend on the ohms measurement range that is selected.

See Section 4 for details on manual and auto ohms.

:RESistance:OCOMpensated <b>

[:SENSe[1]]:RESistance:OCOMpensated <b> Control offset-compensated ohms

Parameters <b> = 1 or ON Enable offset compensation
0 or OFF Disable offset compensation

Query :OCOMpensated? Query state of offset compensation

Description This command is used to enable or disable offset-compensated ohms. When using the auto ohms measurement mode, the current source level is automatically set. When using the manual ohms measurement mode, you must set the source (V or I) output level.

See Section 4, *Offset-compensated ohms* for details on making offset-compensated ohms measurements.

NOTE *Offset-compensated ohms will disable when the :MEASure? command (for the resistance function) or the :CONFigure:RESistance command is sent.*

Select measurement range

Notes:

1. You cannot select a current measurement range if sourcing current. Conversely, you cannot select a voltage measurement range if sourcing voltage. Also, autorange cannot be enabled for those source-measure configurations. The programmed source range determines measurement range.
2. You cannot select an ohms measurement range if in manual ohms (you must be in auto ohms).
3. The highest current measurement range that can be selected is limited by the current compliance range. For example, if current compliance is set for 50mA (100mA range), then the highest available current measurement range is 100mA. Similarly, the highest voltage measurement range is limited by the voltage compliance range.
4. When on the 200V V-Source range, the maximum I-Measure range is 10mA.
5. When on the 100mA I-Source range, the maximum V-Measure range is 20V.

[:UPPer] <n>

[:SENSe[1]]:CURRent[:DC]:RANGe[:UPPer] <n>|UP|DOWN Select range for amps
[:SENSe[1]]:VOLTage[:DC]:RANGe[:UPPer] <n>|UP|DOWN Select range for volts
[:SENSe[1]]:RESistance:RANGe[:UPPer] <n>|UP|DOWN Select range for ohms

Parameters

<n>	=	-105e-3 to 105e-3	Expected reading in amps
		-210 to 210	Expected reading in volts
		0 to 2.1e13	Expected reading in ohms (with PreAmp)
		0 to 2.1e7	Expected reading in ohms (without PreAmp)
		DEFault	1.05e-4 (amps), 21 (volts), 2.1e5 (ohms)
		MINimum	-105e-3 (amps), -210 (volts), 0 (ohms)
		MAXimum	105e-3 (amps), 210 (volts), 2.1e13 (ohms)
		UP	Select next higher measurement range
		DOWN	Select next lower measurement range

Query

:RANGe?	Query measurement range
:RANGe? DEFault	Query *RST default range
:RANGe? MINimum	Query lowest range (returns 0)
:RANGe? MAXimum	Query highest range

Description

This command is used to manually select the measurement range for the specified measurement function. The range is selected by specifying the expected reading. The instrument will then go to the most sensitive reading that will accommodate that reading. For example, if you expect a reading of approximately 50mV, then simply let <n> = 0.05 (or 50e-3) in order to select the 200mV range.

You can also use the UP and DOWN parameters to select range. Each time UP or DOWN is sent, the next higher or lower measurement range is selected. When on the maximum range, sending UP is a No-Op (no operation). When on the lowest range, sending DOWN is a NO-Op.

Measurement ranges can instead be automatically selected by the instrument. See :AUTO.

Select auto range

:AUTO <b>

[:SENSe[1]]:CURRent[:DC]:RANGe:AUTO <b> — Control auto ranging for amps
[:SENSe[1]]:VOLTage[:DC]:RANGe:AUTO <b> — Control auto ranging for volts
[:SENSe[1]]:RESistance:RANGe:AUTO <b> — Control auto ranging for ohms

Parameters <b> =

0 or OFF	Disable auto range
1 or ON	Enable auto range

Query :AUTO? Query state of auto range

Description This command is used to control auto ranging. With auto ranging enabled, the instrument automatically goes to the most sensitive range to perform the measurement.

When this command is used to disable auto range, the instrument remains at the automatically selected range. When a range is manually selected, auto range is disabled. See the previous command.

:LLIMit <n>

[:SENSe[1]]:CURRent[:DC]:RANGe:AUTO:LLIMit <n> — Set auto ranging lower limit for amps
[:SENSe[1]]:VOLTage[:DC]:RANGe:AUTO:LLIMit <n> — Set auto ranging lower limit for volts
[:SENSe[1]]:RESistance:RANGe:AUTO:LLIMit <n> — Set auto ranging lower limit for ohms

Parameters <n> =

-105e-3 to 105e-3	Amps lower limit
-21 to 21	Volts lower limit
0 to 2.1e13	Ohms lower limit with PreAmp
0 to 2.1e7	Ohms lower limit without PreAmp

Query :LLIMit? Query auto range lower limit

Description Auto range lower limits are intended primarily for SYST:RCM MULT support. See :*SYSTem subsystem*. The lower limit for all three functions is programmable and must be less than or equal to the upper limit. If the lower limit is equal to the upper limit, auto ranging is effectively disabled. See below. When autoranging is disabled, you can manually program the unit for any range below the lower limit.

:ULIMit <n>

[:SENSe[1]]:CURRent[:DC]:RANGe:AUTO:ULIMit? — Query auto ranging upper limit for amps
[:SENSe[1]]:VOLTage[:DC]:RANGe:AUTO:ULIMit? — Query auto ranging upper limit for volts
[:SENSe[1]]:RESistance:RANGe:AUTO:ULIMit <n> — Set auto ranging upper limit for ohms

Parameters <n> =

0 to 2.1e13	Ohms upper limit with PreAmp
0 to 2.1e7	Ohms upper limit without PreAmp

Parameters :ULIMit? Query auto range upper limit

Description Auto range upper limits are intended primarily for SYST:RCM MULT support. See :*SYSTem subsystem*. For voltage and current, the upper limit is controlled by the compliance range and, therefore, is available only as a query. When autoranging is disabled, you can manually program the unit for any range above the upper limit (ohms only).

Set compliance limit

[:LEVel] <n>

[:SENSe[1]]:CURRent[:DC]:PROTection[:LEVel] <n> Set current compliance
[:SENSe[1]]:VOLTage[:DC]:PROTection[:LEVel] <n> Set voltage compliance

Parameters

<n> =	-105e-3 to 105e-3	Current compliance limit
	-210 to 210	Voltage compliance limit
	DEFault	105uA, 21V
	MINimum	-105e-3A, -210V
	MAXimum	105e-3A, 210V

Query

:LEVel?	Query compliance value
:LEVel? DEFault	Query *RST default compliance
:LEVel? MINimum	Query minimum allowable compliance
:LEVel? MAXimum	Query maximum allowable compliance

Description This command is used to set compliance limits. A current compliance limit is set for the V-Source, and a voltage compliance limit is set for the I-Source. The SourceMeter cannot source levels that exceed these specified limits.

The :SENSe:CURRent:PROTection[:LIMit] command is used to set the current compliance for the V-Source and the :SENSe:VOLTage:PROTection[:LIMit] command is used to set the voltage compliance for the I-Source.

NOTE *You cannot set compliance less than 0.1% of the present measurement range.*

:TRIPped?

[:SENSe[1]]:CURRent[:DC]:PROTection:TRIPped? Query current compliance state
[:SENSe[1]]:VOLTage[:DC]:PROTection:TRIPped? Query voltage compliance state

Description This command is used to determine if the source is in compliance. If a “1” is returned, then the source is in compliance. A “0” indicates that the source is not in compliance.

The :CURRent:PROTection:TRIPped? command is used to check the compliance state of the V-Source, and the :VOLTage: PROTection:TRIPped? command is used to check the compliance state of the I-Source.

Set measurement speed

:NPLCycles <n>

[:SENSe[1]]:CURRent[:DC]:NPLCycles <n> Set speed (PLC)
[:SENSe[1]]:VOLTage[:DC]:NPLCycles <n> Set speed (PLC)
[:SENSe[1]]:RESistance:NPLCycles <n> Set speed (PLC)

Parameters

<n> =	0.01 to 10	Power-line cycles per integration
	DEFault	10
	MINimum	0.01
	MAXimum	10

Query

:NPLCycles?	Query programmed PLC value
:NPLCycles? DEFault	Query *RST default PLC
:NPLCycles? MINimum	Query minimum PLC
:NPLCycles? MAXimum	Query maximum PLC

Description

This command is used to set the integration period (speed) for measurements. NPLC (Number of Power Line Cycles) expresses the integration period by basing it on the power line frequency. For example, for a PLC of 1, the integration period would be 1/60 (for 60Hz line power) which is 16.67 msec.

Note that this is a global command. Thus, if you set the speed for voltage measurements to 10 PLC, then current and resistance will also set to 10 PLC.

Configure and control filters

NOTE *Detailed information on the repeat, median and moving filters are provided in Section 6,"Filters."*

:AUTO <b>

[:SENSe[1]]:AVERage:AUTO <b> Enable/disable auto filter

Parameters

<b> =	0 or OFF	Disable auto filter
	1 or ON	Enable auto filter

Query

:AUTO?	Query state of auto filter

Description

With auto filter enabled, the instrument automatically selects filter settings for current measurements. Heavy filtering is used for the low current ranges, and less filtering as the current range increases. The auto filter settings are listed in Tables 6-5, 6-6, and 6-7. For voltage measurements, auto filter sets the repeat and moving count to one, and the median rank to zero. These settings effectively disable the three filters.

When auto filter is disabled, the present count and rank settings for the three filters are used for all measurement functions and ranges.

Repeat filter commands

:REPeat:COUNt <n>

[:SENSe[1]]:AVERage:REPeat:COUNt <n> — Set repeat filter count

Parameters

<n> =	1 to 100	Specify repeat filter count
	DEFault	1
	MINimum	1
	MAXimum	100

Query

:COUNt?	Query filter count
:COUNt? DEFault	Query the *RST default filter count
:COUNt? MINimum	Query the lowest allowable filter count
:COUNt? MAXimum	Query the largest allowable filter count

Description This command is used to specify the repeat filter count. In general, the filter count is the number of readings that are acquired and stored in the filter buffer for the averaging calculation. Each aquired group of readings yields a single filtered reading. The larger the filter count, the more filtering that is performed.

:REPeat[:STATe] <b>

[:SENSe[1]]:AVERage:REPeat[:STATe] <b> — Enable/disable repeat filter

Parameters

<b> =	0 or OFF	Disable repeat filter
	1 or ON	Enable repeat filter

Query

[:STATe]?	Query state of repeat filter

Description This command is used to enable or disable the repeat filter. When enabled, voltage, current, and resistance readings are filtered according to how the repeat filter is configured. When disabled, the repeat filter stage is bypassed.

Median filter commands

:MEDian:RANK <NRf>

[:SENSe[1]]:MEDian:RANK <NRf> — Set median filter rank

Parameters

<NRf> =	0 to 5	Specify rank value for median filter
RANK?		Query median filter rank

Description The median filter is used to pass the “middle-most” reading from a group of readings that are arranged according to size. This command is specify the rank, which determines the number of reading samples for the filter process.

The number of reading samples are determined as follows:

Sample readings = 2n + 1

Where; n is the selected rank (0 to 5).

:MEDian[:STATe] <b>

[:SENSe[1]]:MEDian[:STATe] <b> Enable/disable median filter

Parameters <b> = 0 or OFF Disable repeat filter
1 or ON Enable repeat filter

Query [:STATe]? Query state of repeat filter

Description This command is used to enable or disable the median filter. When enabled, voltage, current, and resistance readings are filtered according to the specified rank. When disabled, the median filter stage is bypassed.

Moving filter commands

:AVERage:COUNt <n>

[:SENSe[1]]:AVERage:COUNt <n> Set moving filter count

Parameters <n> = 1 to 100 Specify moving filter count
DEFault 1
MINimum 1
MAXimum 100

Query :COUNt? Query filter count
:COUNt? DEFault Query the *RST default filter count
:COUNt? MINimum Query the lowest allowable filter count
:COUNt? MAXimum Query the largest allowable filter count

Description This command is used to specify the moving filter count. In general, the filter count is the number of readings that are stored in the moving filter buffer for the averaging calculation. After the buffer fills with readings, a new reading goes into the buffer and the oldest reading is discarded. The filter process if performed after each new reading is placed in the buffer.

:AVERage[:STATe] <b>

[:SENSe[1]]:AVERage[:STATe] <b> Enable/disable moving filter

Parameters <b> = 0 or OFF Disable moving filter
1 or ON Enable moving filter

Query [:STATe]? Query state of moving filter

Description This command is used to enable or disable the moving filter. When enabled, voltage, current, and resistance readings are filtered according to how the filter is configured. When disabled, the moving filter stage is bypassed.

:ADVanced:NTOLerance <NRf>

[:SENSe[1]]:AVERage:ADVanced:NTOLerance <NRf> Set moving filter noise filter

Parameters <NRf> = 0 to 105 Specify filter noise filter in %

Query :NTOLerance? Query filter noise filter value

Description When the advanced filter is enabled, using the next command, a noise window is used with the moving filter. This command is used to specify the noise window. If readings are within the noise window, the moving filter operates normally. If, however, a reading falls outside the window, the buffer is flushed of old readings and filled with the new reading.

:ADVanced[:STATe] <b>

[:SENSe[1]]:AVERage:ADVanced[:STATe] <b> Enable/disable advanced filter

Parameters <b> = 0 or OFF Disable advanced filter
1 or ON Enable advanced filter

Query [:STATe]? Query state of advanced filter

Description This command is used to enable or disable the advanced filter. When enabled, the noise window is used with the moving filter. When disabled, the noise window is not used.

SOURce subsystem

This subsystem is used to configure and control the I-Source and V-Source, and to set the logic level (high or low) of each digital output line. The commands for this subsystem are summarized in Table 17-6.

SOURce[1]

Use the following commands to configure and control the I-Source and V-Source. At the end of this subsystem are program examples of sweeps and lists.

Control source output-off

[:IMMediate]

:SOURce[1]:CLEar[:IMMediate] Turn source output off

Description This command is used to turn off the source output. The output will turn off after all programmed source-measure operations are completed and the instrument returns to the idle state.

Note that if auto output-off is enabled, the source output will automatically turn off. See the next command.

:AUTO

:SOURce[1]:CLEar:AUTO <b> Control auto output-off

Parameters <b> = 1 or ON Enable auto output-off
0 or OFF Disable auto output-off

Query :AUTO? Query state of auto output-off

Description This command is used to control auto output-off for the source. With auto output-off enabled, an :INITiate (or :READ? or MEASure?) will start source-measure operation. The output will turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement is completed.

With auto output-off disabled, the source output must be on before an :INITiate or :READ? can be used to start source-measure operation. The :MEASure? command will automatically turn on the source output. Once operation is started, the source output will stay on even after the instrument returns to the idle state. Auto output-off is the *RST and :SYSTem:PRESet default.

WARNING **With auto output-off disabled, the source output will remain on after all programmed source-measure operations are completed. Beware of hazardous voltage that may be present on the output terminals.**

Select function mode

[:MODE] <name>

:SOURce[1]:FUNCtion[:MODE] <name> Select source mode

Parameters <name> = VOLTage Select voltage mode
CURRent Select current mode
MEMory Select memory mode

Query [:MODE]? Query selected source

Description This command is used to select the source mode. With VOLTage selected, the V-Source will be used, and with CURRent selected, the I-Source will be used.

With MEMory selected, a memory sweep can be performed. Operating set-ups (up to 100) saved in memory can be sequentially recalled. This allows multiple source/measure functions to be used in a sweep.

Select sourcing mode

:MODE <name>

:SOURce[1]:CURRent:MODE <name> Select DC sourcing mode for I-Source
:SOURce[1]:VOLTage:MODE <name> Select DC sourcing mode for V-Source

Parameters <name> = FIXed Select fixed sourcing mode
LIST Select list sourcing mode
SWEep Select sweep sourcing mode

Query :MODE? Query DC sourcing mode

Description This command is used to select the DC sourcing mode for the specified source. The three modes are explained as follows:

FIXed — In this DC sourcing mode, the specified source will output a fixed level. Use the :RANGe and :AMPLitude commands to specify the fixed source level. See *Select range* and *Set amplitude for fixed source*.

LIST — In this mode, the source will output levels that are specified in a list. See *Configure list* for commands to define and control the execution of the list.

SWEep — In this mode, the source will perform a voltage, current or memory sweep. See *Configure voltage and current sweeps* and *Configure memory sweep* for commands to define the sweep.

NOTE *The sourcing mode will default to FIXed whenever the SourceMeter goes to the local state.*

Select range

:RANGe <n>

:SOURce[1]:CURRent:RANGe <n> Select range for I-Source
:SOURce[1]:VOLTage:RANGe <n> Select range for V-Source

Parameters

<n> =	-105e-3 to 105e-3	Specify I-Source level (amps)
	-210 to 210	Specify V-Source level (volts)
	DEFault	I-Source: 100µA range V-Source: 20V range
	Minimum	I-Source: 1pA range (Remote PreAmp) 1µA range (Mainframe-only) V-Source: 200mV range
	MAXimum	I-Source: 100mA range V-Source: 200V range
	UP	Select next higher range
	DOWN	Select next lower range

Query

:RANGe?	Query range for specified source
:RANGe? DEFault	Query *RST default source range
:RANGe? MINimum	Query lowest source range
:RANGe? MAXimum	Query highest source range

Description

This command is used to manually select the range for the specified source. Range is selected by specifying the approximate source magnitude that you will be using. The instrument will then go to the lowest range that can accommodate that level. For example, if you expect to source levels around 3V, send the following command:

:SOURce:VOLTage:RANGe 3

The above command will select the 20V range for the V-Source.

As listed in *Parameters*, you can also use the MINimum, MAXimum and DEFault parameters to manually select the source range. The UP parameter selects the next higher source range, while DOWN selects the next lower source range.

Note that source range can be selected automatically by the instrument. See the next command.

:AUTO <b>

:SOURce[1]:CURRent:RANGe:AUTO <b> Select auto range for I-Source
:SOURce[1]:VOLTage:RANGe:AUTO <b> Select auto range for V-Source

Parameters

<b> =	0 or OFF	Disable auto range
	1 or ON	Enable auto range

Query

AUTO? Query state of auto range

Description

This command is used to enable or disable auto range for the specified source. When enabled, the instrument will automatically select the most sensitive range for the specified source level. When disabled, the instrument will use the range that the instrument is currently on.

Auto range will be disabled if a fixed range is selected. See the previous command.

Both *RST and :SYSTem:PREset enables source auto range. When the SourceMeter goes into the local state, source auto range disables.

Set amplitude for fixed source

[:IMMediate][:AMPLitude] <n>

:SOURce[1]:CURRent[:LEVel][:IMMediate][:AMPLitude] <n> Set fixed I-Source amplitude immediately
:SOURce[1]:VOLTage[:LEVel][:IMMediate][:AMPLitude] <n> Set fixed V-Source amplitude immediately

Parameters

<n> =	-105e-3 to 105e-3	Set I-Source amplitude (amps)
	-210 to 210	Set V-Source amplitude (volts)
	DEFault	0A or 0V
	MINimum	-105e-3A or -210V
	MAXimum	+105e-3A or +210V

Query

:CURRent?	Query programmed amplitude of I-Source
:CURRent? DEFault	Query *RST default amplitude
:CURRent? MINimum	Query lowest allowable amplitude
:CURRent? MAXimum	Query highest allowable amplitude
:VOLTage?	Query programmed amplitude of V-Source
:VOLTage? DEFault	Query *RST default amplitude
:VOLTage? MINimum	Query lowest allowable amplitude
:VOLTage? MAXimum	Query highest allowable amplitude

Description

This command is used to immediately update the amplitude of a fixed source. This command is not valid if the list or sweep mode is selected.

NOTE *The sourcing :MODE command is used to select a fixed source. See "Select sourcing mode."*

If a manual source range is presently selected, then the specified amplitude cannot exceed that range. For example, if the V-Source is on the 2V range (auto range disabled), you will not be able to set the V-Source amplitude to 3V. In auto range, the amplitude can be set to any level that is within the capabilities of the source.

The MINimum and MAXimum parameters are only valid if the highest source range is presently selected. Sending the MINimum or MAXimum parameters on a lower source range will generate error -221 (Setting Conflict).

:TRIGgered[:AMPLitude] <n>

:SOURce[1]:CURRent[:LEVel]:TRIGgered[:AMPLitude] <n>	Set fixed I-Source amplitude when triggered
:SOURce[1]:VOLTage[:LEVel]:TRIGgered[:AMPLitude] <n>	Set fixed V-Source amplitude when triggered

Parameters

<n> =	-105e-3 to 105e-3	Set I-Source amplitude (amps)
	-210 to 210	Set V-Source amplitude (volts)
	DEFault	0A or 0V
	MINimum	-105e-3A or -210V
	MAXimum	+105e-3A or +210V

Query

:TRIGgered?	Query triggered amplitude for fixed source
:TRIGgered? DEFault	Query *RST default amplitude
:TRIGgered? MINimum	Query lowest allowable amplitude
:TRIGgered? MAXimum	Query highest allowable amplitude

Description

This command performs the same as the [:IMMediate][:AMPLitude] command except that the amplitude is not updated immediately.

With this command, the amplitude is updated when the SourceMeter is triggered to perform a source-measure operation. For example, if the instrument is waiting in the trigger layer for an external trigger, the amplitude of the source will not update until that external trigger is received by the SourceMeter. See Section 10, *Trigger model* for details on trigger model operation.

The MINimum and MAXimum parameters are only valid if the highest source range is presently selected. Sending the MINimum or MAXimum parameters on a lower source range will generate error -221 (Setting Conflict).

Set voltage limit

[:LEVel] <n>

:SOURce[1]:VOLTage:PROTection[:LEVel] <n> Set voltage limit for V-Source

Parameters

<n> =	-210 to 210	Specify V-Source limit
	20	Set limit to 20V
	40	Set limit to 40V
	60	Set limit to 60V
	80	Set limit to 80V
	100	Set limit to 100V
	120	Set limit to 120V
	160	Set limit to 160V
	161 to 210	Set limit to NONE
	NONE	Set limit to 210V
	DEFault	Set limit to 210V (NONE)
	MINimum	Set limit to 20V
	MAXimum	Set limit to 210V (NONE)

Query

[:LIMit]?	Query limit level
[:LIMit]? DEFault	Query *RST default limit
[:LIMit]? MINimum	Query lowest allowable limit
[:LIMit]? MAXimum	Query highest allowable limit

Description

This command is used to set the Over Voltage Protection (OVP) limit for the V-Source. The V-Source output will not exceed the selected limit. An exception to this is a parameter value that exceeds 160V. Exceeding this value allows the V-Source to output its maximum voltage. The OVP limit is also enforced when in the I-Source Mode.

The limit parameter values are magnitudes and are in effect for both positive and negative output voltage. You can express the limit as a positive or negative value.

If you specify a value that is less than the lowest limit, the lowest limit will be selected. If you specify a value that is between limits, the lower limit will be selected. For example, if you specify a value of 110, the 100V limit will be selected.

WARNING **Even with the voltage protection limit set to the lowest value (20V), NEVER touch anything connected to the terminals of the SourceMeter when the OUTPUT is ON. Always assume that a hazardous voltage (>30V rms) is present when the OUTPUT is ON.**

To prevent damage to DUT (devices under test) or external circuitry, DO NOT program the V-Source to levels that exceed the voltage protection limit.

Set delay

:DELay <n>

:SOURce[1]:DELay <n> — Manually set source delay

Parameters

<n> =	0 to 999.9999	Specify delay in seconds
	MINimum	0 seconds
	MAXimum	999.9999 seconds
	DEFault	0.003

Query

:DELay?	Query delay
:DELay? DEFault	Query *RST default delay
:DELay? MINimum	Query lowest allowable delay
:DELay? MAXimum	Query highest allowable delay

Description

This command is used to manually set a delay (settling time) for the source. After the programmed source is turned on, this delay occurs to allow the source level to settle before a measurement is taken. Note that this delay is the same for both the I-Source and V-Source.

Do not confuse this source delay with the trigger delay. The source delay is part of the device action (SDM cycle) while the trigger delay occurs before the device action. See Section 10, *Trigger model* for more information.

Auto delay can instead be used to automatically set the source delay. See the next command.

:AUTO <b>

:SOURce[1]:DELay:AUTO <b> — Enable/disable auto delay for source

Parameters

<b> =	0 or OFF	Disable auto delay
	1 or ON	Enable auto delay

Query

:AUTO?	Query state of auto delay

Description

This command is used to enable or disable auto delay. When enabled, the instrument will automatically select a delay period that is appropriate for the present source/measure setup configuration. See Table 3-2. *RST and SYST:PRES default is OFF.

Configure voltage and current sweeps

There are two methods to configure the start and stop levels of a sweep. You can use either the :STARt and :STOP commands or you can use the :CENTer and :SPAN commands.

NOTE *In order to run a sweep, the selected source must be in the sweep sourcing mode and the trigger count should be the same as the number of source-measure points in the sweep.*

Use the :FUNCtion:MODE command to select the current or voltage source function. See *Select function mode*. Use the :CURRent:MODE or VOLTage:MODE command to select the SWEep sourcing mode. See *Select sourcing mode*. The trigger count is set using the TRIGger:COUNt command. See *Trigger subsystem*.

:RANGing <name>

:SOURce[1]:SWEep:RANGing <name> — Select source ranging mode

Parameters

<name> =	BEST	Use the best fixed mode
	AUTO	Use the most sensitive source range for each sweep level
	FIXed	Use the present source range for the entire sweep

Query :RANGing? — Query source ranging mode

Description This command is used to select the source ranging mode for sweeps. With BEST selected, the SourceMeter will select a single fixed source range that will accommodate all the source levels in the sweep. For front panel operation, this is the BEST FIXED option.

With AUTO selected, the SourceMeter will automatically go to the most sensitive source range for each source level in the sweep. For front panel operation, this is the AUTO RANGE option.

With FIXed selected, the source remains on the range that it is presently on when the sweep is started. For sweep points that exceed the source range capability, the source will output the maximum level for that range. For front panel operation, this is the FIXED option.

:SPACing <name>

:SOURce[1]:SWEep:SPACing <name> — Select scale for sweep

Parameters

<name> =	LINear	Linear scale
	LOGarithmic	Logarithmic scale

Query :SPACing? — Query scale for sweep

Description This command is used to select the scale for the sweep. With LINear selected, the source-measure points in the sweep will be performed on a linear scale. With LOGarithmic selected, the source-measure points will be performed on a logarithmic scale.

:STARt <n>
:STOP <n>

:SOURce[1]:CURRent:STARt <n>	Specify start current level (current sweep)
:SOURce[1]:VOLTage:STARt <n>	Specify start voltage level (voltage sweep)
:SOURce[1]:CURRent:STOP <n>	Specify stop current level (current sweep)
:SOURce[1]:VOLTage:STOP <n>	Specify stop voltage level (voltage sweep)

Parameters

<n> =	-105e-3 to 105e-3	Set I-Source level (amps)
	-210 to 210	Set V-Source level (volts)
	DEFault	0A or 0V
	MINimum	-105e-3A or -210V
	MAXimum	+105e-3A or +210V

Query

:STARt?	Query start level for sweep
:STARt? DEFault	Query *RST default level
:STARt? MINimum	Query lowest allowable level
:STARt? MAXimum	Query highest allowable level
:STOP?	Query start level for sweep
:STOP? DEFault	Query *RST default level
:STOP? MINimum	Query lowest allowable level
:STOP? MAXimum	Query highest allowable level

Description

These commands are used to specify the start and stop levels for a sweep. If using a fixed (manual) source range, the sweep will be performed using a source range that will accommodate all source values (Best Fixed Range). You can use source auto range if sweeping through one or more source ranges.

When the sweep is started, the source will output the specified start level and, after the delay period of the SDM cycle, a measurement is performed.

The sweep continues until the source outputs the specified stop level. At this level, the instrument again performs another measurement (after the SDM delay) and then stops the sweep.

The source-measure points in a sweep can be set by specifying a step size, or by specifying the number of source-measure points in the sweep. Refer to :STEP and :POINts.

:STARt and :STOP are coupled to :CENTer and :SPAN. Thus, when start and stop values are changed, the values for center and span are affected as follows:

Center = (Start + Stop) / 2
Span = Stop - Start

:CENTer <n>
:SPAN <n>

:SOURce[1]:CURRent:CENTer <n>	Specify center point of current sweep
:SOURce[1]:VOLTage:CENTer <n>	Specify center point of voltage sweep
:SOURce[1]:CURRent:SPAN <n>	Specify span of the current sweep
:SOURce[1]:VOLTage:SPAN <n>	Specify span of the voltage sweep

Parameters

<n> =	-210e-3 to 210e-3	Set I-Source level (amps)
	-420 to 420	Set V-Source level (volts)
	DEFault	0A or 0V
	MINimum	-210e-3A or -420V
	MAXimum	+210e-3A or +420V

Query

:CENTer?	Query center point for sweep
:CENTer? DEFault	Query *RST default level
:CENTer? MINimum	Query lowest allowable level
:CENTER? MAXimum	Query highest allowable level
:SPAN?	Query span for sweep
:SPAN? DEFault	Query *RST default level
:SPAN? MINimum	Query lowest allowable level
:SPAN? MAXimum	Query highest allowable level

Description

A sweep can be configured by specifying center and span parameters. By specifying a center point, you can sweep through the operating point of a device. The span determines the sweep width with the operating point at the center of the sweep.

For example, assume you are testing a device that operates at 10V, and you want to sweep from 8 to 12 volts. To do this, you would specify the center to be 10V and the span to be 4 volts (12 - 8).

Use the :STEP or :POINts command to specify the number of source-measure points in the sweep.

:CENTer and :SPAN are coupled to STARt and :STOP. Thus, when center and span values are changed, the values for start and stop are affected as follows:

Start = Center - (Span / 2)
Stop = Center + (Span / 2)

:STEP <n>

:SOURce[1]:CURRent:STEP <n> Specify step size (current sweep)
:SOURce[1]:VOLTage:STEP <n> Specify step size (voltage sweep)

Parameters

<n> =	-210e-3 to 210e-3	Set I-Source level (amps)
	-420 to 420	Set V-Source level (volts)
	DEFault	0A or 0V
	MINimum	-210e-3A or -420V
	MAXimum	+201e-3A or +420V

Query

:STEP	Query step size for sweep
:STEP? DEFault	Query *RST default level
:STEP? MINimum	Query lowest allowable level
:STEP? MAXimum	Query highest allowable level

Description This command is used to specify a step size for a linear sweep. When the sweep is started, the source level changes in equal steps from the start level to the stop level. A measurement is performed at each source step (including the start and stop levels).

NOTE *This command cannot be used for a logarithmic sweep. Use the :POints command to set the source-measure points for a log sweep.*

To avoid a setting conflicts error, make sure the step size is greater than the start value and less than the stop value.

The number of source-measure points in a linear sweep can be calculated as follows:

Points = [(Stop - Start) / Step] + 1
Points = (Span / Step) + 1

An alternate way to set the source-measure points in a linear sweep is to simply specify the number of source-measure points in the sweep using the :POINts command.

Note that the :STEP and :POINts commands are coupled. Changing the step size also changes the number of source-measure points. Conversely, changing the number of source-measure points changes the step size.

:POINts <n>

:SOURce[1]:SWEep:POINts <n> Set source-measure points for sweep

Parameters

<n> =	1 to 2500	Specify number of source-measure points
	MINimum	1
	MAXimum	2500
	DEFault	2500

Query

:POINts?	Query number of sweep points
:POINts? DEFault	Query *RST default number of sweep points
:POINts? MINimum	Query lowest allowable number of sweep points
:POINts? MAXimum	Query highest allowable number of sweep points

Description

The :POINts command specifies the total number of source-measure points in a sweep. For a linear sweep, the source-measure points are equally spaced (stepped) between the start level and the stop level. For a log sweep, the source-measure points are equally spaced on a logarithmic scale. Note that the start and stop levels are source-measure points.

Step size for a linear sweep can be calculated as follows:

Step Size = (Stop - Start) / (Points - 1)
Step Size = Span / (Points -1)

Step size for a logarithmic sweep can be calculated as follows:

$$\text{Log Step Size} = \frac{\log 10\,(\text{Stop}) - \log 10\,(\text{Start})}{\text{Points} - 1}$$

An alternate way to set the source-measure points in a sweep is to specify the step size using the :STEP command.

Note that the :POINts and :STEP commands are coupled. Changing the number of source-measure points also changes the step size. Conversely, changing the step size changes the number of source-measure points.

:DIRection <name>

:SOURce[1]:SWEep:DIRection <name> Set direction of sweep

Parameters

<name> =	UP	Run sweep from start to stop
	DOWn	Run sweep from stop to start

Query

:DIRection?	Query direction of sweep

Description

Normally, a sweep is run from the start level to the stop level. The :STARt and :STOP, or :CENTer and :SPAN commands are used to set these levels.

This command lets you change the execution direction of the sweep. With DOWn selected, the sweep will begin at the stop level and end at the start level. Selecting UP restores sweep operation to the normal start to stop direction.

Configure list

:CURRent <NRf list>
:VOLTage <NRf list>

:SOURce[1]:LIST:CURRent <NRf list> Define I-Source list
:SOURce[1]:LIST:VOLTage <NRf list> Define V-Source list

Parameters

<NRf list> =	NRf, NRf … NRf	
NRf =	-105e-3 to 105e-3	I-Source value
	-210 to 210	V-Source value

Query

:CURRent?	Query I-Source list
:VOLTage?	Query V-Source list

Description These commands are used to define a list of source values (up to 100) for the list sourcing mode of operation. When operation is started, the instrument will sequentially source each current or voltage value in the list. A measurement is performed at each source level.

The following command shows the proper format for defining an I-Source list using current source values of 10mA, 130mA, and 5mA:

:SOURce[1]:LIST:CURRent 0.01, 0.13, 0.005

If using manual source ranging, you can use auto range for source values that are not within a single range.

NOTE *In order to execute a source list, the selected source must be in the list sourcing mode, and the product of the arm and trigger count should be at least the same as the number of source points in the list.*

Use the :FUNCtion:MODE command to select the current or voltage source function. See *Select function mode*. Use the :CURRent:MODE or VOLTage:MODE command to select the LIST sourcing mode. See *Select sourcing mode*. The trigger count is set using the TRIGger:COUNt command. See *Trigger subsystem*.

:APPend <NRf list>

:SOURce[1]:LIST:CURRent:APPend <NRf list> Add value(s) to I-Source list
:SOURce[1]:LIST:VOLTage:APPend <NRf list> Add value(s) to V-Source list

Parameters

<NRf list> =	NRf, NRf … NRf	
NRf =	-105e-3 to 105e-3	I-Source value
	-210 to 210	V-Source value

Description This command is used to add one or more values (up to 100) to a source list that already exists. The source values are appended to the end of the list. (By using multiple appended lists, up to 2500 points can be in a list.)

:POINts?

:SOURce[1]:LIST:CURRent:POINts? Query length of I-Source list
:SOURce[1]:LIST:VOLTage:POINts? Query length of V-Source list

Description This command is used to determine the length of the specified source list. The response message indicates the number of source values in the list.

Configure memory sweep

A memory sweep lets you perform a sweep using setups stored in up to 100 memory locations. This allows you to sweep using multiple source-measure operations and math expressions. See *CALCulate1*.

NOTE *In order to run a memory sweep, the memory function must be selected, and the trigger count must be the same as the number of memory points in the sweep. Use the :FUNCtion:MODE command to select the MEMory function. See "Select function mode." Arm count (ARM:COUNt) and trigger count (TRIGger:COUNt) are set from the Trigger Subsystem.*

When memory is initialized (:SYSTem:MEMory:INITialize), all 100 memory locations for a memory sweep are initialized to the present setup configuration of the SourceMeter with CALC 1 disabled. User-defined math expressions are replaced with the "Power" math expression.

Error 809 "Source memory location revised" occurs when a memory sweep references an expression that no longer exists. The memory sweep is revised to disable CALC1.

In order to execute a memory sweep, the product of the arm count and trigger count should be at least the same as the number of points in the sweep.

Use the :FUNCtion:MODE command to select the MEMory function. See *Select function mode*. Arm count (ARM:COUNt) and trigger count (TRIGger:COUNt) are set from the Trigger Subsystem.

:SAVE <NRf>

:SOURce[1]:MEMory:SAVE <NRf> Save setup in specified memory location

Parameters <NRf> = 1 to 100 Specify memory location

Description This command is used to save the present instrument setup in a memory location. Up to 100 setups can be saved. The following settings are saved in each source memory location:

SENSe[1]:CURRent:NPLCycles
SENSe[1]:RESistance:NPLCycles
SENSe[1]:VOLTage:NPLCycles
SENSe[1]:FUNCtion:CONCurrent
SENSe[1]:FUNCtion:ON
SENSe[1]:FUNCtion:OFF

SENSe[1]:RESistance:MODE
SENSe[1]:RESistance:OCOMpensated
SENSe[1]:AVERage:STATe
SENSe[1]:AVERage:TCONtrol
SENSe[1]:AVERage:COUNt
SOURce[1]:FUNCtion:MODE
SOURce[1]:DELay
SOURce[1]:DELay:AUTO

SOURce[1]...X...:TRIGgered:SFACtor
SOURce[1]...X...:TRIGgered:SFACtor:STATe
where ...X... = :CURRent or :VOLTage (based on source mode)

Source Value, Range, Auto Range
Sense Protection, Range, Auto Range
SYSTem:AZERo:STATe
CALCulate1:STATe
CALCulate1:MATH[:EXPRession]:NAME
CALCulate2:FEED
CALCulate2:NULL:OFFSet
CALCulate2:NULL:STATe
CALCulate2:LIMit[1]:STATe
CALCulate2:LIMit[1]:COMPliance:FAIL
CALCulate2:LIMit[1]:COMPliance:SOURce2

CALCulate2:LIMitX:STATe
CALCulate2:LIMitX:UPPer[:DATA]
CALCulate2:LIMitX:UPPer:SOURce2
CALCulate2:LIMitX:LOWer[:DATA]
CALCulate2:LIMitX:LOWer:SOURce2
CALCulate2:LIMitX:PASS:SOUR
where X = 2, 3 and 5 through 12

CALCulate2:CLIMits:PASS:SOURce2
CALCulate2:CLIMits:PASS:SMLocation

TRIGger:DELay

After saving the desired setups in consecutive memory locations (unless branching, see CALC2:CLIM:PASS:SML), use the :POINts command to specify how many sweep points to perform and the :STARt command to specify where to start from.

:POINts <NRf>

:SOURCe:MEMory:POINts <NRf> — Specify number of sweep points to execute

Parameters <NRf> = 1 to 100 — Number of sweep points

Description This command is used to specify the number of points for the sweep. For example, if you saved setups in memory locations 1 through 12 for a sweep, specify a 12-point sweep using this command.

:STARt <NRf>

:SOURCe:MEMory:STARt <NRf> — Select Source Memory Sweep start location

Parameters <NRf> = 1 to 100 — Specify memory location

Description This command is used to set the starting location of a Source Memory Sweep. For example, for setups saved in memory locations 98 through 5, specify a starting location of 98.

:RECall <NRf>

:SOURCe:MEMory:RECall <NRf> — Return to specified setup

Parameters <NRf> = 1 to 100 — Specify memory location

Description This command is used to return the SourceMeter to the setup stored at the specified memory location.

Set scaling factor

:TRIGgered:SFACtor <n>

:SOURce[1]:CURRent[:LEVel]:TRIGgered:SFACtor <n> — Set current scaling factor
:SOURce[1]:VOLTage[:LEVel]:TRIGgered:SFACtor <n> — Set voltage scaling factor

Parameters <n> = -999.9999e+18 to 999.9999e+18 — Scaling factor

Query :SFACTor? — Query scaling factor

Description :SFAC instructs the SourceMeter to source the scaling factor times the previous source memory location value. For example, if 10.0V is stored in the first source memory (Source I, Measure V Mode), and the unit is in the Source V, Measure I mode with :SFAC set to 0.1 and enabled, the unit will output 1.0V for the second source memory location.

NOTE *These commands work only with source memory sweeps.*

:TRIGgered:SFACtor:STATe <b>

:SOURce[1]:CURRent[:LEVel]:TRIGgered:SFACtor:STATe <b> Enable/disable current scaling
:SOURce[1]:VOLTage[:LEVel]:TRIGgered:SFACtor:STATe <b> Enable/disable voltage scaling

Parameters	<b> =	1 or ON	Enable scaling
		0 or OFF	Disable scaling
Query	:SFACtor:STATe?	Query enabled/disabled scaling state	
Description	:SFAC:STAT enables or disables scaling.		

NOTE *These commands work only with source memory sweeps.*

Sweep and list program examples

Linear voltage sweep

Linear voltage sweep from 1V to 10V in 1V increments:

```
*RST
SOUR:FUNC:MODE VOLT
SOUR:SWE:SPAC LIN
SOUR:VOLT:STAR 1.0
SOUR:VOLT:STOP 10.0
SOUR:VOLT:STEP 1.0
SOUR:SWE:POIN? (returns 10)
TRIG:COUN 10
SOUR:VOLT:MODE SWE
OUTP ON
INIT
```

Voltage list

The previous Linear Voltage Sweep can instead be performed using a Voltage List as follows:

```
*RST
SOUR:FUNC:MODE VOLT
SOUR:LIST:VOLT 1,2,3,4,5,6,7,8,9,10
SOUR:LIST:VOLT:POIN? (returns 10)
TRIG:COUN 10
SOUR:VOLT:MODE LIST
OUTP ON
INIT
```

Logarithmic current sweep

Logarithmic current sweep from 1mA to 100mA in 20 points:

```
*RST
SOUR:FUNC:MODE CURR
SOUR:SWE:SPAC LOG
SOUR:CURR:STAR .001
SOUR:CURR:STOP .1
SOUR:SWE:POIN 20
TRIG:COUN 20
SOUR:CURR:MODE SWE
OUTP ON
INIT
```

To determine the source values that will be generated:

Start: 0.001 Log_{10}(Start): -3
Stop: 0.1 Log_{10}(Stop): -1

LogStep = (Log_{10}(Stop) - Log_{10}(Start)) / (SWE:POIN -1)
= (-1 - (-3) / (20 - 1)
= 2/ 19
= 0.105263

Now add the LogStep value to Log_{10}(Start) and to each subsequent result. This will create a list of Log_{10} Values. Next take the anti-log of each Log_{10} Value to get the actual sweep values:

Value#	Log_{10} Value	Sweep Value
1	-3.000000	0.001000
2	-2.894737	0.001274
3	-2.789474	0.001623
4	-2.684211	0.002069
5	-2.578948	0.002637
6	-2.473685	0.003360
7	-2.368422	0.004281
8	-2.263159	0.005456
9	-2.157896	0.006952
10	-2.052633	0.008859
11	-1.947370	0.011288
12	-1.842107	0.014384
13	-1.736844	0.018329
14	-1.631581	0.023357
15	-1.526318	0.029763
16	-1.421055	0.037927
17	-1.315792	0.048329
18	-1.210526	0.061584
19	-1.105263	0.078475
20	-1.000000	0.100000

Current list

The Previous Log Current Sweep can instead be performed by using the sweep values in a Current List as follows:

```
*RST
SOUR:FUNC:MODE CURR
SOUR:LIST:CURR 0.001,0.001274,0.001623,0.002069,0.002637,0.003360,0.004281
SOUR:LIST:CURR:APP 0.005456,0.006952,0.008859,0.011288,0.014384,0.018329
SOUR:LIST:CURR:APP 0.023357,0.029763,0.037927,0.048329,0.061584,0.078475,0.1
SOUR:LIST:CURR:POIN? (returns 20)
TRIG:COUN 20
SOUR:CURR:MODE LIST
OUTP ON
INIT
```

Soak time

:SOAK <NRf>

:SOURce[1]:SOAK <NRf> — Set multiple mode soak time

Parameters <NRf> = soak time (s) 0.000 to 9999.999s

Query :SOAK? Query multiple mode soak time

Description With SYST:RCMode set to MULTiple, SOUR:SOAK specifies the amount of time after the first point of a sweep that the unit will sit in a loop actively autoranging up and down to allow a multiple SourceMeter configuration to settle. See :*SYSTem subsystem*. This process will be done only once per INIT, READ?, or MEAS? command. The soak time is especially useful for low current measurements when multiple down-range changes from the higher ranges are required.

SOURce2

The following commands are used to set the logic level of the digital output lines, and control the pulse width of limit test output patterns that are sent to component handlers. Limit tests are configured and controlled from the CALCulate2 Subsystem. For details on limit testing, see Section 11.

Setting digital output

[:LEVel] <NRf> | <NDN>

:SOURce2:TTL[:LEVel][:DEFault] <NRf> | <NDN> — Set digital output pattern

Parameters <NRf> = 0 to 7 Decimal format for 3-bit
0 to 15 Decimal format for 4-bit

<NDN>	#Bx	Binary format: 3-bit: x = 000 to 111 4-bit: x = 0000 to 1111
	#Hx	Hexadecimal format: 3-bit: x = 0 to 7 4-bit: x = 0 to F
	#Qx	Octal format: 3-bit: x = 0 to 7 4-bit: x = 0 to 17

Query :TTL? Query digital output value

Description This command is used to set the logic levels of the output lines of the Digital I/O port. When set high, the specified output line will be at approximately +5V. When set low, the output line will be at 0V.

Use the following table to determine the parameter value for the desired decimal digital output pattern:

OUT 4	OUT 3	OUT 2	OUT 1	Decimal value*
L	L	L	L	0
L	L	L	H	1
L	L	H	L	2
L	L	H	H	3
L	H	L	L	4
L	H	L	H	5
L	H	H	L	6
L	H	H	H	7
H	L	L	L	8
H	L	L	H	9
H	L	H	L	10
H	L	H	H	11
H	H	L	L	12
H	H	L	H	13
H	H	H	L	14
H	H	H	H	15

L = Low (Gnd)
H = High (>+3V)
*0-7 in 3-bit mode.

:ACTual?

:SOURce2:TTL[:LEVel]:ACTual? Query bit pattern on digital output port.

Description This query command is used to read the bit pattern that is actually on the digital output port.

:MODE <name>

:SOURce2:TTL4:MODE <name> Control Digital I/O port line 4 mode

Parameters <name> = EOTest Use line 4 as EOT signal
BUSY Use line 4 as BUSY signal

Query :MODE? Query Digital I/O line 4 mode

Description This command controls the operation of Digital I/O line 4 to act as either an End-of-Test or Busy signal in the 3-bit output mode. EOT is not automatically controlled in 4-bit mode. See :BSIZe below. Likewise, with BUSY enabled in the 4-bit mode, the unit behaves if it were in 3-bit mode by ignoring all attempts to drive Digital I/O line 4.

:BSTate <b>

:SOURce2:TTL4:BSTate <b> Control BUSY and EOT polarity

Parameters <b> = 1 Set EOT/BUSYpolarity high
0 Set EOT/BUSY polarity low

Query :BSTate? Query EOT/BUSY polarity

Description This command sets the polarity of the EOT or BUSY signal in the 3-bit mode.

:BSIZe <n>

:SOURce2:BSIZe <n> Set Digital I/O bit size

Parameters <n> = 3 Set 3-bit size
4 Set 4-bit size
16 Set 16-bit size (2499-DIGIO option)

Query :BSIZe? Query Digital I/O port bit size

Description This command sets the Digital I/O bit size to 3 or 4. In the 3-bit mode, Digital I/O line 4 becomes EOT, /EOT, BUSY, or /BUSY based on the SOUR2:TTL4:MODE and SOUR2:TTL4:BST commands above. In 4-bit mode, Digital I/O line 4 is controlled manually if SOUR2:TTL4:MODE is set to EOT. If SOUR2:TTL4:MODE is set to BUSY, operation is identical to the 3-bit mode. The 16-bit size is available with the 2499-DIGIO option connected to the Digital I/O port.

NOTE *This command is not affected by *RST, :SYSTem:PRESet, or *RCL.*

Clearing digital output

[:IMMediate]

:SOURce2:CLEar[:IMMediate] Clear digital output lines

Description This action command is used to immediately restore the digital output lines to the output pattern defined by the :TTL:LEVel command.

:AUTO <b>

:SOURce2:CLEar:AUTO <b> — Control auto-clear for digital output

Parameters

<b> =	0 or OFF	Disable auto-clear
	1 or ON	Enable auto-clear

Query

:AUTO?	Query auto-clear

Description

This command is used to enable or disable auto-clear for the digital output lines. When enabled, the output pattern will clear automatically after the "pass or fail" output bit pattern of a limit test is sent to a handler via the digital output lines.

The :DELay command specifies the pulse width of the limit test bit pattern. See the next command. After the delay period times out, the digital output clears back to the output pattern programmed by the :TTL:LEVel command.

When auto-clear is disabled, the digital output pattern can only be cleared by the :IMMediate command.

On power-up, auto clear is enabled.

See *:CALCulate2* and Section 11 for details on limit tests.

:DELay <n>

:SOURce2:CLEar:AUTO:DELay <n> — Set delay for auto-clear

Parameters

<n> =	0 to 60	Specify delay (in seconds)
	DEFault	100µsec delay
	MINimum	0 sec
	MAXimum	60 sec

Query

:DELay?	Query delay
:DELay? DEFault	Query *RST default delay
:DELay? MINimum	Query lowest allowable delay
:DELay? MAXimum	Query maximum allowable delay

Description

This command is used to set the delay for digital output auto-clear. This delay determines the pulse width of the limit test output pattern as required by the handler. After the delay, the output returns (clears) to the pattern programmed by the :TTL:LEVel command.

The delay actually defines the pulse width for line 4, which is used by category register component handlers as the EOT (end of test) strobe. The pulse width of the other three lines are 20µsec longer (10µsec before line 4 is toggled, and 10µsec after line 4 is cleared). Skewing the timing on line 4 provides "setup" and "hold" time for category register component handlers. See Section 11 for details on timing.

STATus subsystem

The STATus subsystem is used to control the status registers of the SourceMeter. The commands in this subsystem are summarized in Table 17-7.

NOTE These registers and the overall status structure are fully explained in Section 14.

Read event registers

[:EVENt]?

:STATus:MEASurement[:EVENt]?	Read Measurement Event Register
:STATus:QUEStionable[:EVENt]?	Read Questionable Event Register
:STATus:OPERation[:EVENt]?	Read Operation Event Register

Description These query commands are used to read the contents of the status event registers. After sending one of these commands and addressing the SourceMeter to talk, a value is sent to the computer. This value indicates which bits in the appropriate register are set.

Program event enable registers

:ENABle <NDN> or <NRf>

:STATus:MEASurement:ENABle <NDN> or <NRf>	Program Measurement Event Enable Register
:STATus:QUEStionable:ENABle <NDN> or <NRf>	Program Questionable Event Enable Register
:STATus:OPERation:ENABle <NDN> or <NRf>	Program Operation Event Enable Register

Parameters

<NDN> =	#Bxx...x	Binary format (each x = 1 or 0)
	#Hx	Hexadecimal format (x = 0 to FFFF)
	#Qx	Octal format (x = 0 to 177777)
<NRf> =	0 to 65535	Decimal format

Query :ENABle? Read an enable register

Description These commands are used to program the enable registers of the status structure. The binary equivalent of the parameter value that is sent determines which bits in the register gets set. See Section 14 for details.

Read condition registers

:CONDition?

:STATus:MEASurement:CONDition?	Read Measurement Condition
:STATus:QUEStionable:CONDition?	Read Questionable Register
:STATus:OPERation:CONDition?	Read Operation Condition

Description These query commands are used to read the contents of the condition registers.

Select default conditions

:PRESet

:STATus:PRESet	Return registers to default conditions

Description When this command is sent, the following SCPI event registers are cleared to zero (0):

1. Operation Event Enable Register.
2. Event Enable Register.
3. Measurement Event Enable Register.

NOTE The Standard Event Register is not affected by this command.

Error queue

[:NEXT]?

:STATus:QUEue[:NEXT]?	Read Error Queue

Description As error and status messages occur, they are placed into the Error Queue. This query command is used to read those messages. See Appendix B for a list of messages.

NOTE The :STATus:QUEue[:NEXT]? query command performs the same function as the :SYSTem:ERRor? query command. See ":SYSTem subsystem."

:CLEar

:STATus:QUEue:CLEar	Clear Error Queue

Description This action command is used to clear the Error Queue of messages.

ENABle <list>

:STATus:QUEue:ENABle <list> Enable messages for Error Queue

Parameters <list> = (numlist)

where numlist is a specified list of messages that you wish to enable for the Error.

Query :ENABle? Query list of enabled messages

Description 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. This command is used to specify which messages you want enabled. Messages not specified will be disabled and prevented from entering the queue.

DISable <list>

:STATus:QUEue:DISable <list> Disable messages for Error Queue

Parameters <list> = (numlist)

where numlist is a specified list of messages that you wish to disable for the Error Queue.

Query :DISable? Query list of disabled messages

Description 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. This command is used to specify which messages you want disabled. Disabled messages are prevented from going into the Error Queue.

:SYSTem subsystem

The SYSTem subsystem contains miscellaneous commands that are summarized in Table 17-8.

Default conditions

:PRESet

:SYSTem:PRESet — Return to :SYSTem:PRESet defaults

Description This command returns the instrument to states optimized for front panel operation. :SYSTem:PRESet defaults are listed in the SCPI tables (Tables 17-1 through 17-10).

:POSetup

:SYSTem:POSetup <name> — Program power-on defaults

Parameters	<name> =	RST	Power-up to *RST defaults
		PRESet	Power-up to :SYSTem:PRESet defaults
		SAV0	Power-up to setup stored at memory location 0
		SAV1	Power-up to setup stored at memory location 1
		SAV2	Power-up to setup stored at memory location 2
		SAV3	Power-up to setup stored at memory location 3
		SAV4	Power-up to setup stored at memory location 4
Query	:POSetup?		Query power-on setup

Description This command is used to select the power-on defaults. With RST selected, the instrument powers up to the *RST default conditions. With PRES selected, the instrument powers up to the :SYStem:PRESet default conditions. Default conditions are listed in the SCPI tables (Tables 17-1 through 17-10).

With the SAV0-4 parameters specified, the instrument powers-on to the setup that is saved in the specified location using the *SAV command.

Select guard mode

:GUARd <name>

:SYSTem:GUARd <name> Select guard mode

Parameters <name> = OHMS Ohms guard mode
CABLe Cable guard mode

Query :GUARd? Query guard mode

Description This command is used to select the guard mode. OHMS guard is a low-impedance guard drive used for in-circuit resistance measurements. CABLE guard provides a high-impedance guard drive that is used to eliminate leakage currents in cabling and test fixtures.

When performing 6-wire ohms guard measurements, use the GUARD output state. The OUTPut [1]:SMODe GUARd command is used to select the GUARD output-off state.

NOTE *See Section 2 for details on guarding.*

Initialize memory

:INITialize

:SYSTem:MEMory:INITialize Initializes battery backed RAM

Description When this command is used, the following actions to initialize battery backed RAM occur:

- TRACe (data store) data is lost, buffer size is reset to 100, and timestamp is set to the absolute format.
- SOURce1:LIST:CURR and VOLT are reset to 0A and 0V, respectively.
- Deletes all user-defined math expressions. See *CALCulate1*.
- All 100 memory locations for a memory sweep are initialized to the present setup configuration of the SourceMeter with CALC 1 disabled. User-defined math expressions are replaced with the “Power” math expression.
- The four standard save setups (*SAV0 - *SAV4) are initialized to the present setup configuration of the SourceMeter.
- All CALCulate1 user-defined math expressions are deleted.

Control beeper

[:IMMediate] <freq, time>

:SYSTem:BEEPer[:IMMediate] <freq, time>

Parameters

freq =	65 to 2e6	Specify frequency in Hz
time =	0 to 7.9	Specify time duration

NOTE *The frequency and time values must be separated by a comma (i.e., :syst:beep 100, 3).*

Description The beeper of the SourceMeter can be used to provide an audible signal at a specified frequency and time duration (up to 7.9 seconds @ 65Hz). This beeper can, for example, be used to signal the end of a lengthy sweep.

Example: :SYSTem:BEEPer 500, 1 Beep at 500Hz for 1 second

The correlation between the duration and frequency of the beep is expressed as follows:

Maximum Time = 512/ Frequency

For example, at a frequency of 512Hz, the maximum beep time is one second. You can set the time greater than one (1) second, but it will only beep for one second.

Note that in order to use this command, the beeper must be enabled. See the next command.

:STATe <b>

:SYSTem:BEEPer:STATe <b> Enable or disable beeper

Parameters

<b> =	1 or ON	Enable beeper
	0 or OFF	Disable beeper

Query :STATe? Query state of beeper

Description This command is used to enable or disable the beeper. When enabled, a short beep is provided to signal that a front panel key has been pressed.

Control auto zero

:STATe <name>

:SYSTem:AZERo:STATe <name> Control auto zero

Parameters <name> = ON Enable auto zero
OFF Disable auto zero
ONCE Force immediate auto zero update

Query :STATe? Query state of auto zero

Description This command is used to enable or disable auto zero, or to force an immediate one-time auto zero update if auto zero is disabled. When auto zero is enabled, accuracy is optimized. When auto zero is disabled, speed is increased at the expense of accuracy.

Control NPLC caching

:CACHing

:SYSTem:AZERo:CACHing[:STATe] <b> Enable/disable NPLC caching
:SYSTem:AZERo:CACHing:REFResh Update NPLC cache values
:SYSTem:AZERo:CACHing:RESet Clear NPLC values from cache
:SYSTem:AZERo:CACHing:NPLCycles? Return list of NPLC values

Parameters <b> = 1 or ON Enable NPLC caching
0 or OFF Disable NPLC caching

Query [:STATe]? Query state of NPLC caching
:NPLCycles? Return list of NPLC values stored in cache from oldest to newest.

Description NPLC caching speeds up source memory sweeps by caching A/D reference and zero values. When SYST:AZER:CACH is enabled, the A/D reference and zero values will be saved for up to the 10 most recent [:SENSe[1]] :VOLTage[:DC]:NPLCycles, [:SENSe[1]]:CURRent[: DC]:NPLCycles, or [:SENSe[1]]:RESistance:NPLCycles settings. Whenever the integration rate is changed via an NPLC command, user setup recall (*RCL), or a source memory recall (:SOUR:MEM command or during a source memory sweep), NPLC caching will occur. If the integration rate is already stored in the cache, the stored reference and zero values are recalled and used. Otherwise, a reference and zero value are acquired and stored in the cache. If there are already 10 NPLC values stored, the oldest one will be overwritten by the newest one.

Following these general steps to program and use NPLC caching:

1. Send this command to disable auto zero: SYST:AZER OFF.
2. Enable NPLC caching by sending: SYST:AZER:CACH ON.
3. Set up and run your source memory sweep with the :SOUR:MEM commands along with the various other commands required to program additional operating modes. (See *Configure memory sweep* as well as other pertinent command descriptions in this section for details.)

NOTE *Auto zero should be disabled with the :SYST:AZER OFF command for maximum source memory sweep speed; otherwise, the cache is of little use. With auto zero enabled, new A/D reference and zero values are taken for every reading and saved into the cache, slowing down sweep operation. However, with auto zero disabled, measurements may drift and become erroneous. To minimize drift when using NPLC caching with auto zero disabled, periodically send :SYST:AZER ONCE to force an immediate auto zero update.*

Select power line frequency setting

:LFRequency <freq>

:SYSTem:LFRequency <freq> — Select line frequency

Parameters <freq> = 50 — 50Hz or 400Hz setting
60 — 60Hz setting

Query :LFRequency? — Query line frequency selection.

Description Use this command to manually select the line frequency setting (50 or 60Hz). For 400Hz operation, select 50Hz.

:AUTO <b>

:SYSTem:LFRequency:AUTO <b> — Control auto line frequency selection

Parameters <b> = 1 or ON — Enable and line frequency selection
0 or OFF — Disable auto line frequency selection

Query :AUTO? — Query state of auto line frequency selection.

Description This command is used to enable or disable auto line frequency detection. When enabled, the SourceMeter will sense the line frequency on power-up and select the appropriate line frequency setting.

Manually setting the line frequency disables auto frequency. See the previous command.

Error queue

NOTE *See Section 14 for details on the error queue.*

[:NEXT]?

:SYSTem:ERRor[:NEXT]? Read oldest error (code and message)

Description As error and status messages occur, they are placed in the Error Queue. The Error Queue is a first-in, first-out (FIFO) register that can hold up to 10 messages. After sending this command and addressing the SourceMeter to talk, the oldest message is sent to the computer and is then removed from the queue.

NOTE *The :STATus:Queue? command performs the same function as :SYSTem:ERRor[:NEXT]?. See "STATus subsystem."*

:ALL?

:SYSTem:ERRor:ALL? Read all errors (codes and messages)

Description This query command is similar to the [:NEXT]? command except that all messages in the Error Queue are sent to the computer when the SourceMeter is addressed to talk. All messages are removed from the queue.

:COUNt?

:SYSTem:ERRor:COUNt? Return the number of errors

Description After sending this command and addressing the SourceMeter to talk, a decimal number will be sent to the computer. That is the number of messages in the Error Queue.

:CODE[:NEXT]?

:SYSTem:ERRor:CODE[:NEXT]? Read oldest error (code only)

Description This command is identical to the [:NEXT]? command, except only the code is returned. The message itself is not returned. The error is cleared from the queue.

:CODE:ALL?

SYSTem:ERRor:CODE:ALL? Read all errors (codes only)

Description This query command is identical to the :ALL? command, except only the codes are returned. The actual messages are not returned. All errors are cleared from the queue.

:CLEar

:SYSTem:CLEar Clear Error Queue

Description This action command is used to clear the Error Queue of messages.

Simulate key presses

:KEY

:SYSTem:KEY <NRf> — Simulate key-press

Parameters <NRf> =

1	RANGE up arrow key
2	SOURCE down arrow key
3	left arrow key
4	MENU key
5	FCTN key
6	FILTER key
7	SPEED key
8	EDIT key
9	AUTO key
10	right arrow key
11	EXIT key
12	V (SOURCE) key
13	LIMITS key
14	STORE key
15	V (MEAS) key
16	TOGGLE key
17	RANGE down arrow key
18	ENTER key
19	I (SOURCE) key
20	TRIG key
21	RECALL key
22	I (MEAS) key
23	LOCAL key
24	ON/OFF key
25	-----
26	SOURCE up arrow key
27	SWEEP key
28	CONFIG key
29	Ω key
30	REL key
31	DIGITS key

Query :KEY? Query last “pressed” key.

Description This command is used to simulate front panel key presses. For example, to select the voltage measurement function (V), you can send the following command to simulate pressing the V (MEAS) key:

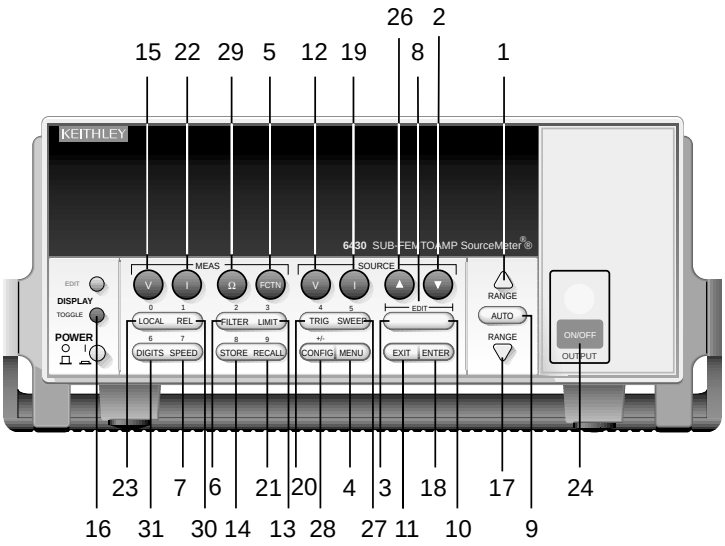
:syst:key 15

The parameter listing provides the key-press code in numeric order. Figure 17-3 also illustrates the key-press codes.

The queue for the :KEY? query command can only hold one key-press. When :KEY? is sent over the bus, and the SourceMeter is addressed to talk, the key-press code number for the last key pressed (either physically or with :KEY) is sent to the computer.

The key-press code number for the last key pressed (either physically or with :key) is sent to the computer.

Figure 17-3
Key-press codes



Parameters

<NRf> =
1 RANGE up arrow key
2 SOURCE down arrow key
3 left arrow key
4 MENU key
5 FCTN key
6 FILTER key
7 SPEED key
8 EDIT key
9 AUTO key
10 right arrow key
11 EXIT key
12 V (SOURCE) key
13 LIMITS key
14 STORE key
15 V (MEAS) key
16 TOGGLE key
17 RANGE down arrow key
18 ENTER key
19 I (SOURCE) key
20 TRIG key
21 RECALL key
22 I (MEAS) key
23 LOCAL key
24 ON/OFF key
25 - (not used)
26 SOURCE up arrow key
27 SWEEP key
28 CONFIG key
29 Ω key
30 REL key
31 DIGITS key

Read version of SCPI standard

:VERSion?

:SYSTem:VERSion? Read SCPI version

Description This query command is used to read the version of the SCPI standard being used by the SourceMeter. Example code:

1996.0

The above response message indicates the version of the SCPI standard.

RS-232 interface

:LOCal

:SYSTem:LOCal — Take SourceMeter out of remote

Description Normally, during RS-232 communications, front panel keys are operational. However, the user may wish to lock out front panel keys during RS-232 communications. See :RWLock.

This action command is used to remove the SourceMeter from the remote state and enables the operation of front panel keys. Note that this command can only be sent over the RS-232 interface.

:REMote

:SYSTem:REMote — Place the SourceMeter in remote

Description This action command is used to place the SourceMeter in the remote state. In remote, the front panel keys will be locked out if local lockout is asserted. See :RWLock. Note that this command can only be sent over the RS-232 interface.

:RWLock <b>

:SYSTem:RWLock <b> — Disable or enable front panel keys

Parameters <b> =

0 or OFF	Disable local lockout
1 or ON	Enable local lockout

Query :RWLock — Query state of local lockout

Description This command is used to enable or disable local lockout. When enabled, the front panel keys are locked out (not operational) when the instrument is in remote. (See :REMote.) When disabled, the front panel keys are operational in remote.

Removing the instrument from remote (:LOCal) restores front panel keys operation but does not change the status of the :RWLock command.

Note that this command can only be sent over the RS-232 interface.

Query timestamp

:TIME?

:SYSTem:TIME? — Query timestamp

Query :TIME? — Query timestamp

Description This query returns the current timestamp value.

Reset timestamp

:RESet

:SYSTem:TIME:RESet — Reset timestamp

Description This action command is used to reset the absolute timestamp to 0 seconds. The timestamp also resets to 0 seconds every time the SourceMeter is turned on.

Auto reset timestamp

:RESet:AUTO <b>

:SYSTem:TIME:RESet:AUTO <b> — Reset timestamp when exiting idle

Parameters

<b> =	1 or ON	Enable auto timestamp reset
	0 or OFF	Disable auto timestamp reset

Query :AUTO? — Query enabled/disabled auto timestamp reset state

Description :RES:AUTO enables or disables auto timestamp reset. When enabled, the timestamp will be automatically reset when exiting the idle layer of the trigger model. This command is intended for use with READ?/INIT when taking more than one reading.

Auto range change mode

:RCMode <name>

:SYSTem:RCMode <name> — Control auto range change mode

Parameters

<name> =	SINGle	Single mode
	MULTiple	Multiple mode

Query :RCMode? — Query auto range change mode

Description This command controls the auto range change mode. In the SINGle mode, the SourceMeter will auto range only after first taking a reading. In the MULTiple mode, the SourceMeter will auto range up on compliance in the Delay phase of the Source-Delay-Measure cycle, thereby minimizing the chance of a SourceMeter being in compliance in a multiple-SourceMeter system. A SourceMeter can downrange only once a reading has been taken. In the MULTiple mode, you can control the soak time using the :SOUR:SOAK command. See *SOURce subsystem*. Note that you can use the LLIMIT and ULIMIT commands to control auto range limits. See *SENSe1 subsystem*.

:TRACe subsystem

The commands in this subsystem are used to configure and control data storage into the buffer. The commands are summarized in Table 17-9.

:TRACe|:DATA

The bar (|) indicates that :TRACe or :DATA can be used as the root command for this subsystem. From this point on, the documentation in this manual uses :TRACe. If you prefer to use :DATA, simply replace all the :TRACe command words with :DATA.

Read and clear buffer

:DATA?

:TRACe:DATA? Read contents of buffer

Description When this command is sent and the SourceMeter is addressed to talk, all the readings stored in the data store are sent to the computer.

The format used to send readings over the bus is controlled from the :FORMat subsystem.

NOTE *See Appendix C for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the types of readings that are acquired by the various commands to read data.*

:CLEar

:TRACe:CLEar Clear buffer

Description This action command is used to clear the buffer of readings. If you do not clear the buffer, a subsequent store will overwrite the old readings.

Configure and control buffer

:FREE?

:TRACe:FREE? Read status of memory

Description This command is used to read the status of storage memory. After sending this command and addressing the SourceMeter to talk, two values separated by commas are sent to the computer. The first value indicates how many bytes of memory are available, and the second value indicates how many bytes are reserved to store readings.

:POINts <n>

:TRACe:POINts <n> — Specify buffer size

Parameters

<n> =	1 to 2500	Specify buffer size
	MINimum	1
	MAXimum	2500
	DEFault	100

Query

:POINts?	Query buffer size
:POINts? MINimum	Query smallest allowable buffer size
:POINts? MAXimum	Query largest allowable buffer size
:POINts? DEFault	Query *RST default buffer size

Description This command is used to specify the size of the buffer.

:ACTual?

:TRACe:POINts:ACTual? — Query number of stored readings

Description This query command is used to determine how many stored readings are in the buffer. After sending this command and addressing the unit to talk, the number of readings stored in the buffer will be sent to the computer.

:FEED <name>

:TRACe:FEED <name> — Specify readings source

Parameters

<name> =	SENSe[1]	Put raw readings in buffer
	CALCulate[1]	Put Calc1 readings in buffer
	CALCulate2	Put Calc2 readings in buffer

Query :FEED? — Query buffer feed

Description This command is used to select the source of readings to be placed in the buffer. With SENSe[1] selected, raw readings are placed in the buffer when storage is performed.

With CALCulate[1] selected, math expression results (Calc1) are placed in the buffer. With CALCulate2 selected, Calc2 readings are placed in the buffer.

TRACe:FEED cannot be changed while buffer storage is active. See Section 8 for more information.

:CONTrol <name>

:TRACe:FEED:CONTrol <name> Start or stop buffer

Parameters <name> = NEXT Fills buffer and stops
NEVer Disables buffer storage

Query :CONTrol? Query buffer control

Description This command is used to select the buffer control. When NEXT is selected, the asterisk (*) annunciator turns on to indicate that the buffer is enabled. The storage process starts when SourceMeter is taken out of idle to perform source-measure operations.

After the buffer stores the specified number of reading arrays (as set by the :POINTs command), the asterisk annuciator turns off to indicate that storage is done.

With NEVer selected, storage into the buffer is disabled.

Select timestamp format

:FORMat <name>

:TRACe:TSTamp:FORMat <name> Select timestamp format

Parameters <name> = ABSolute Reference to first buffer reading
DELTa Time between buffer readings

Query :FORMat? Query timestamp format

Description This command is used to select the timestamp format for buffer readings. With ABSolute selected, each timestamp is referenced to the first reading stored in the buffer. With DELTa selected, timestamps provide the time between each buffer reading.

TRIGger subsystem

The TRIGger subsystem is made up of a series of commands and subsystems to configure the Trigger Model. These commands and subsystems are summarized in Table 17-10.

NOTE *See Section 10 for more details on triggering and the trigger model.*

Clear input triggers

:CLEar

:TRIGger:CLEar — Clear pending input triggers

Description When this action command is sent, any pending (latched) input triggers are cleared immediately. When the SourceMeter is being triggered by another instrument, it may inadvertently receive and latch input triggers that do not get executed. These pending triggers could adversely affect subsequent operation.

When using external triggering, it is recommended that TRIGger:CLEar be sent after sending the ABORt command and at the beginning of a program before sending an initiate command. (See :INITiate command.)

Initiate source/measure cycle

:INITiate

:INITiate[:IMMediate] — Take SourceMeter out of idle state

Description This command is used to initiate source-measure operation by taking the SourceMeter out of idle. The :READ? and :MEASure? commands also perform an initiation.

Note that if auto output-off is disabled (SOURce1:CLEar:AUTO OFF), the source output must first be turned on before an initiation can be performed. The :MEASure? command automatically turns the output source on before performing the initiation.

WARNING **With auto output-off disabled, the source output will remain on after all programmed source-measure operations are completed. Beware of hazardous voltage (30VDC, 42.4 peak-to-peak or more) that may be present on the output terminals.**

With auto output-off enabled, an initiation will start operation immediately. The source output will automatically turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement is completed.

Abort source/measure cycle

:ABORt

Abort operation

Description When this action command is sent, the SourceMeter aborts operation and returns to the idle state.

A faster way to return to idle is to use the DCL or SDC command.

With auto output-off enabled (:SOURce1:CLEar:AUTO ON), the output will remain on if operation is terminated before the output has a chance to automatically turn off.

Program trigger model

:COUNt <n>

:ARM[:SEQuence[1]][LAYer[1]]:COUNt <n> Set arm count
:TRIGger[:SEQuence[1]]:COUNt <n> Set trigger count

Parameters	<n> =	1 to 2500	Specify count (see NOTE)
		DEFault	Sets count to 1
		MINimum	Sets count to 1
		MAXimum	See NOTE
		INFinite	(ARM:COUNt only)

NOTE *The product of arm count and trigger count cannot exceed 2500.*

Query		
	:COUNt?	Queries programmed count
	:COUNt? DEFault	Queries *RST default count
	:COUNt? MINimum	Queries lowest allowable count
	:COUNt? MAXimum	Queries largest allowable count

Description This command is used to specify how many times an operation is performed in the specified layer of the trigger model.

For example, assume the arm count is set to 2 and the trigger counter is set to 10, the SourceMeter is configured to perform 10 source-measure operations twice for a total of 20 source-measure operations.

The product of the arm count and trigger count cannot exceed 2500. If, for example, the arm count is 2, then the maximum trigger count is 1250.

NOTE *INFinite can be used only with ARM:COUNt, and FETCh?, READ?, MEAS?, CALC1:DATA?, or CALC2:DATA? cannot be used with infinite arm count. Only INIT will start measurements, and only interlock, over-temperature, SDC, DCL, or ABORt should be used to stop the sweep.*

ARM:COUNt INFinite can be used for repetitive source waveforms or for long tests where only the last reading is important. For example, the limits could be used to drive the interlock to abort a test when some condition is met. DATA? would then give the answer to the test.

:DELay <n>

:TRIGger[:SEQuence[1]]:DELay <n> — Set trigger layer delay

Parameters

<n> =	0 to 999.9999	Specify delay in seconds
	DEFault	0 second delay
	MINimum	0 second delay
	MAXimum	999.9999 second delay

Query

:DELay?	Query the programmed delay
:DELay? DEFault	Query the *RST default delay
:DELay? MINimum	Query the lowest allowable delay
:DELay? MAXimum	Query the largest allowable delay

Description The delay is used to delay operation in the trigger layer. After the programmed trigger event occurs, the instrument waits until the delay period expires before performing the Device Action.

:SOURce <name>

:ARM[:SEQuence[1]][LAYer[1]]:SOURce <name> — Specify arm event control source
:TRIGger[:SEQuence[1]]:SOURce <name> — Specify trigger event control source

Parameters

<name> =	IMMediate	Pass operation through immediately
	TLINk	Select Trigger Link trigger as event
	TIMer	Select timer as event
	MANual	Select manual event
	BUS	Select bus trigger as event
	NSTest	Select low SOT pulse as event
	PSTest	Select high SOT pulse as event
	BSTest	Select high or low SOT pulse as event

NOTE *Only IMMediate and TLINk are available as trigger layer control sources.*

Query

:SOURce?	Query programmed control source

Description These commands are used to select the event control source. With IMMediate selected, operation immediately continues.

A specific event can be used to control operation. With TLINk selected, operation continues when a trigger pulse is received via the Trigger Link.

NOTE *The following control sources are not available for the trigger layer.*

With TIMer selected, the event occurs at the beginning of the timer interval, and every time it times out. For example, if the timer is programmed for a 30 second interval, the first pass through the control source occurs immediately. Subsequent arm events will then occur every 30 seconds. The interval for the timer is set using the :TIMer command.

With MANual selected, the event occurs when the TRIG key is pressed.

With BUS selected, the event occurs when a GET or *TRG command is sent over the bus.

With NSTESt selected, the event occurs when the SOT (start of test) low pulse is received from a component handler via the Digital I/O port. This is used for limit testing.

With PSTest selected, the event occurs when SOT (start of test) high pulse is received from a component handler via the Digital I/O port. This is used for limit testing.

:TIMer <n>

:ARM[:SEQuence[1]][:LAYer[1]]:TIMer <n> Set interval for arm layer timer

Parameters <n> = 0.001 to 9999.999 Specify timer interval in seconds
10000.00 to 99999.99 Specify timer interval in seconds

Query :TIMer? Query programmed timer interval

Description These commands are used to set the interval for the timer. Note that the timer is in effect only if the timer is the selected control source.

:DIRection <name>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:DIRection <name>Control arm bypass
:TRIGger[:SEQuence[1]][:TCONfigure]:DIRection <name> Control trigger bypass

Parameters <name> = SOURce Enable control source bypass
ACCeptor Disable control source bypass

Query :DIRection? Query state of bypass

Description This command is used to enable (SOURce) or disable (ACCeptor) control source bypass. When enabled, operation will loop around the control source on the first pass in the layer. After that, repeat passes in the layer are held up and will wait for the programmed control source event.

INPut <event list>

:TRIGger[:SEQuence[1]][:TCONfigure][:ASYNchronous]:INPut <event list> Enable event detectors

Parameters <event list> = SOURce Enable Source Event Detector
DELay Enable Delay Event Detector
SENSe Enable Measure Event Detector
NONE Disable all event detectors in Trigger Layer

NOTE *Each event in the list must be separated by a comma (i.e. trigger:input source, delay, sense).*

Query :INPut? Query enabled event detectors in Trigger Layer

Description When TLINk is the selected Trigger Layer control source, and an event detector in the Trigger Layer is enabled, operation will hold up at that detector until an input trigger is received via the Trigger Link. When the event detector is disabled, operation will not hold up. It continues on and performs the appropriate action.

A Trigger Layer event detector is enabled by including the parameter name in the event list for the INPut command. For example, to enable the Source Event Detector and Measure Event Detector, send the following command:

:TRIGger:INPut SOURce, SENSe

The Delay Event Detector will be disabled since the DELay parameter is not included in the above event list.

NOTE *To disable all the Trigger Layer event detectors, the NONE parameter must be sent alone (i.e. trigger:input none). If it is listed with any of the other parameters, NONE will be ignored.*

:ILINe <NRf>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:ILINe <NRf> Select input line; arm layer
:TRIGger[:SEQuence[1]][:TCONfigure]:ILINe <NRf> Select input line; trigger layer

Parameters

<NRf> =	1	Line #1
	2	Line #2
	3	Line #3
	4	Line #4

Query :ILINe? Query input trigger line

Description This command is used to select input lines for the Trigger Link. For normal operation, Trigger Link input and output (see :OLINe) should not share the same line.

:OLINe <NRf>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:OLINe <NRf> Select output line; arm layer
:TRIGger[:SEQuence[1]][:TCONfigure]:OLINe <NRf> Select output line; trigger layer

Parameters

<NRf> =	1	Line #1
	2	Line #2
	3	Line #3
	4	Line #4

Query :OLINe? Query output trigger line

Description This command is used to select output lines for the Trigger Link. For normal operation, Trigger Link input and output (see :ILINe) should not share the same line.

OUTPut <event list>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:OUTPut <event list> Arm layer events
:TRIGger[:SEQuence[1]][:TCONfigure]:OUTPut <event list> Trigger layer events

Parameters

Arm Layer Triggers		
<event list >:	TENTer	Trigger on entering trigger layer
	TEXit	Trigger on exiting trigger layer
	NONE	Disable arm layer output trigger
Trigger Layer Triggers		
<event list>:	SOURce	Output trigger after source level is set
	DELay	Output trigger after delay period
	SENSe	Output Trigger after measurement
	NONE	Disable trigger layer triggers

NOTE *Each event in the list must be separated by a comma (i.e., :arm:output source, delay, sense).*

Query :OUTPut? Query output trigger event(s)

Description This command is used to specify when trigger pulses occur on the specified output trigger line of the Trigger Link (:OLINe).

Arm Layer Triggers — With TEXit selected, an output trigger will occur when exiting the trigger layer. With TENTer selected, an output trigger will occur when entering the trigger layer. With NONE selected, the arm layer output trigger is disabled.

Trigger Layer Triggers — You can specify from one to all three events. Each event in the list must be separated by a comma (,).

The SOURce, DELay and MEASure events refer to the Source-Delay-Measure (SDM) cycle. This is the Device Action in the Trigger Model. See Figures 10-7 and 10-8. With SOURce specified, an output trigger occurs after the source is set. With DELay specified, an output trigger occurs after the delay period. With MEASure specified, an output trigger occurs after the measurement.

NOTE *When disabling triggers, the NONE parameter must be sent alone (i.e., trig:outp none). If it is listed with any of the other event parameters, NONE will be ignored.*

18
Performance Verification

- **Verification Test Requirements** — Summarizes environmental conditions, warm-up period, and line power requirements.
- **Recommended Test Equipment** — Lists all the test equipment needed to perform the verification tests.
- **Verification Limits** — Describes how the verification reading limits are calculated.
- **Performing the Verification Test Procedures** — Details restoring factory defaults and setting ranges and output values.
- **Compliance Considerations** — Discusses the types of compliance and how to take the unit out of compliance.
- **Mainframe Verification** — Covers the procedures necessary to verify accuracy of the mainframe alone *without* the Remote PreAmp.
- **Remote Preamp Verification** — Describes how to verify Remote PreAmp measurement accuracy.

Introduction

Use the procedures in this section to verify that Model 6430 accuracy is within the limits stated in the instrument's one-year accuracy specifications. You can perform these verification procedures:

- When you first receive the instrument to make sure that it was not damaged during shipment.
- To verify that the unit meets factory specifications.
- To determine if calibration is required.
- Following calibration to make sure it was performed properly.

WARNING **The information in this section is intended for qualified service personnel only. Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death if contacted. Use standard safety precautions when working with hazardous voltages.**

The Remote PreAmp connectors carry hazardous voltage. To prevent risk of electric shock, connectors must be fully mated or safety covers must be placed over the open connectors. Proper installation requires that the operator is protected from exposed voltages by insulation or barriers.

NOTE *If the instrument is still under warranty and its performance is outside specified limits, contact your Keithley representative or the factory to determine the correct course of action.*

Verification test requirements

Be sure that you perform the verification tests:

- Under the proper environmental conditions.
- After the specified warm-up period.
- Using the correct line voltage.
- Using the proper test equipment.
- Using the specified output signals and reading limits.

Environmental conditions

Conduct your performance verification procedures in a test environment with:

- An ambient temperature of 18-28°C (65-82°F).
- A relative humidity of less than 60% unless otherwise noted.

Warm-up period

Allow the Model 6430 to warm up for at least one hour before conducting the verification procedures.

If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Also, allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

The Model 6430 requires a line voltage of 100 to 240V and a line frequency of 50 or 60Hz. Verification tests must be performed within this range.

Recommended test equipment

Table 18-1 summarizes recommended verification equipment. You can use alternate equipment as long as that equipment has specifications at least as good as those listed in Table 18-1. Keep in mind, however, that test equipment uncertainty will add to the uncertainty of each measurement. Generally, test equipment uncertainty should be at least four times better than corresponding Model 6430 specifications. Table 18-1 also lists the specifications of the recommended test equipment.

NOTE *Model 5156 Electrometer Calibration Standard uncertainty is less than four times better than Model 6430 specifications. As a result, 1pA-100nA and 2GΩ-200GΩ range reading limits include Model 5156 uncertainty.*

CAUTION **Before testing the 20Ω and 200Ω ohms ranges, make sure your resistance calibrator can safely handle the default test currents for those ranges (100mA and 10mA for the 20Ω and 200Ω ranges, respectively). If not, use the Model 6430 MANUAL ohms mode, and set the test current to the maximum safe calibrator current. Note that Model 6430 measurement accuracy is reduced and reading limits should be recalculated using the additional uncertainty when using MANUAL ohms. See the specifications in Appendix A for details.**

Table 18-1
Recommended verification equipment

Description	Manufacturer/Model	Specifications		
Digital Multimeter[1]	Hewlett Packard HP3458A	DC Voltage	1V: 10V: 100V: 1000V:	5.6ppm 4.3ppm 6.3ppm 6.1ppm
		DC Current	1mA: 10mA: 100mA: 1mA: 10mA: 100mA:	55ppm 25ppm 23ppm 20ppm 20ppm 35ppm
Resistance Calibrator[1]	Fluke 5450A	Resistance	19Ω: 190Ω: 1.9kΩ: 19kΩ: 190kΩ: 1.9MΩ: 19MΩ:	65ppm 10.5ppm 8ppm 7.5ppm 8.5ppm 11.5ppm 30ppm
Electrometer Calibration Standard[2]	Keithley 5156	Resistance	100MΩ 1GΩ 10GΩ 100GΩ	200ppm 300ppm 400ppm 500ppm
Precision Resistors[3]	Any suitable	Resistance	1TΩ 10TΩ	2,000ppm 5,000ppm
Coax Cables (2) Shielded Cables (2) Triax-BNC Adapters Triax-triax Adapters	Keithley 4801 Keithley CA-18-1 Keithley 7078-TRX-GND	Low-noise Dual banana Male/female Male/male		

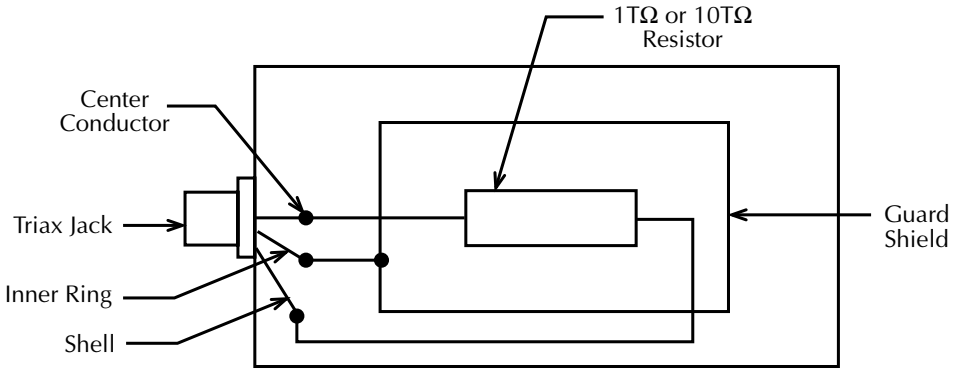
[1]90-day, full-scale DMM accuracy specifications of ranges required for various measurement points.
[2]Characterization accuracy specifications shown for Model 5156.
[3]Resistors should be accurately characterized to uncertainty shown and mounted in a shielded enclosure.

Test resistor construction

The 1TΩ and 10TΩ test resistors used to test the 2TΩ and 20TΩ resistance ranges should be mounted in a shielded, guarded enclosure like the one shown in Figure 18-1. The resistors should be properly characterized to the accuracy stated in Table 18-1 before use. Connect the resistors terminals to the triax jack center conductor and outer shell. Connect the guard shield to the triax jack inner ring.

WARNING **To avoid a shock hazard, do not connect guard to an exposed shield.**

Figure 18-1
Test resistor construction



Verification limits

Most of the verification reading limits stated in this section have been calculated using only the Model 6430 one-year accuracy specifications, and most reading limits do not include test equipment uncertainty. (However, 1pA-100nA and 2GΩ-200GΩ range limits do include the uncertainty of the Model 5156 Electrometer Calibration Standard.) If a particular measurement falls outside the allowable range, recalculate new limits based both on Model 6430 specifications and corresponding test equipment specifications.

Example limits calculation

As an example of how verification limits are calculated, assume you are testing the 20V DC source range using a 20V output value. Using the Model 6430 20V range one-year accuracy specification of ±(0.02% of output + 2.4mV offset), the calculated output limits are:

Output limits = 20V ± [(20V × 0.02%) + 2.4mV]
Output limits = 20V ± (0.004 + 0.0024)
Output limits = 20V ± 0.0064V
Output limits = 19.9936V to 20.0064V

Resistance limits calculation

When verifying the resistance measurement accuracy, it will most likely be necessary to recalculate resistance limits based on the actual calibrator resistance values. You can calculate resistance reading limits in the same manner described above, but be sure to use the actual calibrator resistance values and the Model 6430 normal accuracy specifications for your calculations.

As an example, assume you are testing the 20kΩ range, and that the actual value of the nominal 19kΩ calibrator resistor is 19.01kΩ. Using the Model 6430 20kΩ range one-year normal accuracy specifications of ±(0.063% of reading + 3Ω), the recalculated reading limits are:

Reading limits = 19.01kΩ ± [(19.01kΩ × 0.063%) + 3Ω]
Reading limits = 19.01kΩ ±15Ω
Reading limits = 18.9950kΩ to 19.0250kΩ

Limits calculation with test equipment uncertainty

Reading limits given in this section for the 1pA-100nA and 2GΩ-200GΩ ranges include the characterization accuracy of the Model 5156 Electrometer Calibration Standard. Reading limits for these ranges are calculated as indicated above except that they also take into account Model 5156 uncertainty. For example, using the 1GΩ Model 5156 resistor to test the Model 6430 2GΩ range, we have:

Model 6430 normal accuracy specifications: ±(0.085% + 100kΩ)
Model 5156 1GΩ characterization accuracy: 300ppm (0.03%)

Assuming an actual Model 5156 characterized value of 1.02GΩ, we have:

Reading limits = 1.02GΩ ± [(1.02GΩ × (0.085% + 0.03%)) + 100kΩ]
Reading limits = 1.02GΩ ±1.273MΩ
Reading limits = 1.01873GΩ to 1.02127GΩ

Performing the verification test procedures

Restoring factory defaults

Before performing the verification procedures, restore the instrument to its factory front panel (bench) defaults as follows:

1. Press the MENU key. The instrument will display the following prompt:
   MAIN MENU
   SAVESETUP COMMUNICATION CAL
2. Select SAVESETUP, and then press ENTER. The unit then displays:
   SAVESETUP MENU
   GLOBAL SOURCE-MEMORY

3. Select GLOBAL, and then press ENTER. The unit then displays:
   GLOBAL SETUP MENU
   SAVE RESTORE POWERON RESET
4. Select RESET, and then press ENTER. The unit displays:
   RESET ORIGINAL DFLTS
   BENCH GPIB
5. Select BENCH, and then press ENTER to restore BENCH defaults.

Test summary

- DC voltage output accuracy
- DC voltage measurement accuracy
- DC current output accuracy
- DC current measurement accuracy
- Resistance measurement accuracy

If the Model 6430 is not within specifications and not under warranty, see the calibration procedures in Section 19 for information on calibrating the unit.

Test considerations

When performing the verification procedures:

- Restore factory front panel defaults as previously outlined.
- Make sure that the test equipment is properly warmed up and connected to the Model 6430 jacks.
- Set the Model 6430 to the correct source range. See below.
- Be sure that the Model 6430 output is turned on before making measurements.
- Be sure the test equipment is set up for the proper function and range.
- Allow the Model 6430 output signal to settle before making a measurement.
- Do not connect test equipment to the Model 6430 through a scanner, multiplexer, or other switching equipment.

WARNING **The maximum common-mode voltage (voltage between mainframe LO and chassis ground or PreAmp IN/OUT LOW and chassis ground) is ±42V DC. Exceeding this value may create a shock hazard.**

CAUTION **Exceeding the following voltage values between these terminals may result in instrument damage:**

- **INPUT/OUTPUT HI and LO: 250V peak.**
- **4-WIRE SENSE HI and LO: 250V peak.**
- **INPUT/OUTPUT HI and 4-WIRE SENSE HI: 5V.**
- **INPUT/OUTPUT LO and 4-WIRE SENSE LO: 5V.**
- **Preamp IN/OUT HI or SENSE HI and GUARD: 40V peak.**
- **Preamp GUARD and IN/OUT LOW: 250V peak.**

Setting the source range and output value

Before testing each verification point, you must properly set the source range and output value as outlined below.

1. Press either the SOURCE V or SOURCE I key to select the appropriate source function.
2. Press the EDIT key as required to select the source display field. Note that the cursor will flash in the source field while its value is being edited.
3. With the cursor in the source display field flashing, set the source range to the lowest possible range for the value to be sourced using the RANGE ▲ or ▼ key. For example, you should use the 20V source range to output a 20V source value. With a 20V source value and the 20V range selected, the source field display will appear as follows: Vsrc:+20.0000 V
4. With the source field cursor flashing, set the source output to the required value using either:
   The SOURCE ▲ and ▼ and ◄ and ► keys.
   The numeric keys.
5. Note that the source output value will be updated immediately; you need not press ENTER when setting the source value.

Setting the measurement range

When simultaneously sourcing and measuring either voltage or current, the measure range is coupled to the source range, and you cannot independently control the measure range. Thus, it is not necessary for you to set the measure range when testing voltage or current measurement accuracy.

Compliance considerations

Compliance limits

When sourcing voltage, you can set the unit to limit current from 1fA (with PreAmp) to 105mA. Conversely, when sourcing current, you can set the unit to limit voltage from 0.2mV to 210V. The instrument output will not exceed the programmed compliance limit.

Types of compliance

There are two types of compliance that can occur: “real” and “range.” Depending on which value is lower, the output will clamp at either the displayed compliance setting (“real”) or at the maximum measurement range reading (“range”).

The “real” compliance condition can occur when the compliance setting is less than the highest possible reading of the measurement range. When in compliance, the source output clamps at the displayed compliance value. For example, if the compliance voltage is set to 1V and the measurement range is 2V, the output voltage will clamp (limit) at 1V.

“Range” compliance can occur when the compliance setting is higher than the possible reading of the selected measurement range. When in compliance, the source output clamps at the maximum measurement range reading (not the compliance value). For example, if the compliance voltage is set to 1V and the measurement range is 200mV, the output voltage will clamp (limit) at 210mV.

Maximum compliance values

The maximum compliance values for the measurement ranges are summarized in Table 18-2.

Table 18-2
Maximum compliance values

Measurement range[1]	Maximum compliance value
200mV	210mV
2V	2.1V
20V	21V
200V	210V
1pA	1.05pA
10pA	10.5pA
100pA	105pA
1nA	1.05nA
10nA	10.5nA
100nA	105nA
1µA	1.05µA
10µA	10.5µA
100µA	105µA
1mA	1.05mA
10mA	10.5mA
100mA	105mA

[1] 1pA-100nA ranges with PreAmp.

When the unit goes into compliance, the “Cmpl” label or the units label (i.e., “mA”) for the compliance display will flash.

Determining compliance limit

The relationships to determine which compliance is in effect are summarized as follows. They assume that the measurement function is the same as the compliance function.

- Compliance Setting < Measurement Range = Real Compliance
- Measurement Range < Compliance Setting = Range Compliance

You can determine the compliance that is in effect by comparing the displayed compliance setting to the present measurement range. If the compliance setting is lower than the maximum possible reading on the present measurement range, the compliance setting is the compliance limit. If the compliance setting is higher than the measurement range, the maximum reading on that measurement range is the compliance limit.

Taking the unit out of compliance

Verification measurements should not be made when the unit is in compliance. For purposes of the verification tests, the instrument can be taken out of compliance by going into the edit mode and increasing the compliance limit.

NOTE *Do not take the unit out of compliance by decreasing the source value or changing the range. Always use the recommended range and source settings when performing the verification tests.*

Mainframe verification

Follow the procedures below to verify accuracy of the Model 6430 mainframe without the Remote PreAmp. See *Remote PreAmp verification* later in this section for procedures on verifying the complete unit with the Remote PreAmp.

NOTE *Be sure the Remote PreAmp is completely disconnected from the mainframe before performing these mainframe verification procedures, and replace the safety cap on the mainframe connector.*

Mainframe output voltage accuracy

Follow the steps below to verify that Model 6430 mainframe output voltage accuracy is within specified limits. This test involves setting the output voltage to each full-range value and measuring the voltages with a precision digital multimeter.

1. With the power off, connect the digital multimeter to the Model 6430 INPUT/OUTPUT jacks as shown in Figure 18-2. (Connect Model 6430 INPUT/OUTPUT HI to DMM INPUT HI; INPUT/OUTPUT LO to INPUT LO.)
2. Select the multimeter DC volts measuring function.

3. Press the Model 6430 SOURCE V key to source voltage, and make sure the source output is turned on.
4. Verify output voltage accuracy for each of the voltages listed in Table 18-3. For each test point:
   - Select the correct source range.
   - Set the Model 6430 output voltage to the indicated value.
   - Verify that the multimeter reading is within the limits given in the table.
5. Repeat the procedure for negative output voltages with the same magnitudes as those listed in Table 18-3.

Figure 18-2
Connections for mainframe voltage verification tests

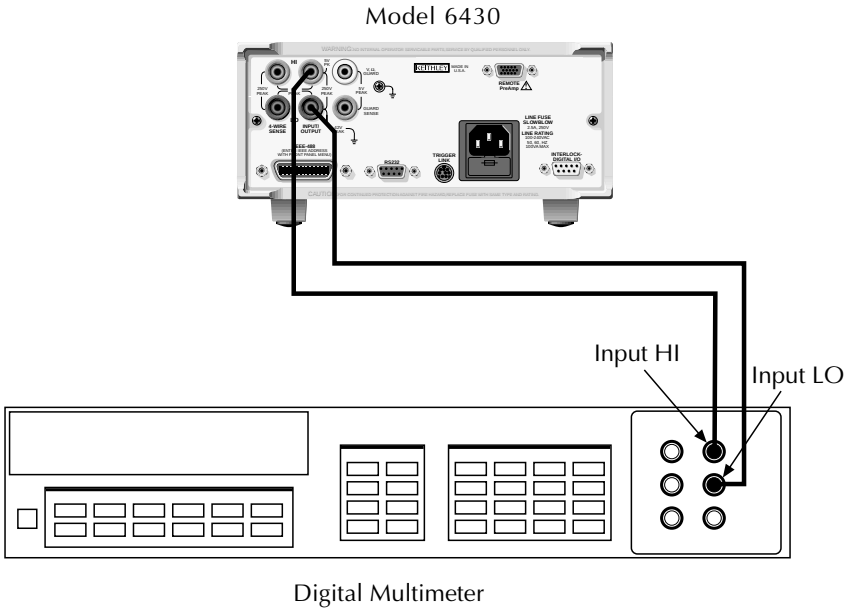


Table 18-3
Mainframe output voltage accuracy limits

Model 6430 source range	**Model 6430 output voltage setting**	**Output voltage limits (1 year, 18°-28°C)**
200mV	200.000mV	199.360 to 200.640mV
2V	2.00000V	1.99900 to 2.00100V
20V	20.0000V	19.9936 to 20.0064V
200V	200.000V	199.936 to 200.064V

Mainframe voltage measurement accuracy

Follow the steps below to verify that Model 6430 mainframe voltage measurement accuracy is within specified limits. The test involves setting the source voltage to full-range values, as measured by a precision digital multimeter, and then verifying that the Model 6430 voltage readings are within required limits.

1. With the power off, connect the digital multimeter to the Model 6430 INPUT/OUTPUT jacks as shown in Figure 18-2. (Connect Model 6430 INPUT/OUTPUT HI to DMM INPUT HI; INPUT OUTPUT LO to INPUT LO.)
2. Select the multimeter DC volts function.
3. Set the Model 6430 to both source and measure voltage by pressing the SOURCE V and MEAS V keys, and make sure the source output is turned on.
4. Verify output voltage accuracy for each of the voltages listed in Table 18-4. For each test point:
   - Select the correct source range.
   - Set the Model 6430 output voltage to the indicated value as measured by the digital multimeter.
   - Verify that the Model 6430 voltage reading is within the limits given in the table.

NOTE *It may not be possible to set the voltage source to the specified value. Use the closest possible setting, and modify reading limits accordingly.*

5. Repeat the procedure for negative source voltages with the same magnitudes as those listed in Table 18-4.

Table 18-4
Mainframe voltage measurement accuracy limits

Model 6430 source and measure range[1]	Source voltage[2]	Model 6430 voltage reading limits (1 year, 18°-28°C)
200mV	200.000mV	199.626 to 200.374mV
2V	2.00000V	1.99941 to 2.00059V
20V	20.0000V	19.9955 to 20.0045V
200V	200.000V	199.960 to 200.040V

[1]Measure range coupled to source range when simultaneously sourcing and measuring voltage.
[2]As measured by precision digital multimeter.

Mainframe output current accuracy

Follow the steps below to verify that Model 6430 output current accuracy is within specified limits. The test involves setting the output current to each full-range value and measuring the currents with a precision digital multimeter.

1. With the power off, connect the digital multimeter to the Model 6430 INPUT/OUTPUT jacks as shown in Figure 18-3. (Connect Model 6430 INPUT/OUTPUT HI to DMM AMPS input; INPUT/OUTPUT LO to INPUT LO.)
2. Select the multimeter DC current measuring function.
3. Press the Model 6430 SOURCE I key to source current, and make sure the source output is turned on.
4. Verify output current accuracy for the currents listed in Table 18-5. For each test point:
   - Select the correct source range.
   - Set the Model 6430 output current to the correct value.
   - Verify that the multimeter reading is within the limits given in the table.
5. Repeat the procedure for negative output currents with the same magnitudes as those listed in Table 18-5.

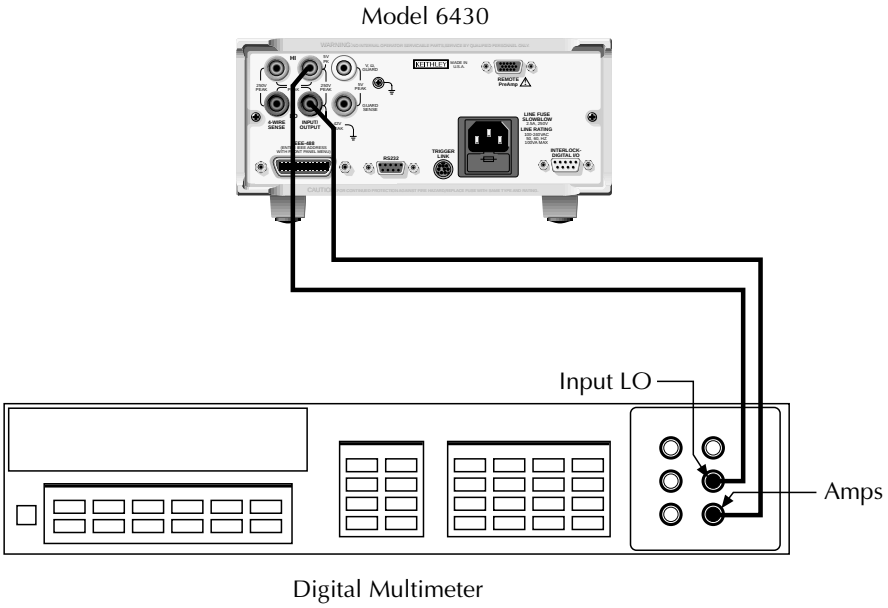


Figure 18-3
Connections for mainframe current verification tests

Table 18-5
Mainframe output current accuracy limits

Model 6430 source range	**Model 6430 output current setting**	**Output current limits (1 year, 18°-28°C)**
1µA	1.00000µA	0.99905 to 1.00095µA
10µA	10.0000µA	9.9947 to 10.0053µA
100µA	100.000µA	99.949 to 100.051µA
1mA	1.00000mA	0.99946 to 1.00054mA
10mA	10.0000mA	9.9935 to 10.0065mA
100mA	100.000mA	99.914 to 100.086mA

Mainframe current measurement accuracy

Follow the steps below to verify that Model 6430 mainframe current measurement accuracy is within specified limits. The procedure involves applying accurate currents from the Model 6430 current source and then verifying that Model 6430 current measurements are within required limits.

1. With the power off, connect the digital multimeter to the Model 6430 INPUT/OUTPUT jacks as shown in Figure 18-3. (Connect Model 6430 INPUT/OUTPUT HI to DMM AMPS input; INPUT/OUTPUT LO to INPUT LO.)
2. Select the multimeter DC current function.
3. Set the Model 6430 to both source and measure current by pressing the SOURCE I and MEAS I keys, and make sure the source output is turned on.
4. Verify measure current accuracy for the currents listed in Table 18-6. For each measurement:
   - Select the correct source range.
   - Set the Model 6430 source output to the correct value as measured by the digital multimeter.
   - Verify that the Model 6430 current reading is within the limits given in the table.

NOTE *It may not be possible to set the current source to the specified value. Use the closest possible setting, and modify reading limits accordingly.*

5. Repeat the procedure for negative calibrator currents with the same magnitudes as those listed in Table 18-6.

Table 18-6
Mainframe current measurement accuracy limits

Model 6430 source and measure range[1]	**Source current[2]**	**Model 6430 current reading limits (1 year, 18°-28°C)**
1µA	1.000000µA	0.99920 to 1.00080µA
10µA	10.00000µA	9.9930 to 10.0070µA
100µA	100.000µA	99.969 to 100.031µA
1mA	1.00000mA	0.99967 to 1.00033mA
10mA	10.0000mA	9.9959 to 10.0041mA
100mA	100.000mA	99.939 to 100.061mA

[1]Measure range coupled to source range when simultaneously sourcing and measuring current.
[2]As measured by precision digital multimeter.

Mainframe resistance measurement accuracy

Use the following steps to verify that Model 6430 resistance measurement accuracy is within specified limits. This procedure involves applying accurate resistances from a resistance calibrator and then verifying that Model 6430 resistance measurements are within required limits.

NOTE *Before making resistance measurements, put the Model 6430 in the AUTO SOURCE mode (press CONFIG, then Ω, select SOURCE, select AUTO, then press ENTER).*

CAUTION **Before testing the 20Ω and 200Ω ohms ranges, make sure your resistance calibrator can safely handle the default test currents for those ranges (100mA and 10mA for the 20Ω and 200Ω ranges respectively). If not, use the Model 6430 MANUAL ohms mode, and set the test current to the maximum safe calibrator current. Note that Model 6430 measurement accuracy is reduced and reading limits should be recalculated using the additional uncertainty when using MANUAL ohms. See the specifications in Appendix A for details.**

1. With the power off, connect the resistance calibrator to the Model 6430 INPUT/ OUTPUT and 4-WIRE SENSE jacks as shown in Figure 18-4. Be sure to use the 4-wire connections as shown.

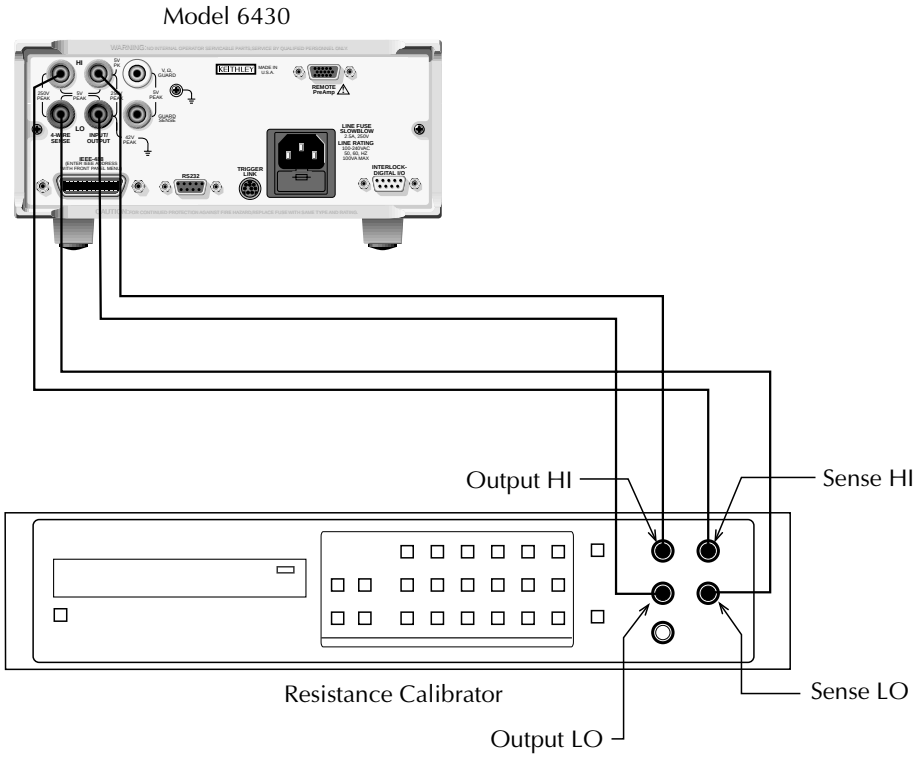


Figure 18-4
Connections for mainframe resistance accuracy verification

2. Select the resistance calibrator external sense mode.
3. For the Model 6430, select the auto ohms measurement method.
4. Press MEAS Ω to select the ohms measurement function, and make sure the source output is turned on.
5. Verify ohms measurement accuracy for each of the resistance values listed in Table 18-7. For each measurement:
   - Set the resistance calibrator output to the nominal resistance or closest available value.

NOTE *It may not be possible to set the resistance calibrator to the specified value. Use the closest possible setting, and modify reading limits accordingly.*

   - Select the appropriate ohms measurement range with the RANGE keys.
   - Verify that the Model 6430 resistance reading is within the limits given in the table.

Table 18-7
Mainframe resistance measurement accuracy limits

Model 6430 range	Calibrator resistance[1]	Model 6430 resistance reading limits[2] (1 year, 18°-28°C)
20Ω	19Ω	18.9784 to 19.0216Ω
200Ω	190Ω	189.824 to 190.176Ω
2kΩ	1.9kΩ	1.89845 to 1.90155kΩ
20kΩ	19kΩ	18.9850 to 19.0150kΩ
200kΩ	190kΩ	189.814 to 190.186kΩ
2MΩ	1.9MΩ	1.89814 to 1.90186MΩ
20MΩ	19MΩ	18.9829 to 19.0171MΩ

[1]Nominal resistance value.
[2]Reading limits based on Model 6430 normal accuracy specifications and nominal resistance values. If actual resistance values differ from nominal values shown, recalculate reading limits using actual calibrator resistance values and Model 6430 normal accuracy specifications. See *Verification limits* earlier in this section for details.

Remote PreAmp verification

Follow the procedures below to verify accuracy of the Model 6430 with the Remote PreAmp.

NOTE *Be sure the Remote PreAmp MAINFRAME connector is connected to the mainframe REMOTE PreAmp connector before performing these Remote PreAmp verification procedures.*

Connecting Remote PreAmp to the mainframe

WARNING **Potentially hazardous source voltage is routed from the mainframe to the Remote PreAmp via the PreAmp cable. Adhere to the following safety precautions to prevent electric shock:**

- **The SourceMeter must be turned off before connecting (or disconnecting) the Remote PreAmp to the mainframe.**
- **When not using the Remote PreAmp, disconnect the PreAmp cable at the PreAmp connector on the mainframe. DO NOT leave the PreAmp cable connected to the mainframe if the other end is not connected to the Remote PreAmp.**
- **ALWAYS re-install the plastic safety cover onto the mainframe PreAmp connector whenever the Remote PreAmp is not being used.**

Use the supplied PreAmp cable to connect the Remote PreAmp to the mainframe as follows:

1. From the front panel of the SourceMeter, turn the POWER off.
2. Connect the PreAmp cable to the Remote PreAmp. The PreAmp connector on the Remote PreAmp is labeled “MAINFRAME.”
3. At the rear panel of the mainframe, remove the plastic safety cover from the PreAmp connector. This PreAmp connector is labeled “REMOTE PreAmp.” The plastic cover is secured to the connector with two screws. Hold on to the plastic cover and the retaining screws. Whenever the Remote PreAmp is not being used, the plastic safety cover must be re-installed on the mainframe PreAmp connector.
4. Connect the other end of the PreAmp cable to the mainframe.

Remote PreAmp output voltage accuracy

Follow the steps below to verify that Model 6430 Remote PreAmp output voltage accuracy is within specified limits. This test involves setting the output voltage to each full-range value and measuring the voltages with a precision digital multimeter.

1. With the power off, connect the digital multimeter to the Remote PreAmp IN/OUT HIGH jack as shown in Figure 18-5. (Connect the IN/OUT HIGH jack to the DMM INPUT HI and LO jacks using the adapters and coax cable as shown.)

NOTE *Use the type of triax-to-BNC adapter that connects triax shell to BNC shell. Also be sure that the cable shield is connected to DMM INPUT LO.*

2. Select the SourceMeter 10µA measurement range.
3. Select the multimeter DC volts measuring function.
4. Press the Model 6430 SOURCE V key to source voltage, and make sure the source output is turned on.

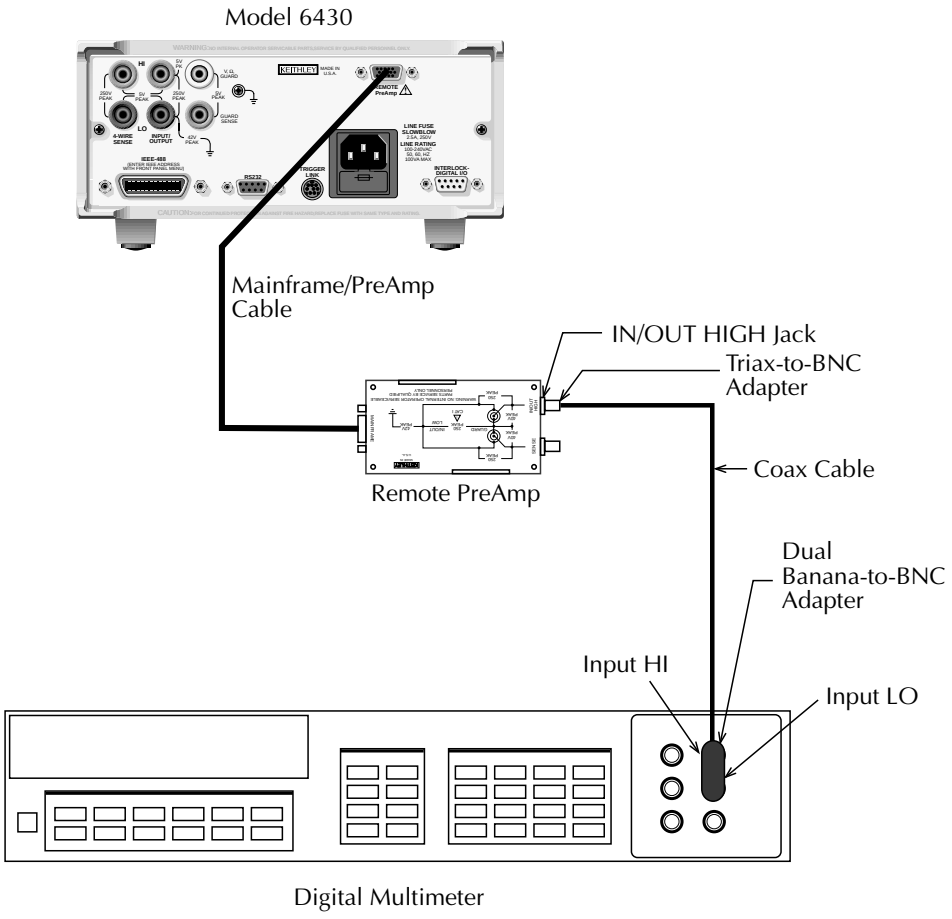


Figure 18-5 *Connections for Remote PreAmp voltage verification tests*

5. Verify output voltage accuracy for each of the voltages listed in Table 18-8. For each test point:
   - Select the correct source range.
   - Set the Model 6430 output voltage to the indicated value.
   - Verify that the multimeter reading is within the limits given in the table.
6. Repeat the procedure for negative output voltages with the same magnitudes as those listed in Table 18-8.

Table 18-8
Remote PreAmp output voltage accuracy limits

Model 6430 source range	Model 6430 output voltage setting	Output voltage limits (1 year, 18°-28°C)
200mV	200.000mV	199.360 to 200.640mV
2V	2.00000V	1.99900 to 2.00100V
20V	20.0000V	19.9936 to 20.0064V
200V	200.000V	199.936 to 200.064V

Remote PreAmp voltage measurement accuracy

Follow the steps below to verify that Model 6430 Remote PreAmp voltage measurement accuracy is within specified limits. The test involves setting the source voltage to full-range values, as measured by a precision digital multimeter, and then verifying that the Model 6430 voltage readings are within required limits.

1. With the power off, connect the digital multimeter to the PreAmp IN/OUT HIGH jack as shown in Figure 18-5. (Connect the IN/OUT HIGH jack to the DMM INPUT HI and LO jacks using the adapters and coax cable as shown.)
2. Select the SourceMeter 10µA measurement range.
3. Select the multimeter DC volts function.
4. Set the Model 6430 to both source and measure voltage by pressing the SOURCE V and MEAS V keys, and make sure the source output is turned on.
5. Verify output voltage accuracy for each of the voltages listed in Table 18-9. For each test point:
   - Select the correct source range.
   - Set the Model 6430 output voltage to the indicated value as measured by the digital multimeter.
   - Verify that the Model 6430 voltage reading is within the limits given in the table.

NOTE *It may not be possible to set the voltage source to the specified value. Use the closest possible setting, and modify reading limits accordingly.*

6. Repeat the procedure for negative source voltages with the same magnitudes as those listed in Table 18-9.

Table 18-9
Remote PreAmp voltage measurement accuracy limits

Model 6430 source and measure range[1]	Source voltage[2]	Model 6430 voltage reading limits (1 year, 18°-28°C)
200mV	200.000mV	199.626 to 200.374mV
2V	2.00000V	1.99941 to 2.00059V
20V	20.0000V	19.9955 to 20.0045V
200V	200.000V	199.960 to 200.040V

[1]Measure range coupled to source range when simultaneously sourcing and measuring voltage.
[2]As measured by precision digital multimeter.

Remote PreAmp output current accuracy

Follow the steps below to verify that Model 6430 Remote PreAmp output current accuracy is within specified limits. The test involves setting the output current to each full-range value and measuring the currents with a precision digital multimeter.

1µA-100mA range accuracy

1. With the power off, connect the digital multimeter to the Model 6430 Remote PreAmp IN/OUT HIGH jack as shown in Figure 18-6. (Connect the IN/OUT HIGH jack to the DMM AMPS and INPUT LO jacks using the adapters shown. Use a triax-to-BNC adapter that connects triax shell to BNC shell, and be sure to connect the cable shield to DMM INPUT LO.)
2. Select the multimeter DC current measuring function.
3. Press the Model 6430 SOURCE I key to source current, and make sure the source output is turned on.
4. Verify output current accuracy for the currents listed in Table 18-10. For each test point:
   - Select the correct source range.
   - Set the Model 6430 output current to the correct value.
   - Verify that the multimeter reading is within the limits given in the table.
5. Repeat the procedure for negative output currents with the same magnitudes as those listed in Table 18-10.

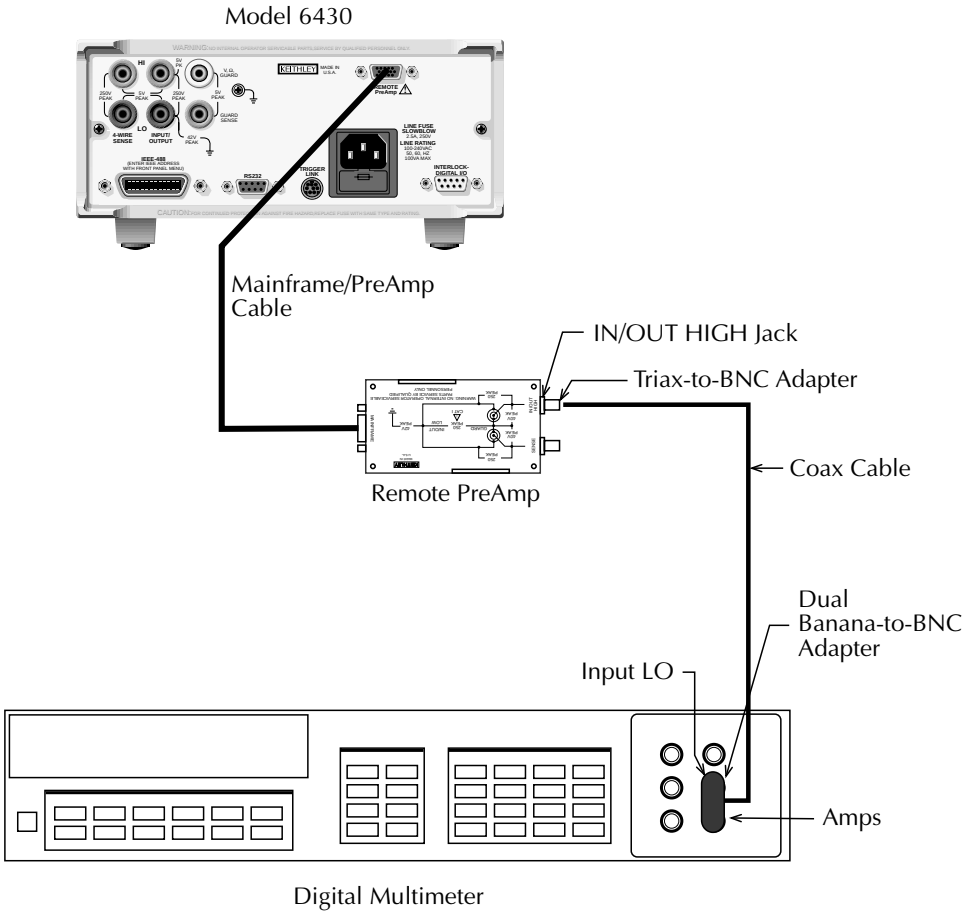


Figure 18-6
Connections for 1µA-100mA range current verification tests

Table 18-10
Remote PreAmp 1µA-100mA range output current accuracy limits

Model 6430 source range	Model 6430 output current setting	Output current limits (1 year, 18°-28°C)
1µA	1.00000µA	099920 to 1.00080µA
10µA	10.0000µA	9.9930 to 10.0070µA
100µA	100.000µA	99.949 to 100.051µA
1mA	1.00000mA	0.99946 to 1.00054mA
10mA	10.0000mA	9.9935 to 10.0065mA
100mA	100.000mA	99.914 to 100.086mA

1pA-100nA range accuracy

1. With the power off, connect the digital multimeter and calibration standard to the Model 6430 mainframe and Remote PreAmp as shown in Figure 18-7. (Connect the mainframe INPUT/OUTPUT HI and LO jacks to DMM INPUT HI and LO respectively. Connect the PreAmp IN/OUT HIGH jack directly to the Model 5156 OUTPUT jack, and connect the BNC shorting cap to the 100GΩ resistance jack. **Also be sure to remove the link between the Model 5156 SHIELD and CHASSIS jacks.**)

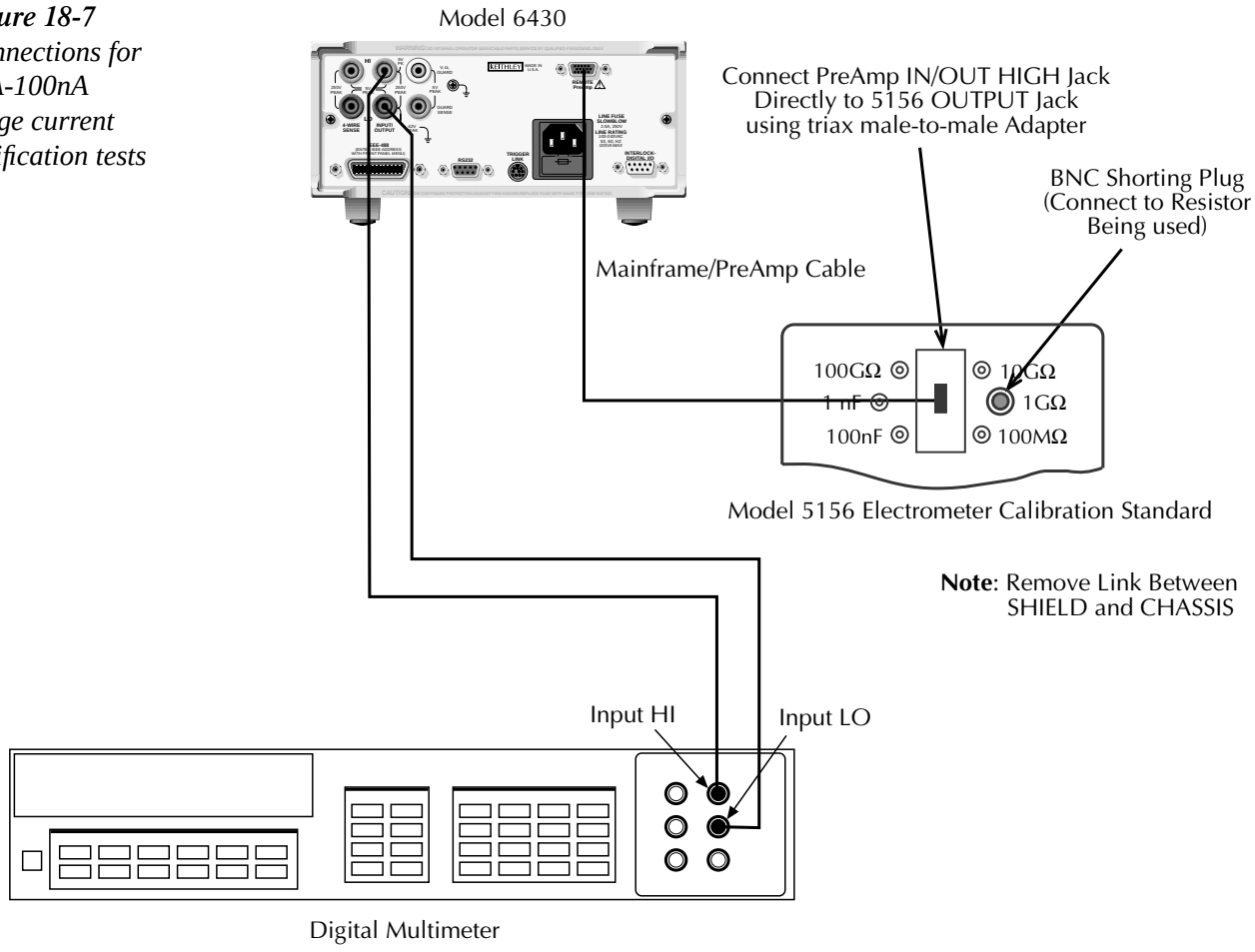


Figure 18-7
Connections for 1pA-100nA range current verification tests

2. Select the multimeter DC current measuring function.
3. Press the Model 6430 SOURCE I key to source current, and make sure the source output is turned on.
4. Verify output current accuracy for the currents listed in Table 18-11. For each test point:
   - Connect the BNC shorting cap to the appropriate Model 5156 resistance jack.
   - Select the correct source range.
   - Set the Model 6430 output current to the correct value.
   - Calculate the current from the DMM reading and actual resistance value: I=V/R.
   - Verify that the calculated current is within the limits given in the table.
5. Repeat the procedure for negative output currents with the same magnitudes as those listed in Table 18-11.

Table 18-11
Remote PreAmp 1pA-100nA range output current accuracy limits

Model 6430 source range	**Standard resistor[1]**	**Model 6430 output current setting**	**Output current limits (1 year, 18°-28°C)[2]**
1pA	100GΩ	1.00000pA	0.97950 to 1.02050pA
10pA	100GΩ	10.0000pA	9.9150 to 10.0085pA
100pA	10GΩ	100.000pA	99.770 to 100.230pA
1nA	1GΩ	1.00000nA	0.99900 to 1.00100nA
10nA	1GΩ	10.0000nA	9.9990 to 10.0100nA
100nA	100MΩ	100.000nA	99.910 to 100.090nA

[1]Nominal Model 5156 values. Use characterized values in calculations.
[2]Calculated from DMM voltage reading and actual standard resistance value: I = V/R. Limits shown include Model 5156 characterization accuracy.

Remote PreAmp current measurement accuracy

Follow the steps below to verify that Model 6430 Remote PreAmp current measurement accuracy is within specified limits. The procedure involves applying accurate currents from the Model 6430 current source and then verifying that Model 6430 current measurements are within required limits.

1µA-100mA range accuracy

1. With the power off, connect the digital multimeter to the PreAmp IN/OUT HIGH jack as shown in Figure 18-6. (Connect the IN/OUT HIGH jack to the DMM AMPS and INPUT LO jacks using the adapters shown. Use a triax-to-BNC adapter that connects triax shell to BNC shell, and be sure to connect the cable shield to DMM INPUT LO.)
2. Select the multimeter DC current function.
3. Set the Model 6430 to both source and measure current by pressing the SOURCE I and MEAS I keys, and make sure the source output is turned on.
4. Verify measure current accuracy for the currents listed in Table 18-12. For each measurement:
   - Select the correct source range.
   - Set the Model 6430 source output to the correct value as measured by the digital multimeter.
   - Verify that the Model 6430 current reading is within the limits given in the table.

NOTE *It may not be possible to set the current source to the specified value. Use the closest possible setting, and modify reading limits accordingly.*

5. Repeat the procedure for negative calibrator currents with the same magnitudes as those listed in Table 18-12.

Table 18-12
Remote PreAmp 1µA-100mA range measurement accuracy limits

Model 6430 range[1]	Source current[2]	Model 6430 current reading limits (1 year, 18°-28°C)
1µA	1.000000µA	0.99920 to 1.00080µA
10µA	10.00000µA	9.9930 to 10.0070µA
100µA	100.000µA	99.969 to 100.031µA
1mA	1.00000mA	0.99967 to 1.00033mA
10mA	10.0000mA	9.9959 to 10.0041mA
100mA	100.000mA	99.939 to 100.061mA

[1]Measure range coupled to source range when simultaneously sourcing and measuring current.
[2]As measured by precision digital multimeter. Use closest possible value, and modify reading limits accordingly if necessary.

1pA-100nA range accuracy

1. With the power off, connect the digital multimeter and calibration standard to the mainframe and PreAmp as shown in Figure 18-7. (Connect the mainframe INPUT/OUTPUT HI and LO jacks to DMM INPUT HI and LO respectively. Connect the PreAmp IN/OUT HIGH jack directly to the Model 5156 OUTPUT jack, and connect the BNC shorting cap to the 100GΩ resistance jack. **Also be sure to remove the link between the Model 5156 SHIELD and CHASSIS jacks.**)
2. Select the multimeter DC current function.
3. Set the Model 6430 to both source and measure current by pressing the SOURCE I and MEAS I keys, and make sure the source output is turned on.
4. Verify measure current accuracy for the currents listed in Table 18-13. For each measurement:
   - Connect the BNC shorting cap to the correct Model 5156 resistance jack.
   - Select the correct source range.
   - Calculate the current from the DMM reading and actual standard resistance: I = V/R.
   - Set the Model 6430 source output to the calculated current.
   - Verify that the Model 6430 current reading is within the limits given in the table.

NOTE *It may not be possible to set the current source to the specified value. Use the closest possible setting, and modify reading limits accordingly.*

5. Repeat the procedure for negative currents with the same magnitudes as those listed in Table 18-13.

Table 18-13
Remote PreAmp 1pA-100nA range measurement accuracy limits

Model 6430 range	Standard resistor[1]	Source current	Model 6430 current reading limits (1 year, 18°-28°C)[2]
1pA	100GΩ	1.000000pA	0.98300 to 1.01700pA
10pA	100GΩ	10.00000pA	9.9430 to 10.0570pA
100pA	10GΩ	100.000pA	99.820 to 100.180pA
1nA	1GΩ	1.00000nA	0.99930 to 1.00070nA
10nA	1GΩ	10.0000nA	9.9930 to 10.0070nA
100nA	100MΩ	100.000nA	99.930 to 100.070nA

[1]Nominal values. Use characterized values in current calculations.
[2]Calculated from DMM reading and nominal resistance values. Use closest value, and modify reading limits accordingly. Limits shown include Model 5156 characterization uncertainty.

Remote PreAmp resistance measurement accuracy

Use the following steps to verify that Model 6430 Remote PreAmp resistance measurement accuracy is within specified limits. This procedure involves applying accurate resistances from a resistance calibrator or standard resistor and then verifying that Model 6430 resistance measurements are within required limits.

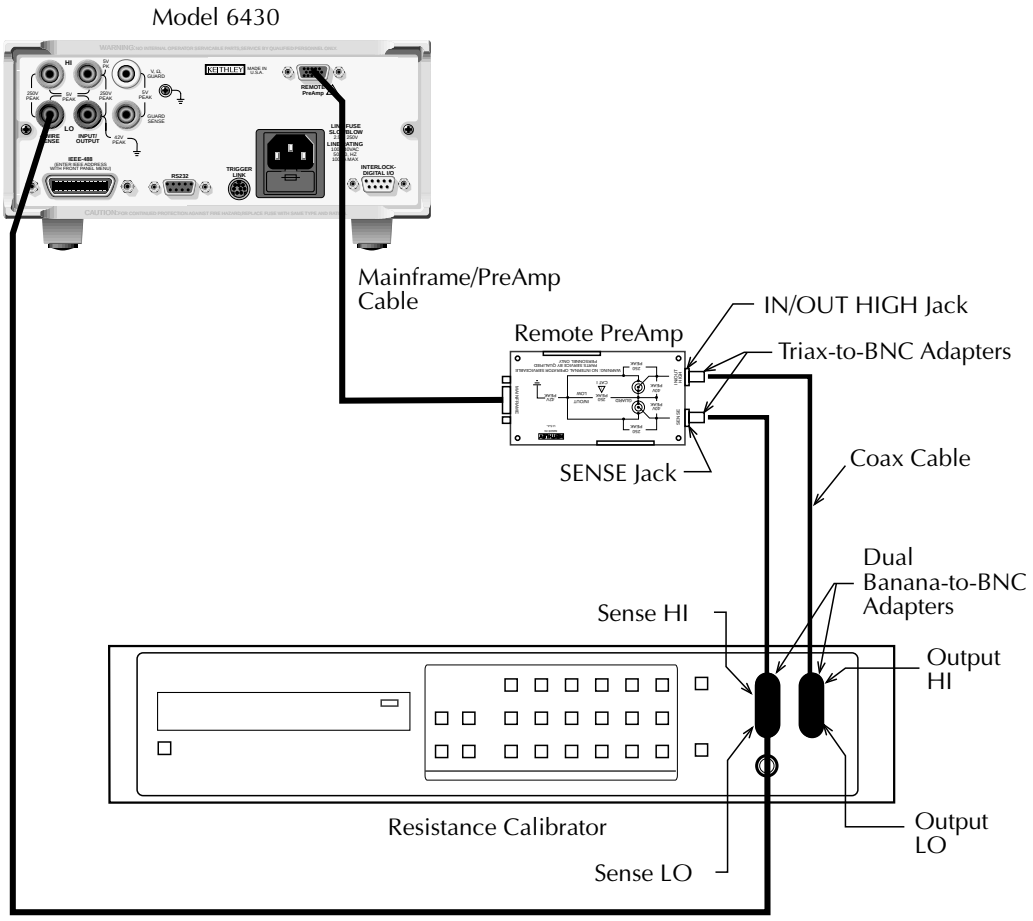
NOTE *Before making resistance measurements, put the Model 6430 in the AUTO SOURCE mode (press CONFIG, then Ω, select SOURCE, select AUTO, then press ENTER).*

CAUTION **Before testing the 20Ω and 200Ω ohms ranges, make sure your resistance calibrator can safely handle the default test currents for those ranges (100mA and 10mA for the 20Ω and 200Ω ranges respectively). If not, use the Model 6430 MANUAL ohms mode, and set the test current to the maximum safe calibrator current. Note that Model 6430 measurement accuracy is reduced and reading limits should be recalculated using the additional uncertainty when using MANUAL ohms. See the specifications in Appendix A for details.**

20Ω-200MΩ range accuracy

1. With the power off, connect the Remote PreAmp IN/OUT HIGH and SENSE jacks to the resistance calibrator as shown in Figure 18-8. (Connect PreAmp IN/OUT HIGH to calibrator OUTPUT; PreAmp SENSE to calibrator SENSE using the adapters and cables shown.)
2. Select the resistance calibrator external sense mode.
3. Press MEAS Ω to select the ohms measurement function, and make sure the source output is turned on.

Figure 18-8
Connections for Remote PreAmp 20Ω-200MΩ range verification



4. Verify ohms measurement accuracy for each of the resistance values listed in Table 18-14. For each measurement:
   - Set the resistance calibrator output to the nominal resistance or closest available value.

NOTE *It may not be possible to set the resistance calibrator to the specified value. Use the closest possible setting, and modify reading limits accordingly.*

   - Select the appropriate ohms measurement range with the RANGE keys.
   - Verify that the Model 6430 resistance reading is within the limits given in the table.

Table 18-14
Remote PreAmp 20Ω-200MΩ range measurement accuracy limits

Model 6430 range	Calibrator resistance[1]	Model 6430 resistance reading limits[2] (1 year, 18°-28°C)
20Ω	19Ω	18.9784 to 19.0216Ω
200Ω	190Ω	189.824 to 190.176Ω
2kΩ	1.9kΩ	1.89845 to 1.90155kΩ
20kΩ	19kΩ	18.9850 to 19.0150kΩ
200kΩ	190kΩ	189.814 to 190.186kΩ
2MΩ	1.9MΩ	1.89814 to 1.90186MΩ
20MΩ	19MΩ	18.9829 to 19.0171MΩ
200MΩ	100MΩ	99.905 to 100.095MΩ

[1]Nominal resistance value.
[2]Reading limits based on Model 6430 normal accuracy specifications and nominal resistance values. If actual resistance values differ from nominal values shown, recalculate reading limits using actual calibrator resistance values and Model 6430 normal accuracy specifications. See *Verification limits* earlier in this section for details.

2GΩ-200GΩ range accuracy

1. With the power off, connect the Remote PreAmp IN/OUT HIGH jack directly to the Model 5156 OUTPUT jack as shown in Figure 18-9. (Use male triax-to-triax adapters. **Also, be sure to remove the link between Model 5156 SHIELD and CHASSIS, and connect the BNC shorting cap to the resistance cap being used.**)

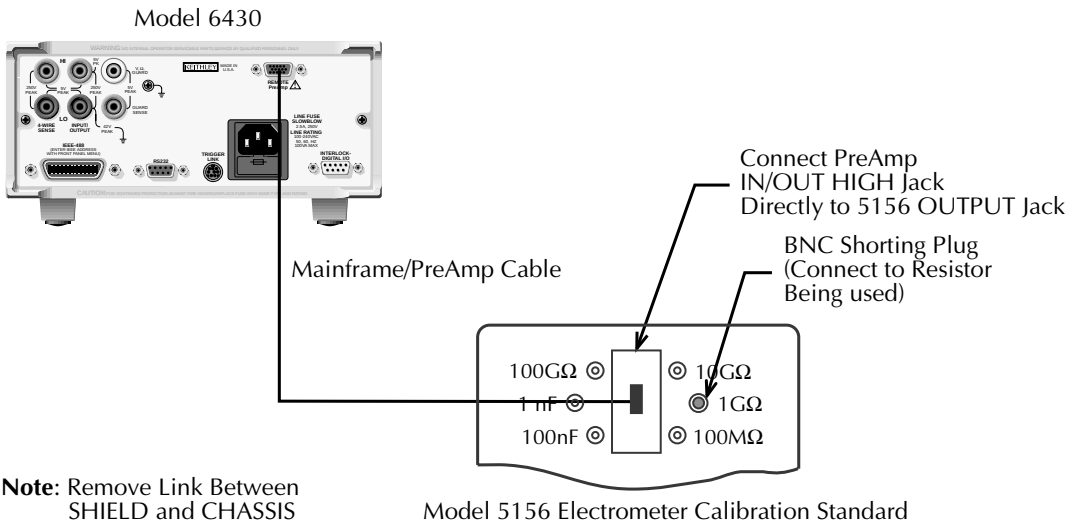


Figure 18-9
Connections for Remote PreAmp 2GΩ-200GΩ range verification

2. Connect the Model 6430 ohms function for the 2-wire sense and configure guard mode as follows:
   - Press CONFIG then MEAS Ω. The instrument will display the following:
     CONFIG OHMS
     SOURCE GUARD
   - Select GUARD, and then press ENTER. The following will be displayed:
     GUARD
     OHMS CABLE
   - Select CABLE, and then press ENTER.
   - Press EXIT to return to normal display.

WARNING **Hazardous voltage may be present on SHIELD when using guarding.**

3. Press MEAS Ω to select the ohms measurement function, and make sure the source output is turned on.

4. Verify ohms measurement accuracy for each of the resistance values listed in Table 18-15. For each measurement:
   - Connect the BNC shorting cap to select the appropriate resistance value.
   - Select the appropriate ohms measurement range with the RANGE keys.
   - Verify that the Model 6430 resistance reading is within the limits given in the table.

Table 18-15
Remote PreAmp 2GΩ-200GΩ range measurement accuracy limits

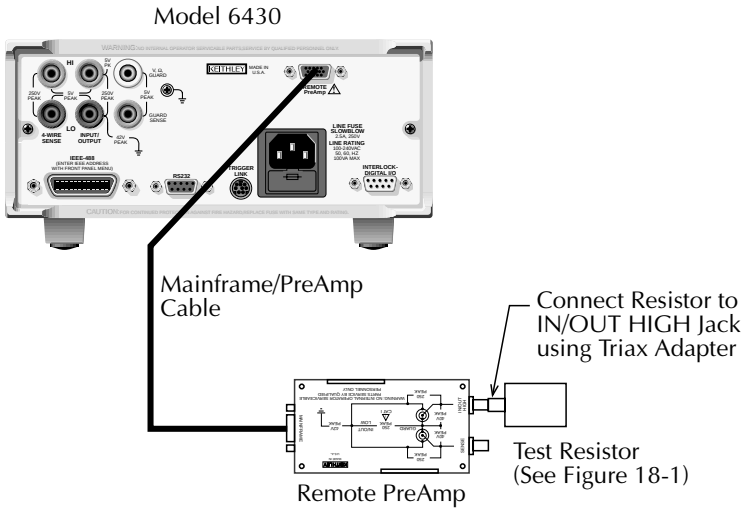
Model 6430 range	Standard resistance[1]	Model 6430 resistance reading limits[2] (1 year, 18°-28°C)
2GΩ	1GΩ	0.99875 to 1.00125GΩ
20GΩ	10GΩ	9.9865 to 10.0135GΩ
200GΩ	100GΩ	99.735 to 100.265GΩ

[1]Nominal values shown. Use characterized values.
[2]Calculated using Model 6430 normal accuracy specifications and Model 5156 nominal values. Limits include Model 5156 characterization accuracy.

2TΩ and 20TΩ range accuracy

1. With the power off, connect the characterized 1TΩ resistor directly to the Remote PreAmp IN/OUT HIGH jack as shown in Figure 18-10. (Use a male triax-to-triax adapter.)

Figure 18-10
Connections for Remote PreAmp 2TΩ and 20TΩ range verification



2. Configure the Model 6430 ohms function for the 2-wire sense and guard modes as follows:
   - Press CONFIG then MEAS Ω. The instrument will display the following:
     CONFIG OHMS
     SOURCE GUARD
   - Select GUARD, and then press ENTER. The following will be displayed:
     GUARD
     OHMS CABLE
   - Select CABLE, and then press ENTER.
   - Press EXIT to return to normal display.

WARNING **Hazardous voltage may be present on SHIELD when using guarding.**

3. Press MEAS Ω to select the ohms measurement function, and make sure the source output is turned on.
4. Verify ohms measurement accuracy for each of the resistance values listed in Table 18-16. For each measurement:
   - Connect the correct standard resistance directly to the IN/OUT HIGH jack.
   - Select the appropriate ohms measurement range with the RANGE keys.
   - Verify that the Model 6430 resistance reading is within the limits given in the table.

Table 18-16
Remote PreAmp 2TΩ and 20TΩ range measurement accuracy limits

Model 6430 range	**Standard resistance[1]**	**Model 6430 resistance reading limits[2] (1 year, 18°-28°C)**
2TΩ	1TΩ	0.99168 to 1.00832TΩ
20TΩ	10TΩ	9.7930 to 10.2070Ω

[1]Nominal values shown.
[2]Calculated using Model 6430 normal accuracy specifications and nominal resistance values.

19 Calibration

- **Environmental Conditions —** Covers the temperature and humidity, warm-up period, and line power required for calibration.
- **Calibration Considerations —** Lists important considerations that should be observed when calibrating the unit.
- **Recommended Calibration Equipment —** Provides a list of recommended test equipment required for calibration.
- **Unlocking Calibration —** Gives the procedure for unlocking calibration and lists calibration unlocked states.
- **Mainframe Calibration —** Includes procedures to calibrate the Model 6430 mainframe without the Remote PreAmp.
- **Remote PreAmp Calibration —** Outlines procedures to calibrate the mainframe and Remote PreAmp together as a unit.
- **Changing the Password —** Details how to change the password.
- **Viewing Calibration Dates and Count —** Describes how to view calibration dates and calibration count.

Introduction

Use the procedures in this section to calibrate both the Model 6430 mainframe and the Remote PreAmp. These procedures require accurate test equipment to measure precise DC voltages and currents.

NOTE *Mainframe and Remote PreAmp calibration are performed separately. The mainframe must be calibrated before the Remote PreAmp.*

WARNING **This information in this section is intended for qualified service personnel only. Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages.**

The Remote PreAmp connectors carry hazardous voltage. To prevent risk of electric shock, connectors must be fully mated or safety covers must be placed over the open connectors. Proper installation requires that the operator is protected from exposed voltages by insulation or barriers.

Environmental conditions

Temperature and relative humidity

Conduct the calibration procedures at an ambient temperature of 18-28°C (65-82°F) with relative humidity of less than 60% unless otherwise noted.

Warm-up period

Allow the Model 6430 to warm up for at least one hour before performing calibration.

If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Also, allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

The Model 6430 requires a line voltage of 100 to 240V at line frequency of 50 or 60Hz. The instrument must be calibrated while operating from a line voltage within this range.

Calibration considerations

When performing the calibration procedures:

- Make sure that the test equipment is properly warmed up and connected to the correct Model 6430 mainframe or Remote PreAmp jacks as appropriate.
- Always allow the source signal to settle before calibrating each point.
- Do not connect test equipment to the Model 6430 through a scanner or other switching equipment.
- If an error occurs during calibration, the Model 6430 will generate an appropriate error message.

WARNING **The maximum common-mode voltage (voltage between mainframe LO and chassis ground or PreAmp IN/OUT LOW and chassis ground) is ±42V DC. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.**

CAUTION **Exceeding the following voltage values between these terminals may result in instrument damage:**

- **INPUT/OUTPUT HI and LO: 250V peak.**
- **4-WIRE SENSE HI and LO: 250V peak.**
- **INPUT/OUTPUT HI and 4-WIRE SENSE HI: 5V.**
- **INPUT/OUTPUT LO and 4-WIRE SENSE LO: 5V.**
- **Preamp IN/OUT HIGH or SENSE HI and GUARD: 40V peak.**
- **Preamp GUARD and IN/OUT LOW: 250V peak.**

Calibration cycle

Perform calibration at least once a year to ensure the unit meets or exceeds its specifications.

Recommended calibration equipment

Table 19-1 lists the recommended equipment for the calibration procedures. You can use alternate equipment as long that equipment has specifications at least as good as those listed in the table.

NOTE *For optimum calibration accuracy, test equipment specifications should be at least four times better than corresponding Model 6430 specifications. The Model 5156 Electrometer Calibration Standard, however, does not meet these requirements. As a result, Model 6430 1pA-100nA and 2GΩ-200GΩ range accuracy specifications will be relative to Model 5156 characterization accuracy.*

Table 19-1
Recommended calibration equipment

Description	**Manufacturer/Model**	**Specifications**		
Digital Multimeter[1]	Hewlett Packard HP3458A	DC Voltage	1V: 10V: 100V: 1000V:	5.6ppm 4.3ppm 6.3ppm 6.1ppm
		DC Current	1µA: 10µA: 100µA: 1mA: 10mA: 100mA:	55ppm 25ppm 23ppm 20ppm 20ppm 35ppm
Electrometer Calibration Standard[2]	Keithley 5156	Resistance	100MΩ 1GΩ 10GΩ 100GΩ	200ppm 300ppm 400ppm 500ppm
Coax Cable Shielded Cable Triax-BNC Adapter Triax-triax Adapter BNC-banana Adapter Triax Shield Cap	Keithley 4801 Keithley CA-18-1 Keithley 7078-TRX-GND Pomona 1269 Keithley CAP-31	Low-noise Dual banana Male/female Male/male		

[1]90-day, full-scale DMM accuracy specifications of ranges required for various measurement points.
[2]Characterization accuracy specifications shown for Model 5156.

Unlocking calibration

Before performing calibration, you must first unlock calibration as follows:

1. Press the MENU key, and then choose CAL, and press ENTER. The instrument will display the following:
   CALIBRATION
   UNLOCK EXECUTE VIEW-DATES
   SAVE LOCK CHANGE-PASSWORD
2. Select UNLOCK, and then press ENTER. The instrument will display the following:
   PASSWORD:
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
3. Use the up and down RANGE keys to select the letter or number, and use the left and right arrow keys to choose the position. (Press down RANGE for letters; up RANGE for numbers.) Enter the present password on the display. (Front panel default: 006430.)
4. Once the correct password is displayed, press the ENTER key. If the password was correctly entered, the following message will be displayed:
   CALIBRATION UNLOCKED
   Calibration can now be executed.
5. Press EXIT to return to normal display. Calibration will be unlocked and assume the states summarized in Table 19-2. Attempts to change any of the settings listed below with calibration unlocked will result in an error +510, “Not permitted with cal unlocked.”

NOTE *With calibration unlocked, the sense function and range track the source function and range.*

Table 19-2
Calibration unlocked states

Mode	State	Mode	State
Concurrent Functions	OFF	Source I Mode	FIXED
Sense Function	Source	Current Autorange	OFF
Sense Volts NPLC	10	Autozero	ON
Sense Volts Range	Source V	Trigger Arm Count	1
Sense Current NPLC	10	Trigger Arm Source	Immediate
Sense Current Range	Source I	Trigger Count	1
Source V Mode	FIXED	Trigger Source	Immediate
Volts Autorange	OFF		

Mainframe calibration

Use the procedures discussed below to calibration the mainframe without the Remote PreAmp. See *Remote PreAmp calibration* later in this section for information in calibrating the Remote PreAmp.

NOTE *The mainframe must be separately calibrated before calibrating the Remote PreAmp.*

Mainframe calibration menu

You can access the calibration menu by pressing the MENU key and then selecting CAL in the main menu. Mainframe calibration menu selections include:

- UNLOCK: Enables calibration.
- EXECUTE: Allows you to execute the calibration procedure for the selected function and range.
- VIEW-DATES: Displays calibration and calibration due dates.
- SAVE: Saves new calibration constants.
- LOCK: Disables calibration.
- CHANGE-PASSWORD: Allows you to change the calibration password.

Mainframe calibration procedure

The mainframe calibration procedure described below calibrates all ranges of both the current and voltage source and measure functions. (Resistance calibration is not required.) Note that each range is separately calibrated by repeating the entire procedure for each range.

Step 1: Prepare the Model 6430 for calibration

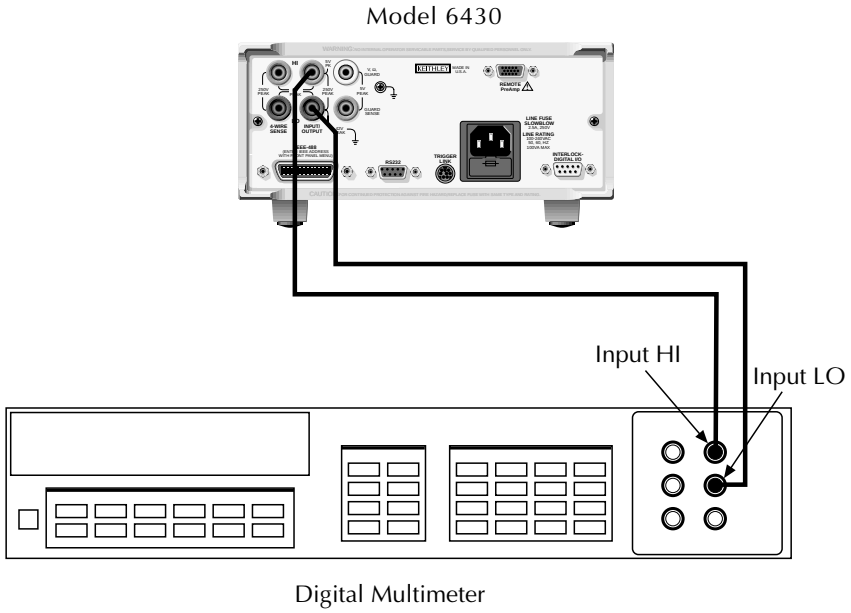
1. With the power off, disconnect the Remote PreAmp from the mainframe.
2. Turn on the Model 6430 and the digital multimeter, and allow them to warm up for at least one hour before performing calibration.
3. Press the MENU key, then choose CAL and press ENTER. Select UNLOCK, and then press ENTER. The instrument will display the following:
   PASSWORD:
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
4. Use the up and down range keys to select the letter or number, and use the left and right arrow keys to choose the position. Enter the present password on the display. (Front panel default: 006430.) Press ENTER to complete the process.
5. Press EXIT to return to normal display. Instrument operating states will be set as summarized in Table 19-2.

Step 2: Voltage calibration

Perform the steps below for each voltage range using Table 19-3 as a guide.

1. Connect the Model 6430 to the digital multimeter as shown in Figure 19-1. (Connect Model 6430 INPUT/OUTPUT HI to DMM INPUT HI; INPUT/OUTPUT LO to DMM INPUT LO.) Select the multimeter DC volts measurement function.

Figure 19-1
Mainframe voltage calibration test connections



2. From normal display, press the SOURCE V key.
3. Press the EDIT key to select the source field (cursor flashing in source display field), and then use the down RANGE key to select the 200mV source range.
4. From normal display, press MENU.
5. Select CAL, and then press ENTER. The unit will display the following:
   CALIBRATION
   UNLOCK EXECUTE VIEW-DATES 4
   3 SAVE LOCK CHANGE-PASSWORD
6. Select EXECUTE, and then press ENTER. The instrument will display the following message:
   V-CAL
   Press ENTER to Output +200.00mV
7. Press ENTER. The Model 6430 will source +200mV and simultaneously display the following:
   DMM RDG: +200.0000mV
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.

8. Note and record the DMM reading, and then adjust the Model 6430 display to agree exactly with the actual DMM reading. Use the up and down arrow keys to select the digit value, and use the left and right arrow keys to choose the digit position (or use the number keys, 0-9, +/-). Note that the display adjustment range is within ±10% of the present range.
9. After adjusting the display to agree with the DMM reading, press ENTER. The instrument will then display the following:
   V-CAL
   Press ENTER to Output +000.00mV
10. Press ENTER. The Model 6430 will source 0mV and at the same time display the following:
    DMM RDG: +000.0000mV
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
11. Note and record the DMM reading, and then adjust the Model 6430 display to agree with the actual DMM reading. Note that the display value adjustment limits are within ±1% of the present range.
12. After adjusting the display value to agree with the DMM reading, press ENTER. The unit will then display the following:
    V-CAL
    Press ENTER to Output -200.00mV
13. Press ENTER. The Model 6430 will source -200mV and display the following:
    DMM RDG: -200.0000mV
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
14. Note and record the DMM reading, and then adjust the Model 6430 display to agree with the DMM reading. Again, the maximum display adjustment is within ±10% of the present range.
15. After adjusting the display value to agree with the DMM reading, press ENTER and note that the instrument displays:
    V-CAL
    Press ENTER to Output +000.00mV
16. Press ENTER The Model 6430 will source 0mV and simultaneously display the following:
    DMM RDG: +000.0000mV
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
17. Note and record the DMM reading, and then adjust the display to agree with the DMM reading. Once again, the maximum adjustment is within ±1% of the present range.
18. After adjusting the display to agree with the DMM reading, press ENTER to complete calibration of the present range.
19. Press EXIT to return to normal display, and then select the 2V source range. Repeat steps 2 through 18 for the 2V range.
20. After calibrating the 2V range, repeat the entire procedure for the 20V and 200V ranges using Table 19-3 as a guide. Be sure to select the appropriate source range with the EDIT and RANGE keys before calibrating each range.
21. Press EXIT as necessary to return to normal display.

Table 19-3
Mainframe voltage calibration summary

Source range[1]	Source voltage	Multimeter voltage reading[2]
0.2V	+200.00mV	_____ mV
	+000.00mV	_____ mV
	-200.00mV	_____ mV
	+000.00mV	_____ mV
2V	+2.0000V	_____ V
	+0.0000V	_____ V
	-2.0000V	_____ V
	+0.0000V	_____ V
20V	+20.000V	_____ V
	+00.000V	_____ V
	-20.000V	_____ V
	+00.000V	_____ V
200V	+200.00V	_____ V
	+000.00V	_____ V
	-200.00V	_____ V
	+000.00V	_____ V

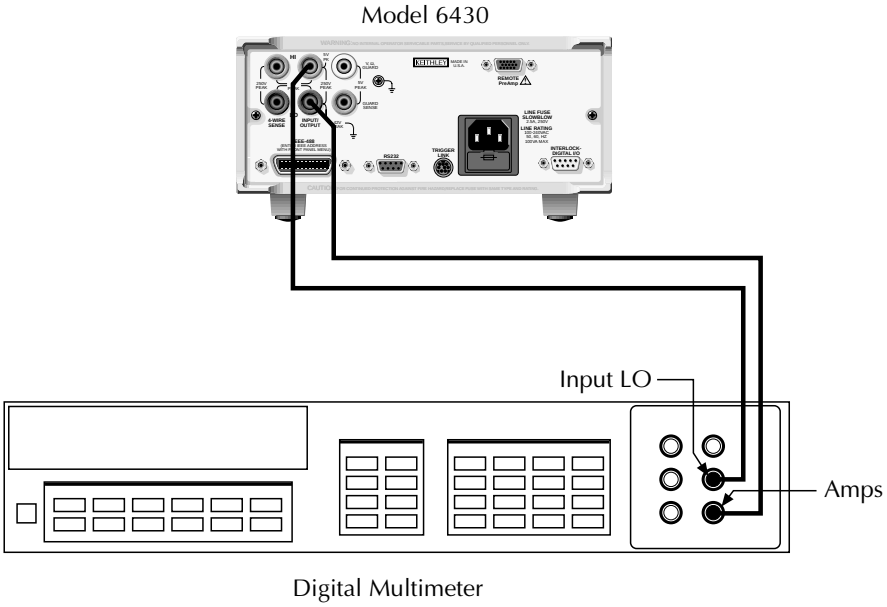
[1]Use EDIT and RANGE keys to select source range.
[2]Multimeter reading used in corresponding calibration step. See procedure.

Step 3: Current calibration

Perform the steps below for each current range using Table 19-4 as a guide.

1. Connect the Model 6430 to the digital multimeter as shown in Figure 19-2. (Connect Model 6430 INPUT/OUTPUT HI to the DMM AMPS input; INPUT/OUTPUT LO to DMM INPUT LO.) Select the multimeter DC current measurement function.

Figure 19-2
Mainframe current calibration connections



2. From normal display, press the SOURCE I key.
3. Press the EDIT key to select the source display field, and then use the down RANGE key to select the 1µA source range.
4. From normal display, press MENU.
5. Select CAL, and then press ENTER. The unit will display the following:
   CALIBRATION
   UNLOCK EXECUTE VIEW-DATES ▶
   ◀ SAVE LOCK CHANGE-PASSWORD
6. Select EXECUTE, and then press ENTER. The instrument will display the following message:
   I-CAL
   Press ENTER to Output +1.0000µA
7. Press ENTER. The Model 6430 will source +1µA and simultaneously display the following:
   DMM RDG: +1.000000µA
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
8. Note and record the DMM reading, and then adjust the Model 6430 display to agree exactly with the actual DMM reading. Use the up and down arrow keys to select the digit value, and use the left and right arrow keys to choose the digit position (or use the

number keys, 0-9, +/-). Note that the display adjustment range is within ±10% of the present range.

9. After adjusting the display to agree with the DMM reading, press ENTER. The instrument will then display the following:
   I-CAL
   Press ENTER to Output +0.0000µA
10. Press ENTER. The Model 6430 will source 0µA and at the same time display the following:
    DMM RDG: +0.000000µA
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
11. Note and record the DMM reading, and then adjust the Model 6430 display to agree with the actual DMM reading. Note that the display value adjustment limits are within ±1% of the present range.
12. After adjusting the display value to agree with the DMM reading, press ENTER. The unit will then display the following:
    I-CAL
    Press ENTER to Output -1.0000µA
13. Press ENTER. The Model 6430 will source -1µA and display the following:
    DMM RDG: -1.000000µA
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
14. Note and record the DMM reading, and then adjust the Model 6430 display to agree with the DMM reading. Again, the maximum display adjustment is within ±10% of the present range.
15. After adjusting the display value to agree with the DMM reading, press ENTER and note that the instrument displays:
    I-CAL
    Press ENTER to Output +0.0000µA
16. Press ENTER. The Model 6430 will source 0µA and simultaneously display the following:
    DMM RDG: +0.000000µA
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
17. Note and record the DMM reading, and then adjust the display to agree with the DMM reading. Once again, the maximum adjustment is within ±1% of the present range.
18. After adjusting the display to agree with the DMM reading, press ENTER to complete calibration of the present range.
19. Press EXIT to return to normal display, and then select the 10µA source range use the EDIT and up RANGE keys. Repeat steps 2 through 18 for the 10µA range.
20. After calibrating the 10µA range, repeat the entire procedure for the 100µA through 100mA ranges using Table 19-4 as a guide. Be sure to select the appropriate source range with the EDIT and up RANGE keys before calibrating each range.

NOTE *For temporary calibration without saving new calibration constants, proceed to "Step 5: Lock out calibration."*

Step 4: Enter calibration dates and save calibration

1. From normal display, press MENU.
2. Select CAL, and then press ENTER. The Model 6430 will display the following:
   CALIBRATION
   UNLOCK EXECUTE VIEW-DATES ▶
   ◀ SAVE LOCK CHANGE-PASSWORD
3. Select SAVE, and then press ENTER. The unit will display the following message:
   SAVE CAL
   Press ENTER to continue; EXIT to abort calibration sequence
4. Press ENTER. The unit will prompt you for the calibration date:
   CAL DATE: 03/15/1999
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
5. Change the displayed date to today's date, and then press the ENTER key. Press ENTER again to confirm the date.
6. The unit will then prompt for the calibration due date:
   NEXT CAL: 03/15/2000
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.

Table 19-4
Mainframe current calibration summary

Source range[1]	Source current	Multimeter current reading[2]
1µA	+1.0000µA	_____ µA
	+0.0000µA	_____ µA
	-1.0000µA	_____ µA
	+0.0000µA	_____ µA
10µA	+10.000µA	_____ µA
	+00.000µA	_____ µA
	-10.000µA	_____ µA
	+00.000µA	_____ µA
100µA	+100.00µA	_____ µA
	+000.00µA	_____ µA
	-100.00µA	_____ µA
	+000.00µA	_____ µA
1mA	+1.0000mA	_____ mA
	+0.0000mA	_____ mA
	-1.0000mA	_____ mA
	+0.0000mA	_____ mA
10mA	+10.000mA	_____ mA
	+00.000mA	_____ mA
	-10.000mA	_____ mA
	+00.000mA	_____ mA

Table 19-4 (cont.)
Mainframe current calibration summary

Source range[1]	Source current	Multimeter current reading[2]
100mA	+100.00mA	_____ mA
	+000.00mA	_____ mA
	-100.00mA	_____ mA
	+000.00mA	_____ mA

[1]Use EDIT and RANGE keys to select source range.
[2]Multimeter current reading used in corresponding calibration step. See procedure.

7. Set the calibration due date to the desired value, and then press ENTER. Press ENTER again to confirm the date.
8. Once the calibration dates are entered, calibration is complete, and the following message will be displayed:
   CALIBRATION COMPLETE
   Press ENTER to confirm; EXIT to abort
9. Press ENTER to save the calibration data (or press EXIT to abort without saving calibration data.) The following message will be displayed:
   CALIBRATION SUCCESS
   Press ENTER or EXIT to continue.
10. Press ENTER or EXIT to complete process.

Step 5: Lock out calibration

1. From normal display, press MENU.
2. Select CAL, and then press ENTER. The Model 6430 will display the following:
   CALIBRATION
   UNLOCK EXECUTE VIEW-DATES ▶
   ◀ SAVE LOCK CHANGE-PASSWORD
3. Select LOCK, and then press ENTER to lock out calibration.

Remote PreAmp calibration

Use the procedures discussed below to calibrate the Remote PreAmp together with the mainframe.

NOTE *The mainframe must be separately calibrated before calibrating the Remote PreAmp. See "Mainframe calibration" earlier in this section for information on calibrating the mainframe.*

Connecting Remote PreAmp to the mainframe

WARNING **Potentially hazardous source voltage is routed from the mainframe to the Remote PreAmp via the PreAmp cable. Adhere to the following safety precautions to prevent electric shock:**

- **The SourceMeter must be turned off before connecting (or disconnecting) the Remote PreAmp to the mainframe.**
- **When not using the Remote PreAmp, disconnect the PreAmp cable at the PreAmp connector on the mainframe. DO NOT leave the PreAmp cable connected to the mainframe if the other end is not connected to the Remote PreAmp.**
- **ALWAYS re-install the plastic safety cover onto the mainframe PreAmp connector whenever the Remote PreAmp is not being used.**

Use the supplied PreAmp cable to connect the Remote PreAmp to the mainframe as follows:

1. From the front panel of the SourceMeter, turn the POWER off.
2. Connect the PreAmp cable to the Remote PreAmp. The PreAmp connector on the Remote PreAmp is labeled "Mainframe."
3. At the rear panel of the mainframe, remove the plastic safety cover from the PreAmp connector. This PreAmp connector is labeled "REMOTE PreAmp." The plastic cover is secured to the connector with two screws. Hold on to the plastic cover and the retaining screws. Whenever the Remote PreAmp is not being used, the plastic safety cover must be re-installed on the mainframe PreAmp connector.
4. Connect the other end of the PreAmp cable to the mainframe.

Remote PreAmp calibration menu

When the Remote PreAmp is connected to the mainframe, you can access the PreAmp calibration menu by pressing the MENU key and selecting CAL. Menu choices include:

- UNLOCK: Enables Remote PreAmp calibration.
- V-BURDEN: Performs voltage burden calibration.
- GAIN: Performs gain calibration.
- OFFSET: Performs offset calibration.
- LOCK: Locks out Remote PreAmp calibration.
- CHANGE-PASSWORD: Allows you to change the calibration password.

Remote PreAmp calibration procedure

Step 1: Prepare the Model 6430 for calibration

1. With the power off, connect the Remote PreAmp MAINFRAME connector to the mainframe REMOTE PreAmp connector using the supplied cable.
2. Turn on the Model 6430, and allow it to warm up for at least one hour before performing calibration.
3. Press the MENU key, then choose CAL and press ENTER. Select UNLOCK, and then press ENTER. The instrument will display the following:
   PASSWORD:
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
4. Use the up and down range keys to select the letter or number, and use the left and right arrow keys to choose the position. Enter the present password on the display. (Front panel default: 006430.) Press ENTER to complete the process.
5. Press EXIT to return to normal display.

Step 2: Voltage burden calibration.

1. Connect the Model 6430 Remote PreAmp IN/OUT HIGH jack to the digital multimeter INPUT HI and LO jacks using the adapters and cables shown in Figure 19-3. (Use the type of adapter that connects BNC shell to triax shell, and be sure the cable shield is connected to DMM INPUT LO.)
2. Select the multimeter DC volts function, 10 PLCs, and enable auto-range.
3. Select V-BURDEN in the calibration menu, then press ENTER. The unit will prompt you as follows:
   PREAMP V-BURDEN CAL
   Connect V-Meter & press ENTER ▶
4. Press ENTER. The instrument will prompt you for the first of three DMM readings:
   DMM RDG: +000.0000mV
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
5. Using the RANGE keys and EDIT keys, adjust the display to agree with the DMM reading.
6. Press ENTER. The instrument will prompt you for the second DMM reading:
   DMM RDG: +000.0000mV
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.

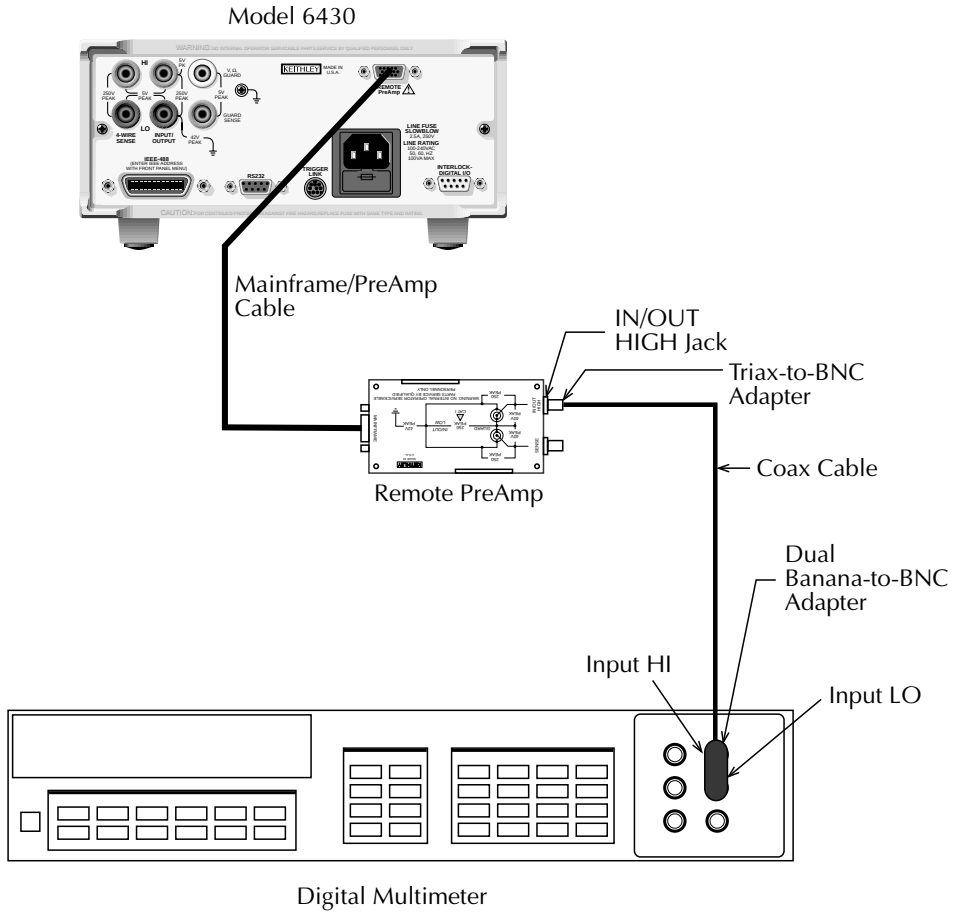


Figure 19-3
Voltage burden calibration connections

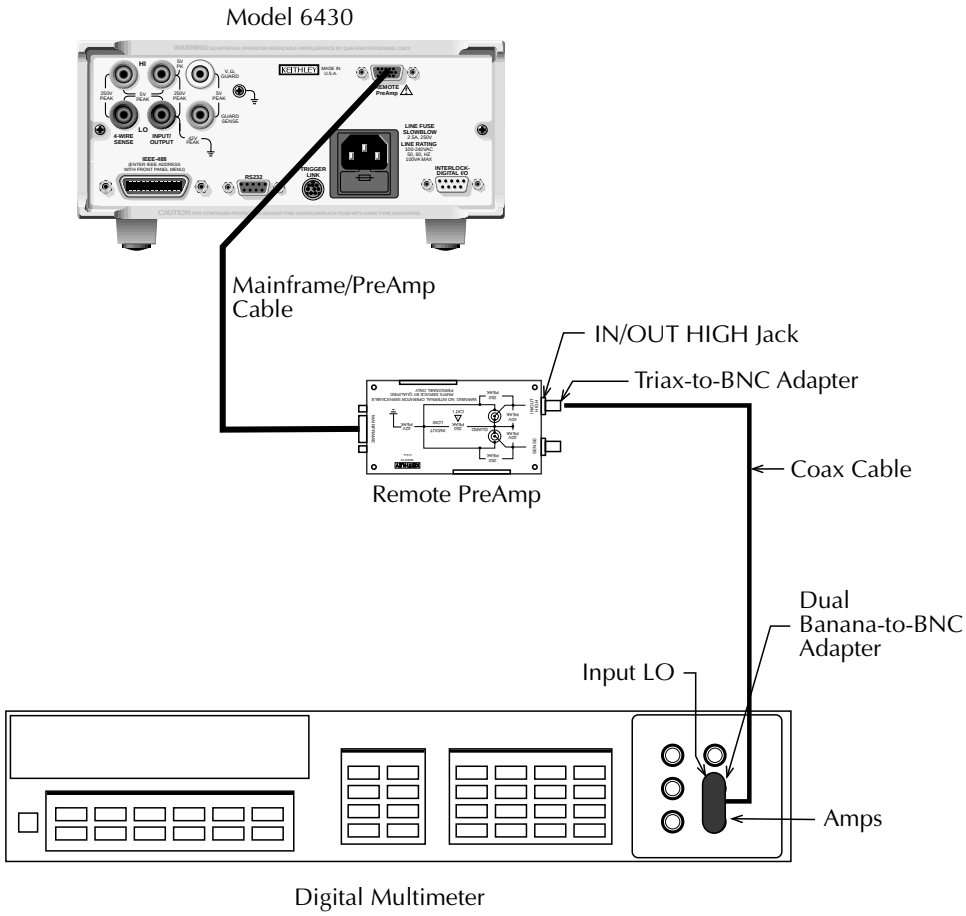
7. Again, adjust the display to agree with the DMM reading.
8. Press ENTER. The instrument will prompt you for the third DMM reading:
   DMM RDG: +000.0000mV
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
9. Adjust the display to agree with the DMM reading, then press ENTER. The unit will return to the calibration menu.

Step 3: Gain calibration

1µA and 10µA ranges

1. Connect the Model 6430 Remote PreAmp IN/OUT HIGH jack to the digital multimeter AMPS and INPUT LO jacks using the adapters and cables shown in Figure 19-4. (Use the type of adapter that connects BNC shell to triax shell, and be sure the cable shield is connected to DMM INPUT LO.)

Figure 19-4
1µA and 10µA range gain calibration connections



2. Select the multimeter DC amps function, 10 PLCs, and enable auto-range.
3. From the calibration menu, select GAIN, then press ENTER. The instrument will prompt you for Remote PreAmp gain calibration:
   PREAMP GAIN CAL
   10mA 1mA 100nA 10nA 1nA ▶
   ◀ 100pA 10pA 1pA
4. Select 10µA, then press ENTER. The unit will prompt you as follows:
   I-CAL
   Press ENTER to Output +00.000µA

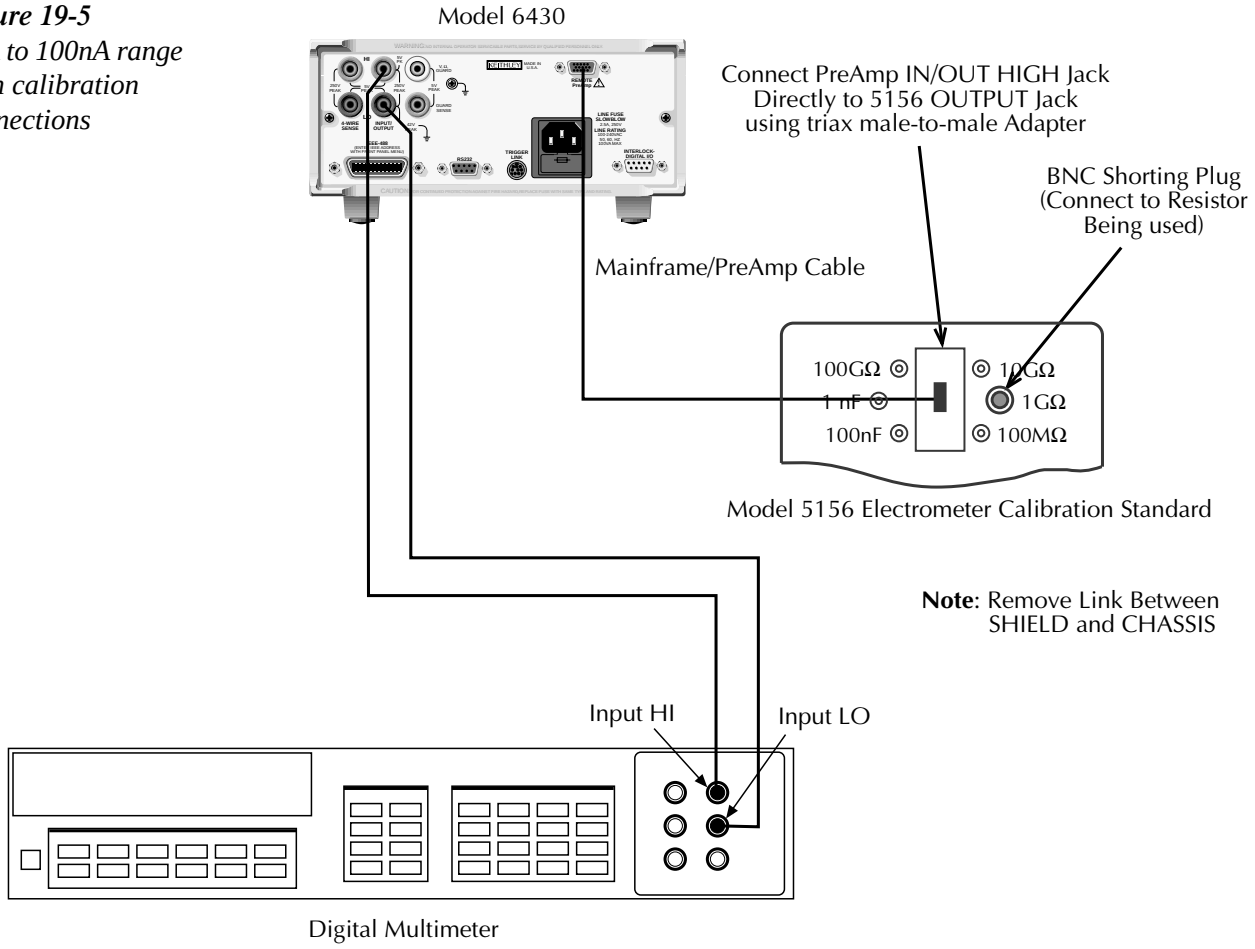
5. Press ENTER. The unit will prompt you for the DMM current reading:
   DMM RDG: +00.00000µA
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
6. Note the DMM current reading, then adjust the Model 6430 display to agree with that value, and press ENTER.
7. The unit will prompt you for the first 85% of full scale output value as follows:
   I-CAL
   Press ENTER to Output +08.50000µA
8. Press ENTER. The unit will prompt you for the DMM current reading:
   DMM RDG: +08.50000µA
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
9. Note the DMM current reading, then adjust the Model 6430 display to agree with that value, and press ENTER.
10. The unit will once prompt you for the second 85% of full scale output value as follows:
    I-CAL
    Press ENTER to Output +08.50000µA
11. Press ENTER. The unit will prompt you for the DMM current reading:
    DMM RDG: +08.50000µA
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
12. Note the DMM current reading, then adjust the Model 6430 display to agree with that value, and press ENTER.
13. Repeat steps 4 through 12 for the 1µA range.

1pA to 100nA ranges

NOTE *Because of Model 5156 characterization accuracy limitations, Model 6430 1pA-100nA range accuracy will be relative to Model 5156 characterization accuracy.*

1. Connect the Model 6430 mainframe and Remote PreAmp to the digital multimeter and calibration standard as shown in Figure 19-5. (Connect mainframe INPUT/OUTPUT HI to DMM INPUT HI and LO respectively. Connect the Remote PreAmp IN/OUT HIGH jack directly to the Model 5156 OUTPUT jack, and connect the BNC shorting cap to the resistance jack being used. Also be sure to remove the link between SHIELD and CHASSIS.)
2. Select the multimeter DC volts function, 10 PLCs, and enable auto-range.
3. From the calibration menu, select GAIN, then press ENTER. The instrument will prompt you for Remote PreAmp gain calibration:
   PREAMP GAIN CAL
   10uA 1uA 100nA 10nA 1nA ▶
   ◀ 100pA 10pA 1pA

Figure 19-5
1pA to 100nA range gain calibration connections



4. From the calibration menu, select GAIN, then press ENTER. The instrument will prompt you for Remote PreAmp gain calibration:
   PREAMP GAIN CAL
   10uA 1uA 100nA 10nA 1nA ▶
   ◀ 100pA 10pA 1pA
5. Select the 100nA range, then press ENTER. The unit will prompt you as follows:
   I-CAL
   Press ENTER to Output +000.00nA
6. Press ENTER. The unit will prompt you for calculated current:
   DMM RDG: +000.0000nA
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
7. Note the DMM voltage reading, then calculate the current from the voltage reading and the actual characterized calibration standard resistance value: I = V/R. Adjust the Model 6430 display to agree with the calculated current value, then press ENTER.
8. The unit will prompt you as follows:
   I-CAL
   Press ENTER to Output +085.00nA

9. Press ENTER. The unit will prompt you for the calculated current:
   DMM RDG: +085.0000nA
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
10. Calculate the current from the DMM voltage reading and resistance value, then adjust the Model 6430 display to agree with the calculated current, and press ENTER.
11. The unit will once again prompt you as follows:
    I-CAL
    Press ENTER to Output +085.00nA
12. Press ENTER. The unit will prompt you for the calculated current:
    DMM RDG: +085.0000nA
    Use ◀, ▲, ▼, ▶, ENTER or EXIT.
13. Calculate the current, then adjust the Model 6430 display to agree with that value, and press ENTER.
14. Repeat steps 4 through 13 for the 10nA - 1pA ranges using the standard resistance values summarized in Table 19-5.

Table 19-5
Standard resistance values for 1pA-100nA gain calibration

Range	Standard resistance[1]	DMM reading[2]	Calibration current[2]
100nA	100MΩ	8.5V	85nA
10nA	1GΩ	8.5V	8.5nA
1nA	10GΩ	8.5V	0.85nA
100pA	100GΩ	8.5V	85pA
10pA	100GΩ	850mV	8.5pA
1pA	100GΩ	8.5mV	0.85pA

[1]Nominal Model 5156 values. Use actual value when calculating current.
[2]Nominal values. Use actual DMM reading and resistance to calculate current: I = V/R

Step 4: Offset calibration

1. Disconnect all cables and test leads connected to the Remote PreAmp or mainframe. However, leave the Remote PreAmp connected to the mainframe REMOTE PreAmp connector.
2. Place the triax shielding cap on the Remote PreAmp FORCE jack.
3. Select OFFSET in the calibration menu, then press ENTER. The unit will display the following:
   PREAMP OFFSET CAL
   ALL BYPASS 10uA 1uA 100nA ▶
4. Select ALL, then press ENTER to calibrate all ranges and the bypass mode. During this process, the instrument will display the range being calibration. For example:
   PREAMP OFFSET CAL
   Now calibrating 1 pA Range.…

5. When the instrument is finished performing offset calibration for all ranges, it will return to the calibration menu.

Step 5: Lock out calibration

1. From the calibration menu, select LOCK, then press ENTER. The instrument will return to the main menu.
2. Press EXIT to return to normal display.

Changing the password

Follow the steps below to change the password:

1. Press the MENU key, then choose CAL and press ENTER. The instrument will display the following:
   CALIBRATION
   UNLOCK EXECUTE VIEW-DATES ▶
   ◀ SAVE LOCK CHANGE-PASSWORD
2. Select UNLOCK, then enter the password. (Default: 006430.)
3. Select CHANGE-PASSWORD, and then press ENTER. The instrument will display the following:
   New Pwd: 006430
   Use ◀, ▲, ▼, ▶, ENTER or EXIT.
4. Using the range keys, and the left and right arrow keys, enter the new password on the display.
5. Once the desired password is displayed, press the ENTER key to store the new password.

Resetting the calibration password

If you lose the calibration password, you can unlock calibration by shorting together the CAL pads, which are located on the display board. Doing so will also reset the password to the factory default (006430).

Viewing calibration dates and calibration count

When calibration is locked, only the UNLOCK and VIEW-DATES selections will be accessible in the mainframe calibration menu. To view calibration dates and calibration count:

1. From normal display, press MENU, select CAL, and then press ENTER. The unit will display the following:
   CALIBRATION
   UNLOCK EXECUTE VIEW-DATES ▶
2. Select VIEW-DATES, and then press ENTER. The Model 6430 will display the next and last calibration dates and the calibration count as in the following example:
   NEXT CAL: 12/15/1999
   Last calibration: 12/15/1999 Count: 0001

20
Routine Maintenance

- **Line Fuse Replacement** — Covers the procedure and recommended part numbers for replacing the line fuse.
- **Front Panel Tests —** Details methods to test the front panel display and keys.

Introduction

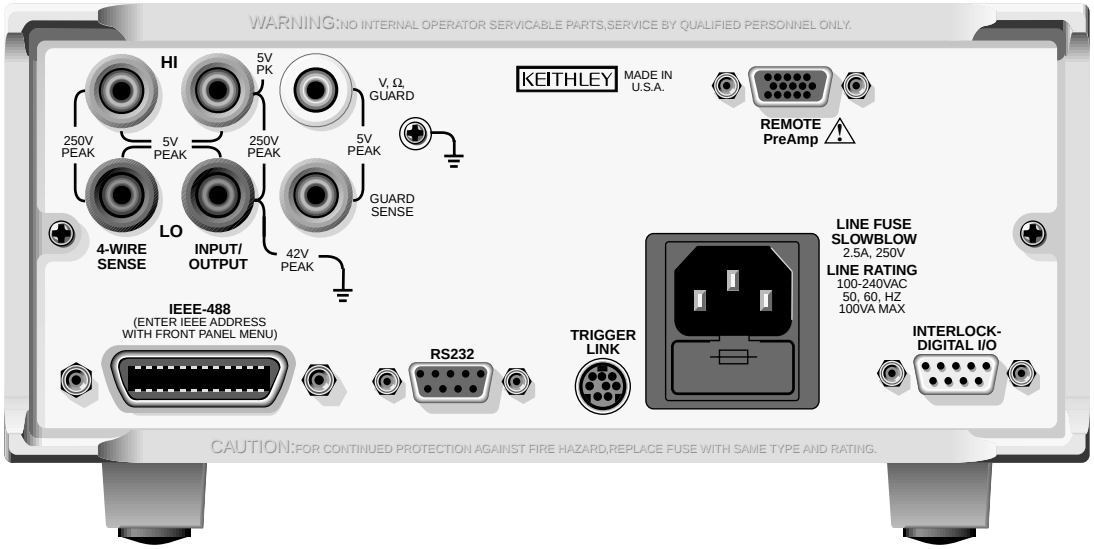
The information in this section deals with routine type maintenance that can be performed by the operator.

Line fuse replacement

WARNING **Disconnect the line cord at the rear panel, and remove all test leads connected to the instrument before replacing the line fuse.**

The power line fuse is accessible from the rear panel, just above the AC power receptacle (Figure 20-1).

Figure 20-1
Rear panel



Perform the following steps to replace the line fuse:

1. Carefully grasp and squeeze together the locking tabs that secure the fuse carrier to the fuse holder.
2. Pull out the fuse carrier, and replace the fuse with the type specified in Table 20-1.

CAUTION **To prevent instrument damage, use only the fuse type specified in Table 20-1.**

3. Reinstall the fuse carrier.

NOTE *If the power line fuse continues to blow, a circuit malfunction exists and must be corrected. Refer to the troubleshooting section of this manual for additional information.*

Table 20-1
Power line fuse

Line voltage	Rating	Keithley part no.
100-240V	250V, 2.5A, Slow Blow 5 × 20mm	FU-72

Front panel tests

There are three front panel tests: one to test the functionality of the front panel keys and two to test the display.

KEYS test

The KEYS test lets you check the functionality of each front panel key. Perform the following steps to run the KEYS test.

1. Display the MAIN MENU by pressing the MENU key.
2. Select TEST, and press ENTER to display the SELF-TEST MENU.
3. Select DISPLAY-TESTS, and press ENTER to display the following menu:
   FRONT PANEL TESTS
   KEYS DISPLAY-PATTERNS CHAR-SET
4. Select KEYS, and press ENTER to start the test. When a key is pressed, the label name for that key will be displayed to indicate that it is functioning properly. When the key is released, the message “No keys pressed” is displayed.
5. Pressing EXIT tests the EXIT key. However, the second consecutive press of EXIT aborts the test and returns the instrument to the SELF-TEST MENU. Continue pressing EXIT to back out of the menu structure.

DISPLAY PATTERNS test

The display test lets you verify that each pixel and annunciator in the vacuum fluorescent display is working properly. Perform the following steps to run the display test:

1. Display the MAIN MENU by pressing the MENU key.
2. Select TEST, and press ENTER to display the SELF-TEST MENU.
3. Select DISPLAY-TESTS, and press ENTER to display the following menu:
   FRONT PANEL TESTS
   KEYS DISPLAY-PATTERNS CHAR-SET
4. Select DISPLAY-PATTERNS, and press ENTER to start the display test. There are five parts to the display test. Each time a front panel key (except EXIT) is pressed, the next part of the test sequence is selected. The five parts of the test sequence are as follows:
   - Checkerboard pattern (alternate pixels on) and all annunciators.
   - Checkerboard pattern and the annunciators that are on during normal operation.
   - Horizontal lines (pixels) of the first digit are sequenced.
   - Vertical lines (pixels) of the first digit are sequenced.
   - Each digit (and adjacent annunciator) is sequenced. All the pixels of the selected digit are on.
5. When finished, abort the display test by pressing EXIT. The instrument returns to the FRONT PANEL TESTS MENU. Continue pressing EXIT to back out of the menu structure.

CHAR SET test

The character set test lets you display all characters. Perform the following steps to run the character set test:

1. Display the MAIN MENU by pressing the MENU key.
2. Select TEST, and press ENTER to display the SELF-TEST MENU.
3. Select DISPLAY-TESTS, and press ENTER to display the following menu:
   FRONT PANEL TESTS
   KEYS DISPLAY-PATTERNS CHAR-SET
4. Select CHAR-SET, and press ENTER to start the character set test. Press any key except EXIT to cycle through all displayable characters.
5. When finished, abort the character set test by pressing EXIT. The instrument returns to the FRONT PANEL TESTS MENU. Continue pressing EXIT to back out of the menu structure.

A
Specifications

SOURCE SPECIFICATIONS[1]

Voltage Programming Accuracy (4-wire sense)[2]

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±% rdg. + volts	Noise (peak-peak) 0.1Hz – 10Hz
200.000 mV	5 µV	0.02% + 600 µV	5 µV
2.00000 V	50 µV	0.02% + 600 µV	50 µV
20.0000 V	500 µV	0.02% + 2.4 mV	500 µV
200.000 V	5 mV	0.02% + 24 mV	5 mV

TEMPERATURE COEFFICIENT (0°–18°C & 28°–40°C): ±(0.15 × accuracy specification)/°C.
MAX. OUTPUT POWER: 2.2W (four quadrant source or sink operation).
SOURCE/SINK LIMITS: ±21V @ ±105mA, ±210V @ ±10.5mA.
VOLTAGE REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 100µV.
NOISE 10Hz–1MHz (p-p): 10mV.
OVER VOLTAGE PROTECTION: User selectable values, 5% tolerance. Factory default = None.
CURRENT LIMIT: Bipolar current limit (compliance) set with single value. Min. 0.1% of range.

Current Programming Accuracy (with remote preamp)

Range	Programming Resolution	Accuracy (1 Year)[1] 23°C ±5°C ±% rdg. +amps	Noise (peak-peak) 0.1Hz – 10Hz
1.00000 pA	50 aA	1.0 % + 10 fA	5 fA
10.0000 pA	500 aA	0.50 % + 30 fA	10 fA
100.000 pA	5 fA	0.15 % + 40 fA	20 fA
1.00000 nA	50 fA	0.050 % + 200 f A	50 fA
10.0000 nA	500 fA	0.050 % + 2 pA	500 fA
100.000 nA	5 pA	0.050 % + 20 pA	3 pA
1.00000 µA	50 pA	0.050 % + 300 pA	20 pA
10.0000 µA	500 pA	0.050 % + 2 nA	200 pA
100.000 µA	5 nA	0.031 % + 20 nA	500 pA
1.00000 mA	50 nA	0.034 % + 200 nA	5 nA
10.0000 mA	500 nA	0.045 % + 2 µA	50 nA
100.000 mA	5 µA	0.066 % + 20 µA	500 nA

Current Programming Accuracy (without remote preamp)

Range	Programming Resolution	Accuracy (1 Year)[1] 23°C ±5°C ±% rdg. +amps	Noise (peak-peak) 0.1Hz – 10Hz
1.00000 µA	50 pA	0.035 % + 600 pA	20 pA
10.0000 µA	500 pA	0.033 % + 2 nA	200 pA
100.000 µA	5 nA	0.031 % + 20 nA	500 pA
1.00000 mA	50 nA	0.034 % + 200 nA	5 nA
10.0000 mA	500 nA	0.045 % + 2 µA	50 nA
100.000 mA	5 µA	0.066 % + 20 µA	50 nA

TEMPERATURE COEFFICIENT (0°–18°C & 28°–40°C): ±(0.15 × accuracy specification)/°C.
MAX. OUTPUT POWER: 2.2W (four quadrant source or sink operation).
SOURCE/SINK LIMITS: ±10.5mA @ 210V, ±105mA @ 21V.
CURRENT REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 1fA.
VOLTAGE LIMIT: Bipolar voltage limit (compliance) set with single value. Min. 0.1% of range.

[1] For sink mode, 1pA to 100mA range, accuracy is ±(0.15% + offset*4).
[2] Voltage source accuracies are not affected by the remote preamp.

ADDITIONAL SOURCE SPECIFICATIONS

COMMAND PROCESSING TIME: Maximum time required for the output to begin to change following the receipt of :SOURce:VOLTage|CURRent <nrf> command.**Autorange On:** 10ms. **Autorange Off:** 7ms.

OUTPUT SETTLING TIME (typical to 10% of final value): <2s, 1pA and 10pA ranges; <50ms, 100pA through 10nA ranges; <5ms, 100nA through 100mA ranges.

OUTPUT SLEW RATE: 30V/ms, any V range, 10mA compliance.

COMMON MODE VOLTAGE: ±42VDC maximum.

4-WIRE SENSE: Up to 1V drop per load lead, 10Ω maximum per sense lead, 100µA range and up. For details on using 4-wire sense with the 10µA range and below, refer to the User's Manual.

OVER TEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.

RANGE CHANGE OVERSHOOT: Overshoot into a fully resistive 100kΩ load, 10Hz to 1MHz BW, adjacent ranges, 100mV typical, except 20V/200V range boundary.

MINIMUM COMPLIANCE VALUE: 0.1% of range.

MEASURE SPECIFICATIONS [1]

Voltage Measurement Accuracy (4-wire sense)[3]

Range	Max. Resolution	Input[2] Resistance	Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + volts)
200.000 mV	1 µV	>10^{16}Ω	0.012% + 350 µV
2.00000 V	10 µV	>10^{16}Ω	0.012% + 350 µV
20.0000 V	100 µV	>10^{16}Ω	0.015% + 1.5 mV
200.000 V	1 mV	>10^{16}Ω	0.015% + 10 mV

TEMPERATURE COEFFICIENT (0°–18°C & 28°–40°C): ±(0.15 × accuracy specification)/°C.

Current Measurement Accuracy (2- or 4-wire sense)[4]

Range	Max. Resolution	Voltage Burden[5]	Accuracy (23°C ± 5°C) 1 Year ±(%rdg + amps)
1.00000 pA	10 aA	< 1mV	1.0 % + 7 fA
10.0000 pA	100 aA	< 1mV	0.50 % + 7 fA
100.000 pA	1 fA	< 1mV	0.15 % + 30 fA
1.00000 nA	10 fA	< 1mV	0.050 % + 200 fA
10.0000 nA	100 fA	< 1mV	0.050 % + 2 pA
100.000 nA	1 pA	< 1mV	0.050 % + 20 pA
1.00000 µA	10 pA	< 1mV	0.050 % + 300 pA
10.0000 µA	100 pA	< 1mV	0.050 % + 2 nA
100.000 µA	1 nA	< 1mV	0.025 % + 6 nA
1.00000 mA	10 nA	< 1mV	0.027 % + 60 nA
10.0000 mA	100 nA	< 1mV	0.035 % + 600 nA
100.000 mA	1 µA	< 1mV	0.055 % + 6 µA

TEMPERATURE COEFFICIENT (0°–18°C & 28°–40°C): ±[(0.15 × accuracy specification) + 1fA]/°C.

INPUT CURRENT: <3fA at 23°C, <40% RH; typically ±0.5fA/°C around 23°C, <40% RH.

ADDITIONAL MEASURE SPECIFICATIONS

OUTPUT SETTLING TIME (typical to 10% of final value): <2s, 1pA and 10pA ranges; <50ms, 100pA through 10nA ranges; <5ms, 100nA through 100mA ranges.

CURRENT NOISE: When observed over 1 minute intervals, peak to peak noise will be within 400aA during 90% of the intervals using Autofilter (5s 10% to 90% rise time), with triax connectors capped, Autozero OFF, Source Delay = 0, on the 1pA range for at least 3 minutes.

Resistance Measurement Accuracy (4-wire sense with remote preamp)

Source I Mode, Auto Ohms

Range	Max. Resolution	Default Test Current	Normal Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + ohms)	Enhanced Accuracy (23°C ± 5°C) [7] 1 Year, ±(%rdg + ohms)
<2.00000 Ω [6]	1 µΩ	—	Source I_{ACC} + Measure V_{ACC}	Measure I_{ACC} + Measure V_{ACC}
20.0000 Ω	100 µΩ	100 mA	0.098% + 0.003 Ω	0.068% + 0.001 Ω
200.000 Ω	1 mΩ	10 mA	0.077% + 0.03 Ω	0.048% + 0.01 Ω
2.00000 kΩ	10 mΩ	1 mA	0.066% + 0.3 Ω	0.040% + 0.1 Ω
20.0000 kΩ	100 mΩ	100 µA	0.063% + 3 Ω	0.038% + 1 Ω
200.000 kΩ	1 Ω	10 µA	0.082% + 30 Ω	0.064% + 10 Ω
2.00000 MΩ	10 Ω	1 µA	0.082% + 300 Ω	0.064% + 100 Ω
20.0000 MΩ	100 Ω	1 µA	0.085% + 1 kΩ	0.067% + 500 Ω
200.000 MΩ	1 kΩ	100 nA	0.085% + 10 kΩ	0.068% + 5 kΩ
2.00000 GΩ	10 kΩ	10 nA	0.085% + 100 kΩ	0.070% + 50 kΩ
20.0000 GΩ	100 kΩ	1 nA	0.085% + 1 MΩ	0.070% + 500 kΩ
200.000 GΩ	1 MΩ	100 pA	0.205% + 10 MΩ	0.185% + 5 MΩ
2.00000 TΩ	10 MΩ	10 pA	0.822% + 100 MΩ	0.619% + 50 MΩ
20.0000 TΩ	100 MΩ	1 pA	2.06% + 1 GΩ	1.54% + 500 MΩ
>20.0000 TΩ [6]	—	—	Source I_{ACC} + Measure V_{ACC}	Measure I_{ACC} + Measure V_{ACC}

Resistance Measurement Accuracy (4-wire sense without remote preamp)

Source I Mode, Auto Ohms

Range	Max. Resolution	Default Test Current	Normal Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + ohms)	Enhanced Accuracy (23°C ± 5°C) [7] 1 Year, ±(%rdg + ohms)
<2.00000 Ω [6]	1 µΩ	—	Source I_{ACC} + Measure V_{ACC}	Measure I_{ACC} + Measure V_{ACC}
20.0000 Ω	100 µΩ	100 mA	0.098% + 0.003 Ω	0.068% + 0.001 Ω
200.000 Ω	1 mΩ	10 mA	0.077% + 0.03 Ω	0.048% + 0.01 Ω
2.00000 kΩ	10 mΩ	1 mA	0.066% + 0.3 Ω	0.040% + 0.1 Ω
20.0000 kΩ	100 mΩ	100 µA	0.063% + 3 Ω	0.038% + 1 Ω
200.000 kΩ	1 Ω	10 µA	0.082% + 30 Ω	0.040% + 10 Ω
2.00000 MΩ	10 Ω	1 µA	0.082% + 300 Ω	0.042% + 100 Ω
20.0000 MΩ	100 Ω	1 µA	0.085% + 1 kΩ	0.045% + 500 Ω
200.000 MΩ	1 kΩ	100 nA	0.085% + 10 kΩ	0.349% + 5 kΩ

TEMPERATURE COEFFICIENT (0°–18°C & 28°–40°C): ±(0.15 × accuracy specification)/°C.

SOURCE I MODE, MANUAL OHMS: Total uncertainty = I source accuracy + V measure accuracy (4-wire sense).

SOURCE V MODE: Total uncertainty = V source accuracy + I measure accuracy (4-wire sense).

6-WIRE OHMS MODE: Available using active ohms guard and guard sense (mainframe rear panel ONLY). **Max. Guard Output Current:** 50 mA. Accuracy is load dependent. Refer to manual for calculation formula.

MAINFRAME GUARD OUTPUT RESISTANCE: 0.1Ω in ohms mode.

[1] Speed = 10 PLC, Autofilter ON, properly zeroed and settled.
[2] Source I mode, I = 0.
[3] Voltage measurement accuracy is not affected by the remote preamp.
[4] Current measurement accuracy is not affected by the remote preamp; however, the 1pA through 100nA ranges are available only when using a preamp.
[5] 4-wire mode.
[6] Manual ohms mode only.
[7] Source readback enabled, offset compensation ON. Source delay must be programmed such that the source is fully settled for each reading.

SYSTEM SPEEDS

MEASUREMENT[1]

MAXIMUM RANGE CHANGE RATE: 75/second.

SWEEP OPERATION[2] READING RATES (rdg/second) FOR 60Hz (50Hz):

Speed	NPLC/ Trigger Origin	Measure To Mem.	Measure To GPIB	Source-Measure To Mem.	Source-Measure To GPIB	Source-Measure Pass/Fail Test[3] To Mem.	Source-Measure Pass/Fail Test[3] To GPIB	Source-Memory[3] To Mem.	Source-Memory[3] To GPIB
Fast	0.01 / internal	2080 (2030)	1210 (1210)	1550 (1515)	1010 (1010)	930 (900)	840 (840)	163 (162)	163 (162)
	0.01 / external	1250 (1200)	1090 (1050)	1030 (990)	920 (920)	860 (830)	780 (780)	161 (160)	161 (160)
Medium	0.10 / internal	505 (433)	505 (433)	465 (405)	465 (405)	390 (343)	390 (343)	132 (126)	132 (126)
	0.10 / external	435 (380)	435 (380)	405 (360)	405 (360)	375 (333)	375 (333)	130 (125)	130 (125)
Normal	1.00 / internal	59 (49)	59 (49)	58 (48)	58 (48)	57 (47)	57 (47)	44 (38)	44 (38)
	1.00 / external	57 (48)	57 (48)	57 (48)	57 (48)	56 (47)	56 (47)	44 (38)	44 (38)

SINGLE READING OPERATION READING RATES (rdg/second) FOR 60Hz (50Hz):

Speed	NPLC/Trigger Origin	Measure To GPIB	Source-Measure[4] To GPIB	Source-Measure Pass/Fail Test[3, 4] To GPIB
Fast	0.01 / internal	256 (256)	83 (83)	83 (83)
Medium	0.10 / internal	181 (166)	73 (70)	73 (70)
Normal	1.00 / internal	49 (42)	35 (31)	34 (30)

COMPONENT HANDLER INTERFACE TIME: [3, 5]

Speed	NPLC/Trigger Origin	Measure Pass/Fail Test	Source Pass/Fail Test	Source-Measure Pass/Fail Test[6]
Fast	0.01 / external	1.01 ms (1.08 ms)	0.5 ms (0.5 ms)	5.3 ms (5.3 ms)
Medium	0.10 / external	2.5 ms (2.9 ms)	0.5 ms (0.5 ms)	6.7 ms (7.1 ms)
Normal	1.00 / external	17.5 ms (20.9 ms)	0.5 ms (0.5 ms)	21.7 ms (25.0 ms)

[1] Reading rates applicable for voltage or current measurements. Auto zero off, autorange off, filter off, display off, trigger delay = 0, source auto clear off, and binary reading format.

[2] 1000 point sweep was characterized with the source on a fixed range.

[3] Pass/Fail test performed using one high limit and one low math limit.

[4] Includes time to re-program source to a new level before making measurement.

[5] Time from falling edge of START OF TEST signal to falling edge of END OF TEST signal.

[6] Command processing time of :SOURce:VOLTage|CURRent:TRIGgered <nrf> command not included.

GENERAL

NOISE REJECTION:

	NPLC	NMRR	CMRR
Fast	0.01	—	80 dB
Medium	0.1	—	80 dB
Normal	1	60 dB	90 dB

LOAD IMPEDANCE: Stable into 20,000pF on the 100mA through 100µA ranges, 470pF on the 10µA and 1µA ranges, and 100pF on the nA and pA ranges. Refer to the User's Manual for details on measuring large capacitive loads.

COMMON MODE VOLTAGE: ±42VDC maximum.

COMMON MODE ISOLATION: >$10^9\Omega$, <1000pF.

OVERRANGE: 105% of range, source and measure.

MAX. VOLTAGE DROP BETWEEN INPUT/OUTPUT AND SENSE TERMINALS: 5V. (To meet specified accuracy with 4-wire sense, refer to the User's Manual.)

MAX. SENSE LEAD RESISTANCE: 10Ω for rated accuracy.

SENSE INPUT RESISTANCE: 1MΩ.

MAINFRAME GUARD OFFSET VOLTAGE: 300µV, typical.

PREAMP GUARD OFFSET VOLTAGE: 1mV, typical.

PREAMP GUARD OUTPUT RESISTANCE: 110kΩ.

SOURCE OUTPUT MODES:
Fixed DC level
Memory List (mixed function)
Stair (linear and log)

SOURCE MEMORY LIST: 100 points max.

MEMORY BUFFER: 5,000 readings @ 5½ digits (two 2,500 point buffers). Includes selected measured value(s) and time stamp. Lithium battery backup (3 yr+ battery life).

PROGRAMMABILITY: IEEE-488 (SCPI-1995.0), RS-232, 5 user-definable power-up states plus factory default and *RST.

DIGITAL INTERFACE:
Safety Interlock: Active low input.
Handler Interface: Start of test, end of test, 3 category bits. +5V @ 300mA supply.
Digital I/O: 1 trigger input, 4 TTL/Relay Drive outputs (33V @ 500mA sink, diode clamped).

POWER SUPPLY: 100V–240V rms, 50–60Hz (automatically detected at power up), 100VA max.

WARRANTY: 1 year.

EMC: Conforms with European Union Directive 89/336/EEC EN 55011, EN 50082-1, EN 61000-3-2 and 61000-3-3, FCC part 15 class B.

SAFETY: Conforms with European Union Directive 73/23/EEC EN 61010-1.

VIBRATION: MIL-PRF-28800F, Class 3.

WARM-UP: 1 hour to rated accuracies.

DIMENSIONS: 89mm high × 213mm wide × 370mm deep (3½ in × 8⅜ in × 14⁹⁄₁₆ in). Bench Configuration (with handle & feet): 104mm high × 238mm wide × 370mm deep (4⅛ in × 9⅜ in × 14⁹⁄₁₆ in).
Amplifier: 20mm high × 57mm wide × 97mm deep (0.783 in × 2.225 in × 3.75 in).

WEIGHT: 3.45kg (7.61 lbs).

ENVIRONMENT:
Operating: 0°–40°C, 60% R.H. (non-condensing) up to 35°C. Derate 5% R.H./°C, 35°–40°C.
Storage: –25°C to 65°C. Non-condensing humidity.

ACCESSORIES SUPPLIED:

Model 6430-322-1	Low Noise Triax Cable, 3-slot triax to alligator clips, 20cm (8 in)
Model 8607	Safety High Voltage Dual Test Leads
Model CA-186-1	Banana Lead to Screw Terminal Adapter

Specifications subject to change without notice.

Accuracy calculations

The following information discusses how to calculate accuracy for both sense and source functions.

Measure accuracy

Measurement accuracy is calculated as follows:

Accuracy = ±(% of reading + offset)

As an example of how to calculate the actual reading limits, assume that you are measuring 10V on the 20V range. You can compute the reading limit range from one-year measure voltage accuracy specifications as follows:

Accuracy = ±(% of reading + offset)
= ±[(0.015% × 10V) + 1.5mV]
= ±(1.5mV + 1.5mV)
= ±3mV

Thus, the actual reading range is 10V ±3mV or from 9.997 to 10.003V.

DC current measurement calculations are performed in exactly the same manner using the pertinent specifications, ranges, and input signal values.

Source accuracy

Source accuracy is calculated similarly, except source specifications are used. As an example of how to calculate the actual source output limits, assume that you are sourcing 0.7mA on the 1mA source range. You can compute the reading limit range from source current one-year accuracy specifications as follows:

Accuracy = ±(0.034% of output + 200nA offset)
= ±[(0.034% × 0.7μA) + 200νA)]
= ±(238nA + 200nA)
= ±438nA

In this case, the actual current output range is 0.7mA ±438nA or from 0.69956mA to 0.70044mA.

Source-Delay-Measure (SDM) cycle timing

The following timing information assumes that the SourceMeter is being triggered externally via the Trigger Link.

For Cases I through IV, it is assumed that the Output Auto-Off feature is enabled (:SOURce1:CLEar:AUTO ON), and the source setting changes for each triggered SDM cycle. The discussion is applicable for linear, log, and custom sweeps. It is also applicable to applications that use the "triggered source" feature (:SOURce1:VOLTage:TRIGger or SOURce1:CURRent:TRIGger). The discussion is not applicable for memory sweeps (:SOURce1:MEMory).

For Cases V and VI, it is assumed that the Output Auto-Off feature is disabled (:SOURce1:CLEar:AUTO OFF), and the source setting remains the same for each triggered SDM cycle. In this configuration, the static source remains on during all SDM cycles.

Definitions

Trigger latency

Trigger latency is the time from when an external trigger event occurs to when the SourceMeter takes the appropriate action. It is from when an external trigger is detected in the Trigger Layer of the trigger model to when the trigger delay begins.

Trigger delay

Trigger delay is the time from when the external event is detected to when the source configuration begins. This is a user-programmable delay that can be set from 0000.0000 seconds to 999.99990 seconds.

Source configuration

This is the time it takes to configure the source DAC. For the following discussion, it is assumed that the range and polarity do not change when the source value is changed.

Source delay

This is the time between the source configuration and the start of the first A/D conversion. This programmable delay is typically used to allow the source to settle before starting the measurement. With Auto-Delay enabled, 100µsec is added to the user-programmed source delay. The user-programmed delay can be set from 0000.0000 seconds to 9999.99900 seconds.

A/D conversion

This is the time it takes to measure the specified A/D converter phase. In general, there are three A/D phases required to generate a voltage or current reading. These phases are often referred to as the "signal," "reference," and "reference zero" phases. The "signal" phase

measures the input signal. The “reference” and “reference zero” phases are associated with a precision voltage reference inside the SourceMeter. By measuring all three phases, zero drift for the reading is reduced. A/D conversion time is programmable with 0.01 power line cycle resolution.

When Auto-Zero is enabled, all three phases are measured each time the SourceMeter is triggered. With Auto-Zero disabled, only the “signal” is measured. Hence, speed is increased at the expense of long term drift.

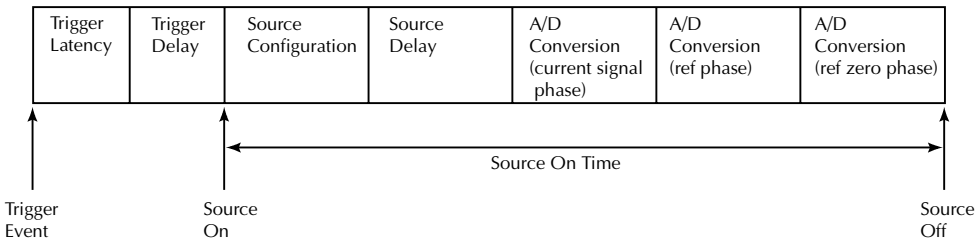
Firmware overhead

This is the time associated with A/D communication, reading calibration, and other operations necessary to perform the SDM cycle. This time is not illustrated in the following timing diagrams.

Timing diagrams

Case I: Auto-Zero enabled and measuring a single function

Figure A-1 Case I timing diagram



Trigger Latency: 225µsec max
Source Configuration: 50µsec max
A/D Conversion: [NPLC Setting × (1/power line frequency)] + 185
Firmware Overhead: 1.8msec for Source V
2.15msec for Source I

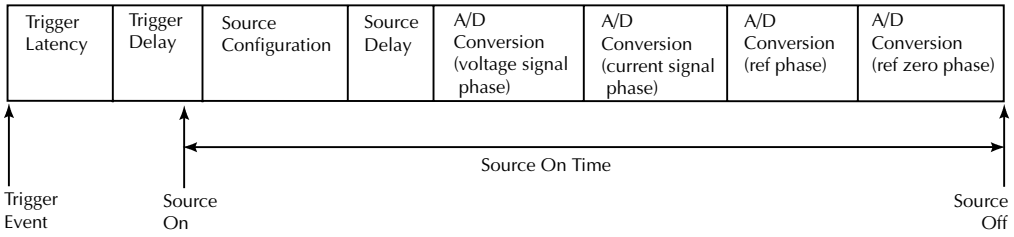
Source On Time ≅ Source Configuration + Source Delay + (3 × A/D Conversion) + Firmware Overhead

Example: Source Delay = 0µsec
NPLC Setting = 0.01 PLC
Power Line Frequency = 60Hz

Source On Time ≅ 50µsec + 0 + [(3 × 0.01 × 1/60) + 185µsec] + 1.6msec
≅ 2.9msec for Source V
≅ 3.25msec for Source I

Case II: Auto-Zero enabled and measuring two functions

Figure A-2 Case II timing diagram



Trigger Latency: 225µsec max
Source Configuration: 50µsec max
A/D Conversion: [NPLC Setting × (1 / power line frequency)] + 185µsec
Firmware Overhead: 2.3msec for Source V
2.65msec for Source I

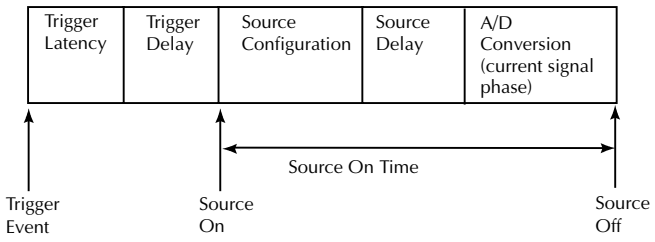
Source On Time ≅ Source Configuration + Source Delay + (4 × A/D Conversion) + Firmware Overhead

Example: Source Delay = 0µsec
NPLC Setting = 0.06 PLC
Power Line Frequency = 60Hz

Source On Time ≅ 50µsec + 0 + [(4 × 0.06 × 1/60) + 185µsec] + 2.6msec
≅ 7.1msec for Source V
≅ 7.45msec for Source I

Case III: Auto-Zero disabled and measuring one function

Figure A-3 Case III timing diagram



Trigger Latency: 225µsec max
Source Configuration: 50µsec max
A/D Conversion: [NPLC Setting × (1 / power line frequency)] + 185µsec
Firmware Overhead: 300µsec for Source V
640µsec for Source I

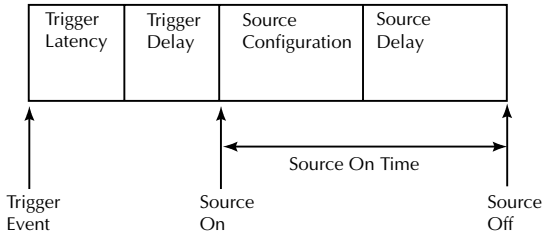
Source On Time ≅ Source Configuration + Source Delay + A/D Conversion + Firmware Overhead

Example: Source Delay = 0
NPLC Setting = 0.08 PLC
Power Line Frequency = 60Hz

Source On Time ≅ 50µsec + 0 + [(0.08 × 1/60) + 185µsec] + 40µsec
≅ 1.85msec for Source V
≅ 2.2msec for Source I

Case IV: Auto-Zero disabled and all measurements disabled

Figure A-4
Case IV timing diagram



Trigger Latency: 225µsec max
Source Configuration: 50µsec max
Firmware Overhead: 310µsec for Source V
590µsec for Source I

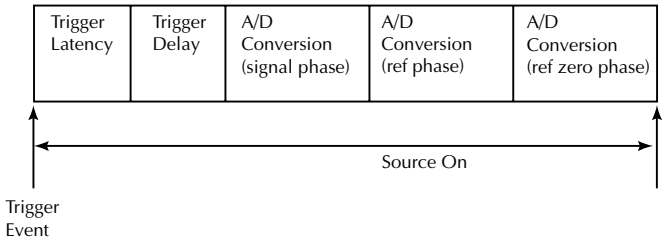
Source On Time ≅ Source Configuration + Source Delay + Firmware Overhead

Example: Source Delay = 0

Source On Time ≅ 50µsec + 0 + 125µsec
≅ 360µsec for Source V
≅ 640µsec for Source I

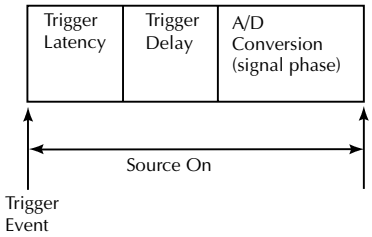
Cases V and VI: Measure one function, Output Auto-Off disabled, and no source setting changes.

Figure A-5
Case V timing diagram



Auto-Zero: Enabled
Trigger Latency: 500µsec max

Figure A-6
Case VI timing diagram



Auto Zero: Disabled
Trigger Latency: 100µsec max

The source turns on as soon as the output is turned on and remains on until the source is turned off. As shown in the two timing diagrams, the static source remains on for every measurement cycle. The Source-Delay portion of the SDM cycle is omitted. With Trigger Delay set to zero, Trigger Latency is the time from when the trigger event occurs to when the SourceMeter begins an A/D conversion.

B
Status and Error Messages

Introduction

This Appendix contains a summary of status and error messages, which status register bits are set when messages occur, and methods to avoid or eliminate most common SCPI errors.

Status and error messages

Table B-1 summarizes status and error messages, which are stored in the Error Queue. Each message is preceded by a code number. Negative (-) numbers are used for SCPI-defined messages, and positive (+) numbers are used for Keithley-defined messages. Note that error and status conditions will also set specific bits in various status registers, as summarized in Table B-1.

Section 14 has detailed information on registers and queues. Briefly, you can use the following queries to obtain error and status information:

- :SYST:ERR? — reads Error Queue.
- *ESR? — reads Standard Event Status Register.
- :STAT:OPER? — reads Operation Event Register.
- :STAT:MEAS? — reads Measurement Event Register.
- :STAT:QUES? — reads Questionable Event Register.

NOTE *SCPI-confirmed messages are described in volume 2: Command Reference of the Standard Commands for Programmable Instruments. Refer to the :SYSTem:ERRor? command.*

Table B-1
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
-440	Query UNTERMINATED after indefinite response	EE	Standard Event	2
-430	Query DEADLOCKED	EE	Standard Event	2
-420	Query UNTERMINATED	EE	Standard Event	2
-410	Query INTERRUPTED	EE	Standard Event	2
-363	Input buffer overrun	EE	Standard Event	3
-362	Framing error in program message	EE	Standard Event	3
-361	Parity error in program message	EE	Standard Event	3
-360	Communications error	EE	Standard Event	3
-350	Queue overflow	SYS	Standard Event	3
-330	Self-test failed	EE	Standard Event	3
-314	Save/recall memory lost	EE	Standard Event	3
-315	Configuration memory lost	EE	Standard Event	3
-285	Program syntax error	EE	Standard Event	4
-284	Program currently running	EE	Standard Event	4
-282	Illegal program name	EE	Standard Event	4
-281	Cannot create program	EE	Standard Event	4
-260	Expression error	EE	Standard Event	4
-241	Hardware missing	EE	Standard Event	4
-230	Data corrupt or stale	EE	Standard Event	4
-225	Out of memory	EE	Standard Event	4
-224	Illegal parameter value	EE	Standard Event	4
-223	Too much data	EE	Standard Event	4
-222	Parameter data out of range	EE	Standard Event	4
-221	Settings conflict	EE	Standard Event	4
-220	Parameter error	EE	Standard Event	4
-215	Arm deadlock	EE	Standard Event	4
-214	Trigger deadlock	EE	Standard Event	4
-213	Init ignored	EE	Standard Event	4
-212	Arm ignored	EE	Standard Event	4
-211	Trigger ignored	EE	Standard Event	4
-210	Trigger error	EE	Standard Event	4

[1]EE = Error Event
SE = Status Event
SYS = System Error Event

[2]Use following queries to read status registers:
Standard Event: *ESR?
Operation Event: STAT:OPER?
Measurement Event: STAT:MEAS?
Questionable Event: STAT:QUES?

Table B-1 (cont.)
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
-202	Settings lost due to rtl	EE	Standard Event	4
-201	Invalid while in local	EE	Standard Event	4
-200	Execution error	EE	Standard Event	4
-178	Expression data not allowed	EE	Standard Event	5
-171	Invalid expression	EE	Standard Event	5
-170	Expression error	EE	Standard Event	5
-168	Block data not allowed	EE	Standard Event	5
-161	Invalid block data	EE	Standard Event	5
-160	Block data error	EE	Standard Event	5
-158	String data not allowed	EE	Standard Event	5
-154	String too long	EE	Standard Event	5
-151	Invalid string data	EE	Standard Event	5
-150	String data error	EE	Standard Event	5
-148	Character data not allowed	EE	Standard Event	5
-144	Character data too long	EE	Standard Event	5
-141	Invalid character data	EE	Standard Event	5
-140	Character data error	EE	Standard Event	5
-128	Numeric data not allowed	EE	Standard Event	5
-124	Too many digits	EE	Standard Event	5
-123	Exponent too large	EE	Standard Event	5
-121	Invalid character in number	EE	Standard Event	5
-120	Numeric data error	EE	Standard Event	5
-114	Header suffix out of range	EE	Standard Event	5
-113	Undefined header	EE	Standard Event	5
-112	Program mnemonic too long	EE	Standard Event	5
-111	Header separator error	EE	Standard Event	5
-110	Command header error	EE	Standard Event	5
-109	Missing parameter	EE	Standard Event	5
-108	Parameter not allowed	EE	Standard Event	5

[1]EE = Error Event
SE = Status Event
SYS = System Error Event
[2]Use following queries to read status registers:
Standard Event: *ESR?
Operation Event: STAT:OPER?
Measurement Event: STAT:MEAS?
Questionable Event: STAT:QUES?

Table B-1 (cont.)
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
-105	GET not allowed	EE	Standard Event	5
-104	Data type error	EE	Standard Event	5
-103	Invalid separator	EE	Standard Event	5
-102	Syntax error	EE	Standard Event	5
-101	Invalid character	EE	Standard Event	5
-100	Command error	EE	Standard Event	5
+000	No error	SE		
	Measurement events:			
+100	Limit 1 failed	SE	Measurement Event	0
+101	Low limit 2 failed	SE	Measurement Event	1
+102	High limit 2 failed	SE	Measurement Event	2
+103	Low limit 3 failed	SE	Measurement Event	3
+104	High limit 3 failed	SE	Measurement Event	4
+105	Active limit tests passed	SE	Measurement Event	5
+106	Reading available	SE	Measurement Event	6
+107	Reading overflow	SE	Measurement Event	7
+108	Buffer available	SE	Measurement Event	8
+109	Buffer full	SE	Measurement Event	9
+111	OUTPUT interlock asserted	SE	Measurement Event	11
+112	Temperature limit exceeded	SE	Measurement Event	12
+113	Voltage limit exceeded	SE	Measurement Event	13
+114	Source in compliance	SE	Measurement Event	14
	Standard events:			
+200	Operation complete	SE	Standard Event	0
	Operation events:			
+300	Device calibrating	SE	Operation Event	0
+303	Device sweeping	SE	Operation Event	3

[1]EE = Error Event
SE = Status Event
SYS = System Error Event
[2]Use following queries to read status registers:
Standard Event: *ESR?
Operation Event: STAT:OPER?
Measurement Event: STAT:MEAS?
Questionable Event: STAT:QUES?

Table B-1 (cont.)
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
+305	Waiting in trigger layer	SE	Operation Event	5
+306	Waiting in arm layer	SE	Operation Event	6
+310	Entering idle layer	SE	Operation Event	10
	Questionable events:			
+408	Questionable Calibration	SE	Questionable Event	8
+414	Command Warning	SE	Questionable Event	14
	Calibration errors:			
+500	Date of calibration not set	EE	Standard Event	3
+501	Next date of calibration not set	EE	Standard Event	3
+502	Calibration data invalid	EE	Standard Event	3
+503	DAC calibration overflow	EE	Standard Event	3
+504	DAC calibration underflow	EE	Standard Event	3
+505	Source offset data invalid	EE	Standard Event	3
+506	Source gain data invalid	EE	Standard Event	3
+507	Measurement offset data invalid	EE	Standard Event	3
+508	Measurement gain data invalid	EE	Standard Event	3
+509	Not permitted with cal locked	EE	Standard Event	3
+510	Not permitted with cal un-locked	EE	Standard Event	3
	Lost data errors:			
+601	Reading buffer data lost	EE	Standard Event	3
+602	GPIB address lost	EE	Standard Event	3
+603	Power-on state lost	EE	Standard Event	3
+604	DC calibration data lost	EE	Standard Event	3
+605	Calibration dates lost	EE	Standard Event	3
+606	GPIB communication language lost	EE	Standard Event	3
	Communication errors:			
+700	Invalid system communication	EE	Standard Event	3
+701	ASCII only with RS-232	EE	Standard Event	3
+702	Preamp Timeout	EE	Standard Event	3

[1]EE = Error Event
SE = Status Event
SYS = System Error Event
[2]Use following queries to read status registers:
Standard Event: *ESR?
Operation Event: STAT:OPER?
Measurement Event: STAT:MEAS?
Questionable Event: STAT:QUES?

Table B-1 (cont.)
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
	Additional command execution errors:			
+800	Illegal with storage active	EE	Standard Event	4
+801	Insufficient vector data	EE	Standard Event	4
+802	OUTPUT blocked by interlock	EE	Standard Event	4
+803	Not permitted with OUTPUT off	EE	Standard Event	4
+804	Expression list full	EE	Standard Event	4
+805	Undefined expression exists	EE	Standard Event	4
+806	Expression not found	EE	Standard Event	4
+807	Definition not allowed	EE	Standard Event	4
+808	Expression cannot be deleted	EE	Standard Event	4
+809	Source memory location revised	EE	Standard Event	4
+810	OUTPUT blocked by Over Temp	EE	Standard Event	4
+811	Not an operator or number	EE	Standard Event	4
+812	Mismatched parenthesis	EE	Standard Event	4
+813	Not a number of data handle	EE	Standard Event	4
+814	Mismatched brackets	EE	Standard Event	4
+815	Too many parenthesis	EE	Standard Event	4
+816	Entire expression not parsed	EE	Standard Event	4
+817	Unknown token	EE	Standard Event	4
+818	Error parsing mantissa	EE	Standard Event	4
+819	Error parsing exponent	EE	Standard Event	4
+820	Error parsing value	EE	Standard Event	4
+821	Invalid data handle index	EE	Standard Event	4
+822	Too small for sense range	EE	Standard Event	4
+823	Invalid with source read-back on	EE	Standard Event	4
+824	Cannot exceed compliance range	EE	Standard Event	4
+825	Invalid with auto-ohms on	EE	Standard Event	4
+826	Attempt to exceed power limit	EE	Standard Event	4
+827	Invalid with ohms guard on	EE	Standard Event	4
+830	Invalid with INF ARM:COUNT	EE	Standard Event	4
+900	Internal System Error	EE	Standard Event	3

[1]EE = Error Event
SE = Status Event
SYS = System Error Event

[2]Use following queries to read status registers:
Standard Event: *ESR?
Operation Event: STAT:OPER?
Measurement Event: STAT:MEAS?
Questionable Event: STAT:QUES?

Eliminating common SCPI errors

There are three SCPI errors that occur more often than any others:

- -113, “Undefined header”
- -410, “Query INTERRUPTED”
- -420, “Query UNTERMINATED”

The following paragraphs discuss the most likely causes for these errors and methods for avoiding them.

-113, “Undefined header”

This error indicates that the command you sent to the instrument did not contain a recognizable command name. The most likely causes for this error are:

- *Missing space between the command and its parameter.* There must be one or more spaces (blanks) between the command and its parameter. For example:

:SENS:VOLT:DC:RANGl00	Incorrect (no space between command and parameter)
:SENS:VOLT:DC:RANG 100	Correct

- *Improper short or long form.* Check the command list in Section 17 for the correct command name.
- *Blanks (spaces) within the command name.* For example:

:SYST :ERR?	Incorrect (space between :SYST and :ERR?)
:SYST:ERR?	Correct

-410, “Query INTERRUPTED”

This error occurs when you have sent a valid query to the instrument, and then send it another command or query, or a Group Execute Trigger (GET) before it has had a chance to send the entire response message (including the line-feed/EOI terminator). The most likely causes are:

- *Sending a query to the instrument and then sending another command or query before reading the response to the first query.* For example, the following sequence of commands will cause an error -410:

  ```
  :SYST:ERR?
  *OPC?
  ```

  This sequence generates an error because you must read the response to :SYST:ERR? before sending the *OPC? query.
- *Incorrectly configured IEEE-488 driver.* The driver must bc configured so that when talking on the bus it sends line-feed with EOI as the terminator, and when listening on the bus it expects line-feed with EOI as the terminator. See the reference manual for your particular IEEE-488 interface.

-420, "Query UNTERMINATED"

This error occurs when you address the instrument to talk, and there is no response message to send. The most likely causes are:

- *Not sending a query.* You must send a valid query to the instrument before addressing it to talk.
- *Sending an invalid query.* If you have sent a query and still get this error, make sure that the instrument is processing the query without error. For example, sending an ill-formed query that generates an error -113, "Undefined header" and then addressing the instrument to talk will generate an error -420, "Query UNTERMINATED" as well.
- *Valid query following an invalid command.* This situation can occur when you send multiple commands or queries (program message units) within one command string (program message). When the Model 6430 detects an error in a program message unit, it discards all further program message units until the end of the string; for example:

  :SENS:DATE?; :SENS:FUNC?

  In the above program message, the program message unit :SENS:DATE? will generate error -113, "Undefined header," and the Model 6430 wi|| discard the second program message unit :SENS:FUNC? even though it is a valid query.

C
Data Flow

Introduction

Data flow for remote operation is summarized by the block diagram shown in Figure C-1. Refer to this block diagram for the following discussion.

The SENSE block represents the basic measured readings of voltage, current and resistance. If Filter is enabled, the readings will be filtered. The SENSE block also measures time for the timestamp.

When the INITiate command is sent, the programmed number of source-measure operations are performed and the respective data is temporarily stored in the Sample Buffer. For example, if 20 source-measure operations were performed, then 20 sets of data will be stored in the Sample Buffer. Data from this buffer is then routed to other enabled data flow blocks.

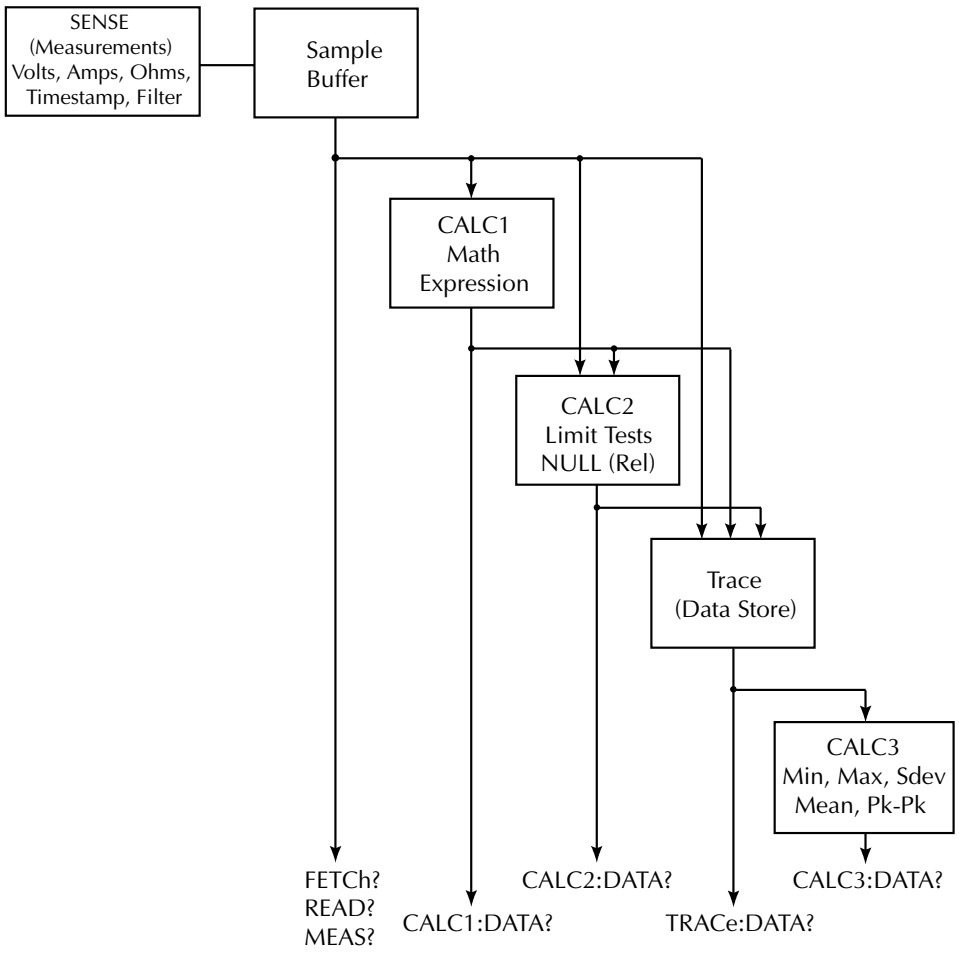


Figure C-1
Data flow block diagram

Assuming that all functions are enabled, the data that is output by the read commands (FETCh?, CALC1:DATA?, CALC2:DATA?, TRACe:DATA?, and CALC3:DATA?) depend on which data elements are selected. With all elements selected, available data will include voltage, current and resistance readings as well as the timestamp and status information. Note that if a measurement function is not enabled, then either the NAN (not a number) value or the source reading will be used instead. See Section 17, *FORMat Subsystem* for details.

After all source-measure operations are completed the SourceMeter returns to the idle state. The data stored in the Sample Buffer will remain there until data from another source-measure cycle overwrites the buffer. Data in the Sample Buffer is lost if the SourceMeter goes to the local state (REM annunciator off).

NOTE *With no data in the Sample Buffer, the FETCh?, CALCulate1:DATA? and CALCulate2:DATA? commands to read data will display the message "Data corrupt or stale."*

FETCh?

This command is used to read data stored in the Sample Buffer. If, for example, there are 20 data arrays stored in the Sample Buffer, then all 20 data arrays will be sent to the computer when FETCh? is executed. Note that FETCh? does not affect data in the Sample Buffer. Thus, subsequent executions of FETCh? acquire the same data.

The READ? command performs an INITiate and then a FETCh? The INITiate triggers a new source-measure cycle which puts new data in the Sample Buffer. FETCh? reads that new data. The MEASure? command places the SourceMeter in a "one-shot" source-measure mode and then performs a READ?. See Section 16 for more information on READ? and MEASure?.

CALCulate[1]:DATA?

If CALCulate1 is enabled, Sample Buffer data is fed to the CALC1 block where the results for the selected math expression are calculated. The CALC1:DATA? command will read the results of the math expression. If, for example, 20 data arrays in the Sample Buffer yield 10 math expression results, then CALC1:DATA? will acquire 10 readings (results).

CALCulate2:DATA?

If CALCulate2 is enabled, Sample Buffer data and CALC1 math expression results become available to the CALC2 block for limit testing. Depending on the selected feed, limit testing can be performed on the voltage, current, resistance, or timestamp readings of Sample Buffer data, or it can be performed on the CALC1 math expression results. If NULL (rel) is enabled, the readings used for limit testing will be the results of the null operation.

The CALCulate2:DATA? command acquires the readings used for limit testing.

TRACe:DATA?

If the data store is enabled, Sample Buffer data, CALC1 results, and CALC2 readings become available to the TRACE block for storage. The selected feed determines which group of readings are stored.

The TRACe:DATA? command reads the entire contents of the data store.

CALCulate3:DATA?

Statistical information (minimum, maximum, mean, standard deviation, and peak-to-peak) is available for measure readings stored in the buffer. If the readings in the data store came directly from the Sample Buffer, then the selected statistic calculation will be performed on all enabled measurement functions. The calculation results are returned in the following fixed order:

VOLTage result, CURRent result, RESistance result

When the TRACE buffer is feeding off CALC1 or CALC2, the selected statistic calculation is performed on the selected feed. Thus, a single statistic result is acquired for each reading stored in the data store.

The CALCulate3:DATA? command acquires the results of the selected calculation.

D
IEEE-488 Bus Overview

Introduction

Basically, the IEEE-488 bus is a communication system between two or more electronic devices. A device can be either an instrument or a computer. When a computer is used on the bus, it serves to supervise the communication exchange between all the devices and is known as the controller. Supervision by the controller consists of determining which device will talk and which device will listen. As a talker, a device will output information and as a listener, a device will receive information. To simplify the task of keeping track of the devices, a unique address number is assigned to each one.

On the bus, only one device can talk at a time and is addressed to talk by the controller. The device that is talking is known as the active talker. The devices that need to listen to the talker are addressed to listen by the controller. Each listener is then referred to as an active listener. Devices that do not need to listen are instructed to unlisten. The reason for the unlisten instruction is to optimize the speed of bus information transfer since the task of listening takes up bus time.

Through the use of control lines, a handshake sequence takes place in the transfer process of information from a talker to a listener. This handshake sequence helps ensure the credibility of the information transfer. The basic handshake sequence between an active controller (talker) and a listener is as follows:

1. The listener indicates that it is ready to listen.
2. The talker places the byte of data on the bus and indicates that the data is available to the listener.
3. The listener, aware that the data is available, accepts the data and then indicates that the data has been accepted.
4. The talker, aware that the data has been accepted, stops sending data and indicates that data is not being sent.
5. The listener, aware that there is no data on the bus, indicates that it is ready for the next byte of data.

Bus description

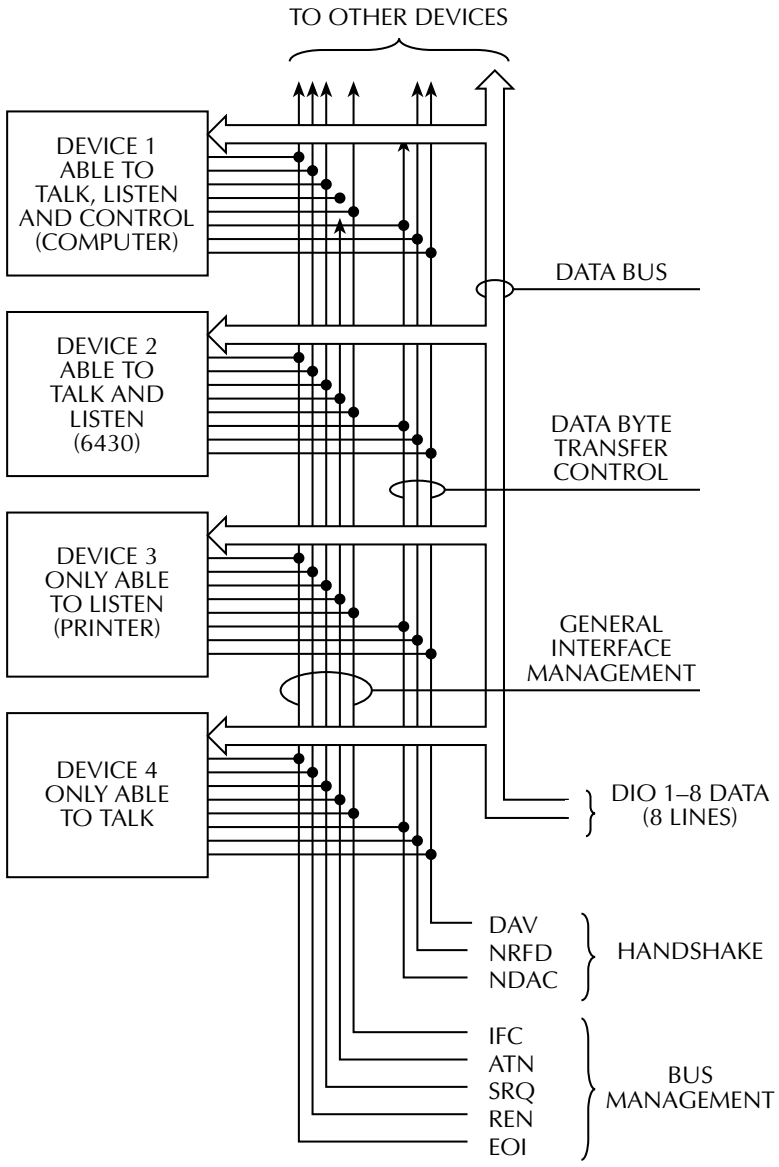
The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines.

A typical set up for controlled operation is shown in Figure D-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker, and listener. The controller does what its name implies; it controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only, or both a talker and listener.

There are two categories of controllers: system controller and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

Figure D-1
IEEE-488 bus configuration



A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 31, and is generally set by rear panel DIP switches or programmed from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with #H20. For example, if the primary address is #H16, the actual listen address is #H36 (#H36 = #H16 + #H20). In a similar manner, the talk address is obtained by ORing the primary address with #H40. With the present example, the talk address derived from a primary address of 16 decimal would be #H56 (#H56 = #H16 + #H40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of #H60-#H7F. Note, however, that many devices, including the SourceMeter, do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example: if the instrument is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information and the appropriate software can be used to direct the information to the desired location.

Bus lines

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines, and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the operation of these lines.

Data lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 (Data Input/Output) through DIO8 (Data Input/Output) are the eight data lines used to transmit both data and multiline commands and are bidirectional. The data lines operate with low true logic.

Bus management lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands.

ATN (Attention) — The ATN line is one of the more important management lines. The state of this line determines how information on the data bus is to be interpreted.

IFC (Interface Clear) — As the name implies, the IFC line controls clearing of instruments from the bus.

REN (Remote Enable) — The REN line is used to place the instrument on the bus in the remote mode.

EOI (End or Identify) — The EOI is usually used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request) — This line is used by devices when they require service from the controller.

Handshake lines

The bus handshake lines operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (DATA VALID) — The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data) — The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

NDAC (Not Data Accepted) — NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

The complete handshake sequence for one data byte is shown in Figure D-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100nsec after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The sequence just described is used to transfer both data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses or commands as described in the following paragraph.

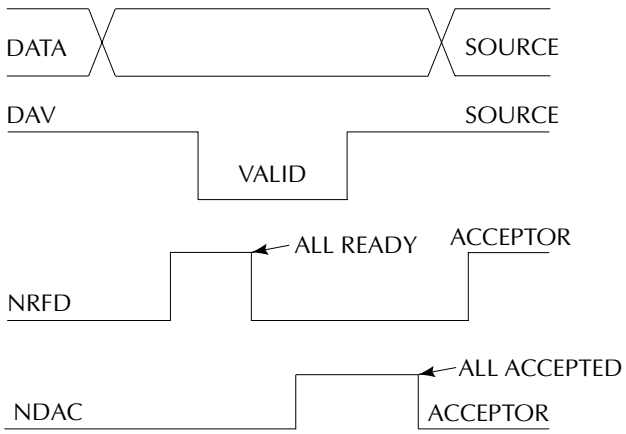


Figure D-2
IEEE-488 handshake sequence

Bus commands

The instrument may be given a number of special bus commands through the IEEE-488 interface. This section briefly describes the purpose of the bus commands which are grouped into the following four categories.

1. **Uniline commands** — Sent by setting the associated bus lines true. For example, to assert REN (Remote Enable), the REN line would be set low (true).
2. **Multiline commands** — General bus commands which are sent over the data lines with the ATN line true (low).
3. **Common commands** — Commands that are common to all devices on the bus; sent with ATN high (false).
4. **SCPI commands** — Commands that are particular to each device on the bus; sent with ATN (false).

These bus commands and their general purpose are summarized in Table D-1.

Table D-1
IEEE-488 bus command summary

Command type	Command	State of ATN line	Comments
Uniline	REN (Remote Enable)	X	Set up devices for remote operation.
	EOI (End Or Identify)	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ (Service Request)	X	Controlled by external device.
Multiline Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Poll Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from the bus.
	UNT (Untalk)	Low	Removes any talkers from the bus.
Common	–	High	Programs IEEE-488.2 compatible instruments for common operations.
SCPI	–	High	Programs SCPI compatible instruments for particular operations.

Uniline commands

ATN, IFC and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

REN (Remote Enable) — REN is sent to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL key (if the device is so equipped) may be locked out when REN is true. Generally, REN should be sent before attempting to program instruments over the bus.

EOI (End or Identify) — EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

IFC (Interface Clear) — IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention) — The controller sends ATN while transmitting addresses or multiline commands.

SRQ (Service Request) — SRQ is asserted by a device when it requires service from a controller.

Universal multiline commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout) — LLO is sent to the instrument to lock out the LOCAL key and thus all the front panel controls.

DCL (Device Clear) — DCL is used to return instruments to some default state. Usually, instruments return to the power-up conditions.

SPE (Serial Poll Enable) — SPE is the first step in the serial polling sequences, which is used to determine which device has requested service.

SPD (Serial Poll Disable) — SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Addressed multiline commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands. Both the commands and the address preceding it are sent with ATN true.

SDC (Selective Device Clear) — The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local) — The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger) — The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

Address commands

Addressed commands include two primary command groups and a secondary address group. ATN is true when these commands are asserted. The commands include:

LAG (Listen Address Group) — These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with #H20.

TAG (Talk Address Group) — The talk commands are derived from the primary address by ORing the address with #H40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group) — Commands in this group provide additional addressing capabilities. Many devices (including the SourceMeter) do not use these commands.

Unaddress commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten) — Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk) — Any previously commanded talkers will be placed in the talker idle state by the UNT command.

Common commands

Common commands are commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a common operation, such as reset. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

SCPI commands

SCPI commands are commands that are particular to each device on the bus. These commands are designated by the instrument manufacturer, and are based on the instrument model defined by the Standard Commands for Programmable Instruments (SCPI) Consortium's SCPI standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a particular operation, such as setting a range or closing a relay. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command codes

Command codes for the various commands that use the data lines are summarized in Figure D-3. Hexadecimal and the decimal values for the various commands are listed in Table D-2.

Table D-2
Hexadecimal and decimal command codes

Command	Hex value	Decimal value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SCG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Figure D-3
Command codes

D_7 D_6 D_5 D_4						X 0 0 0	Command	X 0 0 1	Command	X 0 1 0	Primary Address	X 0 1 1	Primary Address	X 1 0 0	Primary Address	X 1 0 1	Primary Address	X 1 1 0		X 1 1 1	
Bits	D_3 →	D_2 →	D_1 →	D_0 →	Column → Row →	0 (A)	0 (B)	1 (A)	1 (B)	2 (A)	2 (B)	3 (A)	3 (B)	4 (A)	4 (B)	5 (A)	5 (B)	6 (A)	6 (B)	7 (A)	7 (B)
	0	0	0	0	0	NUL	GTL	DLE		SP	0	0	16	@	0	P	16	a		p	
	0	0	0	1	1	SOH		DC1	LLO	!	1	1	17	A	1	Q	17	b		q	
	0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	c		r	
	0	0	1	1	3	ETX		DC3		#	3	3	19	C	3	S	19	d		s	
	0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	e		t	
	0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	f		u	
	0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	g		v	
	0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	h		w	
	1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	i		x	
	1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	j		y	
	1	0	1	0	10	LF		SUB		•	10	:	26	J	10	Z	26	k		z	
	1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	l		{	
	1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	m		:	
	1	1	0	1	13	CR		GS		–	13	=	29	M	13	]	29	n		}	
	1	1	1	0	14	SO		RS		.	14	>	30	N	14	^	30	o		≅	
	1	1	1	1	15	SI		US		/	15	?	UNL	O	15	_	UNT			DEL	

ADDRESSED COMMAND GROUP (ACG)
UNIVERSAL COMMAND GROUP (UCG)
LISTEN ADDRESS GROUP (LAG)
TALK ADDRESS GROUP (TAG)
PRIMARY COMMAND GROUP (PCG)
SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE) PPU (PARALLEL POLL UNCONFIGURE), and TCT (TAKE CONTROL) not implemented by Model 6430.
Note: D_0 = D101 ...D_7 = D108; X = Don't Care.

Typical command sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table D-3 lists a typical bus sequence for sending the addressed multiline commands. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table D-3
Typical addressed multiline command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	8	38	56
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 24.

Table D-4 gives a typical common command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the common command string.

Table D-4
Typical addressed common command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	8	38	56
3	Data	Set high	*	2A	42
4	Data	Stays high	R	52	82
5	Data	Stays high	S	53	83
6	Data	Stays high	T	54	84

*Assumes primary address = 24.

IEEE command groups

Command groups supported by the SourceMeter are listed in Table D-5. Common commands and SCPI commands are not included in this list.

Table D-5
IEEE command groups

HANDSHAKE COMMAND GROUP	
	NDAC = NOT DATA ACCEPTED NRFD = NOT READY FOR DATA DAV = DATA VALID
UNIVERSAL COMMAND GROUP	
	ATN = ATTENTION DCL = DEVICE CLEAR IFC = INTERFACE CLEAR REN = REMOTE ENABLE SPD = SERIAL POLL DISABLE SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP	
LISTEN	LAG = LISTEN ADDRESS GROUP MLA = MY LISTEN ADDRESS UNL = UNLISTEN
TALK	TAG = TALK ADDRESS GROUP MTA = MY TALK ADDRESS UNT = UNTALK OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP	
	ACG = ADDRESSED COMMAND GROUP GTL = GO TO LOCAL SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP	
	RQS = REQUEST SERVICE SRQ = SERIAL POLL REQUEST STB = STATUS BYTE EOI = END

Interface function codes

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the SourceMeter are listed in Table D-6. The codes define SourceMeter capabilities as follows:

Table D-6
SourceMeter interface function codes

Code	Interface function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T5	Talker (basic talker, serial poll, unaddressed to talk on LAG)
L4	Listener (basic listener, unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open collector bus drivers
TE0	No Extended Talker capability
LE0	No Extended Listener capability

SH (Source Handshake Function) — SH1 defines the ability of the instrument to initiate the transfer of message/data over the data bus.

AH (Acceptor Handshake Function) — AH1 defines the ability of the instrument to guarantee proper reception of message/data transmitted over the data bus.

T (Talker Function) — The ability of the instrument to send data over the bus to other devices is provided by the T function. Instrument talker capabilities (T5) exist only after the instrument has been addressed to talk.

L (Listener Function) — The ability for the instrument to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities (L4) of the instrument exist only after it has been addressed to listen.

SR (Service Request Function) — SR1 defines the ability of the instrument to request service from the controller.

RL (Remote-Local Function) — RL1 defines the ability of the instrument to be placed in the remote or local modes.

PP (Parallel Poll Function) — The instrument does not have parallel polling capabilities (PP0).

DC (Device Clear Function) — DC1 defines the ability of the instrument to be cleared (initialized).

DT (Device Trigger Function) — DT1 defines the ability of the SourceMeter to have readings triggered.

C (Controller Function) — The instrument does not have controller capabilities (C0).

TE (Extended Talker Function) — The instrument does not have extended talker capabilities (TE0).

LE (Extended Listener Function) — The instrument does not have extended listener capabilities (LE0).

E (Bus Driver Type) — The instrument has open-collector bus drivers (E1).

E
IEEE-488 and SCPI Conformance Information

Introduction

The IEEE-488.2 standard requires specific information about how the SourceMeter implements the standard. Paragraph 4.9 of the IEEE-488.2 standard (Std 488.2-1987) lists the documentation requirements. Table E-1 provides a summary of the requirements, and provides the information or references the manual for that information. Table E-2 lists the coupled commands used by the SourceMeter.

The SourceMeter complies with SCPI version 1996.0. Tables 17-1 through 17-10 list the SCPI confirmed commands and the non-SCPI commands implemented by the SourceMeter.

Table E-1
IEEE-488 documentation requirements

	Requirements	**Description or reference**
(1)	IEEE-488 Interface Function Codes.	See Appendix D.
(2)	Behavior of SourceMeter when the address is set outside the range 0-30.	Cannot enter an invalid address.
(3)	Behavior of SourceMeter when valid address is entered.	Address changes and bus resets.
(4)	Power-On Setup Conditions.	Determine by :SYSTem:POSetup. See Section 17.
(5)	Message Exchange Options:	
(a)	Input buffer size.	2048 bytes.
(b)	Queries that return more than one response message unit.	None.
(c)	Queries that generate a response when parsed.	All queries (Common Commands and SCPI).
(d)	Queries that generate a response when read.	None.
(e)	Coupled commands.	See Table E-2.
(6)	Functional elements required for SCPI commands.	Contained in SCPI command subsystems tables (see Tables 17-1 through 17-10).
(7)	Buffer size limitations for block data.	Block display messages: 32 characters max.
(8)	Syntax restrictions.	See Section 13, *Programming syntax*.
(9)	Response syntax for every query command.	See Section 13, *Programming syntax*.
(10)	Device-to-device message transfer that does not follow rules of the standard.	None.
(11)	Block data response size.	See Section 17, *FORMat subsystem*.
(12)	Common Commands implemented by SourceMeter.	See Section 15, *Common commands.*
(13)	Calibration query information.	See Service Manual.
(14)	Trigger macro for *DDT.	Not applicable.
(15)	Macro information.	Not applicable.
(16)	Response to *IDN (identification).	See Section 15, *Common commands*.
(17)	Storage area for *PUD and *PUD?.	Not applicable.
(18)	Resource description for *RDT and *RDT?.	Not applicable.
(19)	Effects of *RST, *RCL and *SAV.	See Section 15, *Common commands*.
(20)	*TST information.	See Section 15, *Common commands*.
(21)	Status register structure.	See Section 14, *Status structure*.
(22)	Sequential or overlapped commands.	All are sequential except :INIT.
(23)	Operation complete messages.	*OPC, *OPC? and *WAI; see Section 15, *Common commands*.

Table E-2
Coupled commands

Command	Also changes
:SENSe...:RANGe:UPPER	:SENSe...:RANGe:AUTO
:SENSe...:NPLC	:NPLC for all other functions
:SOURce...:RANGe	:SOURce...:RANGe:AUTO
:SOURce...:STARt	:SOURce...:STEP
	:SOURce...:CENTer
	:SOURce...:SPAN
:SOURce...:STOP	:SOURce...:STEP
	:SOURce...:CENTer
	:SOURce...:SPAN
:SOURce...:STEP	:SOURce...:POINts
:SOURce...:POINts	:SOURce...:STEP
:SOURce...:CENTer	:SOURce...:STARt
	:SOURce...:STOP
	:SOURce...:STEP
:SOURce...:SPAN	:SOURce...:STARt
	:SOURce...:STOP
	:SOURce...:STEP
REN, GTL	See local and remote transition in Section 13, *Differences: remote vs. local operation*.
:SYSTem:MEMory:INITialize	See command description in Section 17, *SYSTem subsystem*.

F
Measurement Considerations

NOTE *This appendix summarizes considerations to make safe, accurate measurements using the Model 6430. For comprehensive information on these and additional measurement considerations, refer to the Low Level Measurements handbook, which is available from Keithley.*

Floating measurement safety concerns

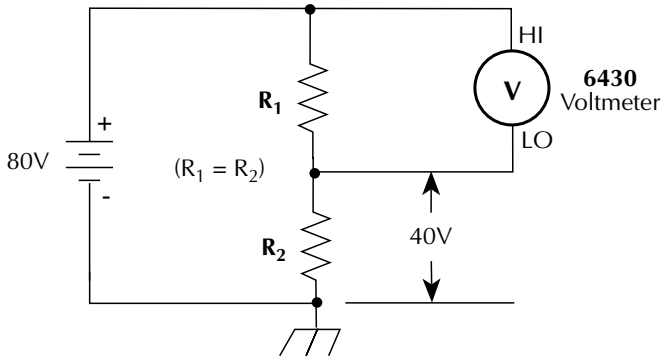
The Model 6430 can perform floating measurements up to 42V above chassis ground. Even though 42V is not considered a lethal level, it is high enough to cause a shock.

Figure F-1 shows two examples where the Model 6430 floats at 40V above chassis ground. Keep in mind the outer shells of the triax connectors on the Remote PreAmp are connected to input/output LO. Therefore, 40V is present on those shells as well as the outer casings of the triax cable(s). If meter LO is connected to a noise shield, then 40V will also be present on that shield. Typically, a test circuit is enclosed in a test fixture that is connected to a safety earth ground. The test connection drawings in Section 2 show how a test fixture should be used.

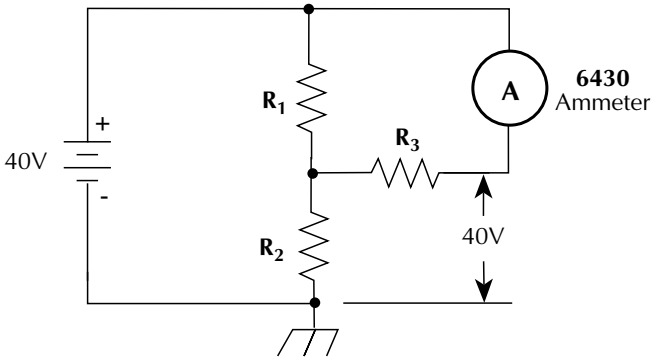
WARNING **To prevent a shock hazard and possible damage to the Model 6430, never exceed 42V peak between input/output LO and chassis ground.**

WARNING **To prevent injury from electric shock, DO NOT touch the triax cables (or connectors) of the Remote PreAmp while the SourceMeter is turned on or any external source is turned on.**

Figure F-1
Floating measurements



A. Voltage measurement



B. Current measurement

Low current measurements

Low current measurements are subject to a number of error sources that can have a serious impact on measurement accuracy. First, the Remote PreAmp may cause measurement errors if not connected properly. Making proper shielded connections is discussed in Section 2. The voltage burden and input offset current of the ammeter may also affect the measurements. The source impedance of the device under test will affect the noise performance of the Remote PreAmp. Possible external error sources include leakage current from cables and fixtures, as well as currents generated by effects such as triboelectric or piezoelectric.

Leakage currents and guarding

Leakage currents are generated by high resistance paths between the measurement circuit and nearby voltage sources. These currents can considerably degrade the accuracy of low current measurements. Some ways to reduce leakage currents are to use good quality insulators, reduce humidity, and use guarding. Guarding can also be used to reduce the effect of shunt capacitance in the measurement circuit.

One way to reduce leakage currents is to use good quality insulators when building the test circuit. Some good quality insulators include Teflon, polyethylene, and sapphire. Avoid materials such as phenolics and nylon.

Humidity may also degrade low current measurements. The amount of water an insulator absorbs will vary depending upon the insulator. It is best to choose an insulator on which water vapor does not readily form a continuous film. Sometimes this is unavoidable if the material being measured absorbs water easily, so it is best to make the measurements in an environmentally controlled room. In some cases, an insulator may have ionic contaminants and, especially in high humidity, a spurious current may be generated.

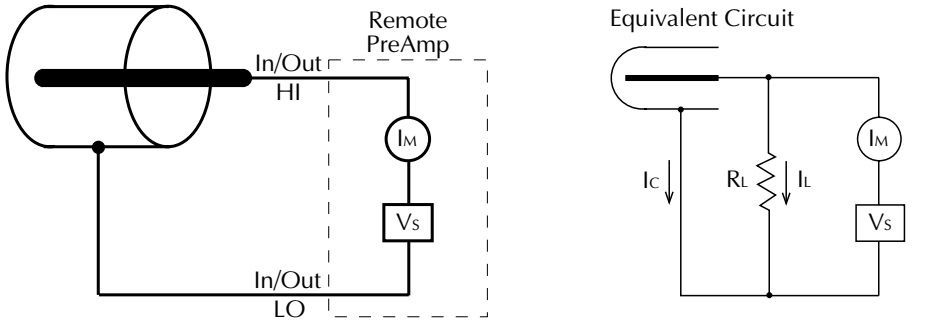
Another way to reduce leakage currents is to use guarding. A guard is a conductor connected to a low impedance point in the circuit that is nearly at the same potential as the high impedance lead being guarded. Guarding can isolate the high-impedance input lead of the Remote PreAmp from leakage current due to voltage sources. The concepts of guarding are covered in Section 5.

An example of guarding as applied to an ionization chamber is shown in Figure F-2. An unguarded ionization chamber and the corresponding equivalent circuit are shown in Figure F-2A. The equivalent circuit shows that the full bias voltage appears across the insulator leakage resistance (R_L) and thus, a leakage current (I_L) will be added to the measured ion current ($I_M = I_C + I_L$). The leakage resistance is primarily due to the insulator of the ionization chamber.

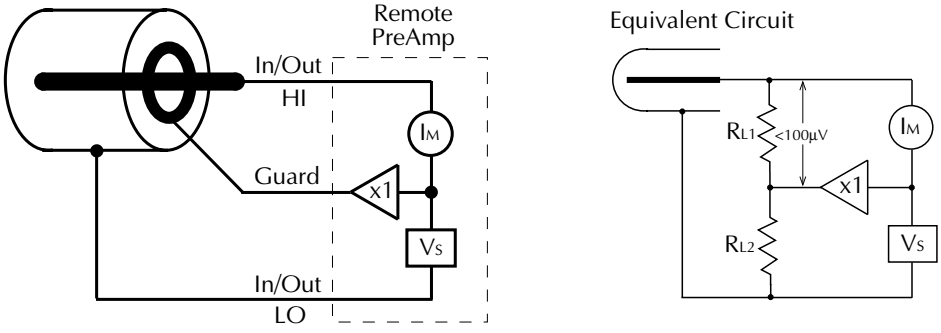
In Figure F-2B, a metal guard ring is added to the ionization chamber. This guard ring is connected to the driven guard of the Remote PreAmp. This circuit splits the leakage resistance into two parts; R_{L1} and R_{L2}. The driven guard is at almost the same voltage potential as output HI. The voltage difference is <1mV, and is known as the voltage burden of the Remote PreAmp. Since the top and bottom of R_{L1} are at nearly the same potential, no significant current will flow through it.

In a similar manner, guarding may also be necessary to prevent leakage current in test fixtures. See *Cable guard* and Figure 5-11 in Section 5 for details.

Figure F-2 *Guarding an ionization chamber*



A. Unguarded ionization chamber



B. Guarded ionization chamber

Noise and source impedance

Noise can seriously affect sensitive current measurements. This section discusses how DUT (device under test) resistance and capacitance affect noise performance.

DUT resistance

The resistance of the DUT will affect the noise performance of the ammeter. As the DUT resistance is reduced, the noise gain of the ammeter will increase. Noise gain can be given by the following equation:

$$\text{Output } V_{NOISE} = \text{Input } V_{NOISE} (1 + R_F/R_{DUT})$$

where;

- Output V_{NOISE} is noise seen at the output of the ammeter.
- Input V_{NOISE} is the noise seen at the input of the ammeter.
- R_F is the internal feedback resistance for the ammeter.
- R_{DUT} is the resistance of the DUT.

Note that as R_{DUT} decreases in value, the output noise increases. For example, when $R_F = R_{DUT}$, the input noise is multiplied by a factor of two. Since decreasing the source resistance can have a detrimental effect on noise performance, there are usually minimum recommended source resistance values based on measurement range. Table F-1 summarizes minimum recommended source resistance values for various measurement ranges for the ammeter. Note that the recommended source resistance varies by measurement range because the R_F value also depends on the measurement range.

Table F-1
Minimum recommended source resistance values

I-measure range	Minimum recommended source resistance
1pA – 100pA	1GΩ to 100GΩ
1nA – 100nA	1MΩ to 100MΩ
1µA – 100µA	1kΩ to 100kΩ
1mA – 100mA	1Ω to 100Ω

Source capacitance

DUT source capacitance will also affect the noise performance of the ammeter. In general, as source capacitance increases, the noise gain also increases.

The elements of interest for this discussion are the capacitance (C_{DUT}) of the DUT and the internal feedback capacitance (C_F) for the ammeter. Taking into account the capacitive reactance of these two elements, our previous noise gain formula must be modified as follows:

Output V_{NOISE} = Input V_{NOISE} $(1 + Z_F/Z_{DUT})$

where;

- Output V_{NOISE} is the noise seen at the output of the ammeter.
- Input V_{NOISE} is the noise seen at the input of the ammeter.
- Z_F is the internal feedback impedance for the ammeter that is formed by C_F and R_F.
- Z_{DUT} is the internal impedance of the DUT that is formed by C_{DUT} and R_{DUT}.

Furthermore,

$$Z_F = \frac{R_F}{\sqrt{(2\pi f R_F C_F)^2 + 1}}$$

and

$$Z_{DUT} = \frac{R_S}{\sqrt{(2\pi f R_S C_S)^2 + 1}}$$

Note that as C_S increases in value, Z_{DUT} decreases in value, thereby increasing the noise gain. Again, at the point where $Z_{DUT} = Z_F$, the input noise is amplified by a factor of two.

The maximum values of DUT capacitance (C_{DUT}) for the ammeter are listed in Table 3-3 (see *Basic source-measure procedure, current measurements and capacitive loads* in Section 3. You can, however, usually measure at higher load capacitance values by inserting a resistor in series with the ammeter input. Remember that any series resistance will increase the voltage burden by a factor of $I_{IN} \times R_{SERIES}$. For example, the range of resistance listed in Table F-1 will result in voltage burden values in range of l mV to 1V. A useful alternative to a series resistor is a series diode, or two diodes in parallel back-to-back. The diodes can be small-signal types and should be in a light-tight enclosure.

Generated currents

Any extraneous generated currents in the test system will add to the desired current, causing errors. Currents can be internally generated, as in the case of instrument input offset current, or they can come from external sources such as insulators and cables.

Offset currents

Internal offset current — The ideal ammeter should read zero when its input terminals are left open. Practical ammeters, however, do have some small current that flows when the input is

open. This current is known as the input offset current, and it is caused by bias currents of active devices as well as by leakage currents through insulators within the instrument.

The internal input offset current adds to the source current so that the meter measures the sum of the two currents:

$I_M = I_S + I_{I0}$

where; I_M is the measured current.
I_S is the source current.
I_{I0} is the internal input offset current.

Internal current noise — Peak-to-peak noise over any one minute interval will be within 400aA during 90% of the interval for following conditions:

- The triax input connectors of the Remote PreAmp capped, and on the 1pA range for at least three minutes.
- Auto filter on.
- Auto zero off.
- Source delay set to 0 sec.

External offset current — Offset currents can also be generated from external effects, such as electrochemical effect (discussed below). The external offset current also adds to the source current, and the ammeter again measures the sum of the currents:

$I_M = I_S + I_{I0} + I_{EO}$

where; I_{EO} is the external offset current.

As long as the internal and external offsets remain stable for a reasonable period of time, the Relative feature of the SourceMeter can be used to zero out offset current. With the source current (I_S) set to zero, the ammeter will only measure and display the offset current reading. When REL is enabled, the display will zero. What happens is that the offset current reading is acquired as the rel value and is subtracted from present and future readings. When the source current is applied, the displayed reading will not include the offset:

$I_M = I_S + I_{I0} + I_{EO}$ - rel
$I_M = I_S$

where; rel is the rel value ($I_{I0} + I_{EO}$).

As long as the rel value equals the sum of the offsets, only the source current will be displayed. See Section 7 for details on Relative.

Offset current drift is a function of time and/or temperature. Therefore, when offset current drifts significantly, you will have to re-zero the ammeter.

Electrochemical effects

Error currents also arise from electrochemical effects when ionic chemicals create weak batteries on a circuit board. These batteries could generate a few nanoamps of current between conductors. Ionic contamination may be the result of body oils, salts or solder flux. The problem is further enhanced by high humidity (moisture) that decreases insulation resistance.

When building test fixtures, select insulators that resist water absorption, and use the fixture in a moderate humidity environment. Also, be sure that all insulators are kept clean and free of contamination.

Humidity

Excess humidity can reduce insulation resistance on PC boards and in test connection insulators. Reduction in insulation resistance can, of course, seriously affect high-impedance measurements. Also, humidity (moisture) can combine with contaminants to produce offset currents caused by electrochemical effects (see *Electrochemical effects*). To minimize the effects or moisture, keep humidity to a minimum (ideally <50%), and keep components and connectors in the test system clean.

Triboelectric effects

Triboelectric currents are generated by charges created between a conductor and an insulator due to friction. Here, free electrons rub off the conductor and create a charge imbalance that causes the current flow. For example, bending a triaxial cable causes friction between the center conductor (HI) and its surrounding insulator resulting in triboelectric currents.

Triboelectric currents can be minimized as follows:

- Use “low noise” cables. These cables are specially designed to minimize charge generation and use graphite to reduce friction. The triax cable supplied with the Model 6430 is low noise.
- Use the shortest cables possible, and secure them (i.e., taping or tying) to a non-vibrating surface to keep them from moving.

Piezoelectric and stored charge effects

Piezoelectric currents are generated when mechanical stress is applied to certain insulating materials (i.e., crystalline). In some plastics, pockets of stored charge cause the material to behave in a similar manner.

When building test fixtures, choose good insulating materials and make connecting structures as rigid as possible. Make sure there are no mechanical stresses on the insulators.

Dielectric absorption

Dielectric absorption in an insulator can occur when a voltage across that insulator causes positive and negative charges within the insulator to polarize because various polar molecules relax at different rates. When the voltage is removed, the separated charges generate a decaying current through circuits connected to the insulator as they recombine.

To minimize the effects of dielectric absorption on current measurements, avoid applying voltages greater than a few volts to insulators being used for sensitive current measurements. In cases where this practice is unavoidable, it may take minutes or even hours in some cases for the current caused by dielectric absorption to dissipate.

Voltage burden

The input resistance of the ammeter causes a small voltage drop across the input terminals. This voltage is known as the voltage burden. If the voltage burden is large in relation to the voltage of the measured circuit, then significant measurement errors will occur.

Refer to Figure F-3 to see how voltage burden affects current measurements. Assume V_S is set to output 5mV and R_L is 5kΩ. An ideal ammeter with zero voltage burden would measure the current source as follows:

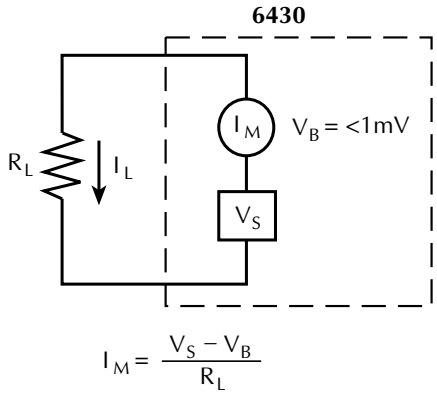
$$I_M = V_S/R_S$$
$$= 5mV/5k\Omega$$
$$= 1$$

In practice however, every ammeter has a voltage burden. If the voltage burden (V_B) is lmV, the current will be measured as follows:

$$I_M = (V_S + V_B) / R_S$$
$$= (5mV + 1mV) / 5k\Omega$$
$$= 1.2$$

The lmV voltage burden caused a 20% measurement error. The voltage burden of Model 6430 is <1mV.

Figure F-3
Voltage burden



Overload protection

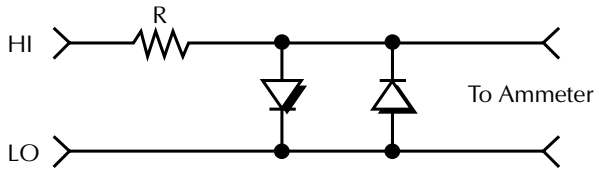
The Model 6430 may be damaged if more than 200V is applied to the input. In some applications, this maximum voltage may be unavoidably exceeded. In these cases, additional overload protection is required to avoid damaging the input circuitry of the instrument.

Figure F-4 shows a protection circuit consisting of a resistor and two diodes (IN3595). The leakage of the 1N3595 diode is generally less than 1pA even with 1mV of forward bias, so the circuit will not interfere with measurements of 10pA or more. This diode is rated to carry 225mA (450mA repeated surge). Since the voltage burden of the ammeter is less than 1mV, the diodes will not conduct. With two diodes in parallel back to back, the circuit will provide protection regardless of the input polarity.

The resistor (R,) must be large enough to limit the current through the diodes to prevent damage to the diodes. It also must be large enough to withstand the output voltage. A good rule of thumb is to use a large enough resistor to cause a one volt drop at the maximum current to be measured.

The protection circuit should be enclosed in a light-tight shield that is connected to input/output low.

Figure F-4
Overload protection for ammeter input



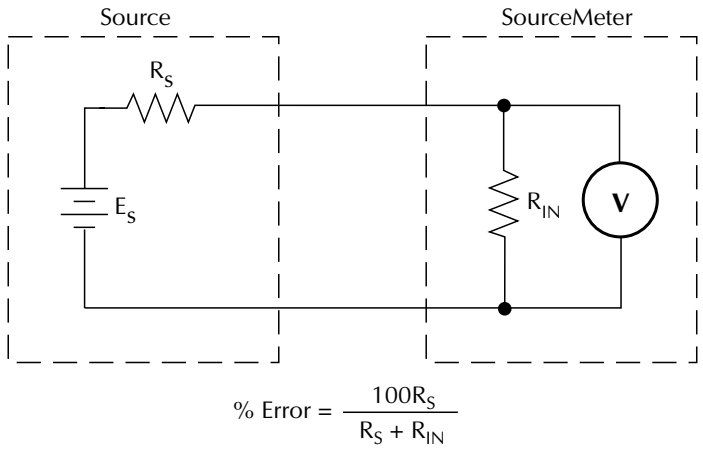
High impedance voltage measurements

Loading effects

Circuit loading can be detrimental to high-impedance voltage measurements. Fortunately, the input resistance of the Model 6430 voltmeter is very high ($>10^{16}\Omega$), therefore, it would take a very large load resistance to cause voltmeter loading.

To see how meter loading can affect accuracy, refer to Figure F-5 where the SourceMeter is configured to measure voltage only. R_S represents the resistance component of the source, while R_{IN} represents the input resistance of the voltmeter. The percent error due to loading can be calculated using the formula in the illustration. To keep the error under 0.1%, the input resistance (R_{IN}) must be about 1000 times the value of the source resistance (R_S). The input resistance of Model 6430 is $>10^{16}\Omega$. Therefore, to keep the error under 0.1%, the source resistance of the measured voltage must be $<10^{13}\Omega$.

Figure F-5
Meter loading



Cable leakage resistance

For a voltage measurement, leakage resistance in a triax cable (from HI to LO) shunts the voltage source to be measured. If the voltage source has a very high-impedance, the resultant leakage current could be high enough to corrupt the measurement.

The Remote PreAmp uses guarded triax connectors to, for the most part, eliminate the problem of leakage current in triax cables. The center conductor (HI) is surrounded by the inner shield, which is cable guard. Ideally, guard is at the same potential as the HI terminal, and therefore, no leakage current will flow through the insulation. However, in reality, there is a small voltage differential between HI and guard (<1mV). Therefore, there will be a small leakage current through the cable. If the insulation resistance is 2GΩ, then the leakage current will be <0.5pA (<1mV / 2GΩ = 0.5pA).

For voltmeters that do not use guarding, the leakage current would be dependent on the voltage seen at input HI. For example, with input HI at 10V, the leakage current would be 5nA (10V / 2GΩ = 5nA). This leakage is 10,000 times higher than the Model 6430 Remote PreAmp.

Input capacitance (settling time)

The settling time of the circuit is particularly important when making volts measurements of a source that has high internal resistance (Figure F-6).

The shunt capacitance (C) has to fully charge before an accurate voltage measurement can be made by VM of Model 6430. The time period for charging the capacitor is determined by the RC time constant (one time constant, τ = RC), and the familiar exponential curve of Figure F-7 results. Therefore, it becomes necessary to wait four or five time constants to achieve an accurate reading. For example, if R = 100GΩ and C = 10pF, RC time constant would be 1 second. If 1% accuracy is required, a single measurement would require at least five seconds.

For voltmeters that do not use guarding, the triax input cable is a primary source of capacitance. Inside the cable, the insulation between the HI and LO terminals form a capacitor that shunts the input of the voltmeter. The longer the cable, the larger the capacitance.

The guarded triax connectors of the Remote PreAmp minimize the problem of capacitance in cables. The center conductor (HI) is surrounded by the inner shield, which is cable guard. Ideally, guard is at the same potential as the HI terminal. With HI and guard at the same voltage, there is no charge-discharge capacitive action to slow down the measurement. However, in reality, there is a small voltage differential between HI and guard (<1mV). Therefore, there will be a little capacitive action due to the cables. The best way to minimize this capacitance is to use short triax cables.

Figure F-6
Effects of input capacitance

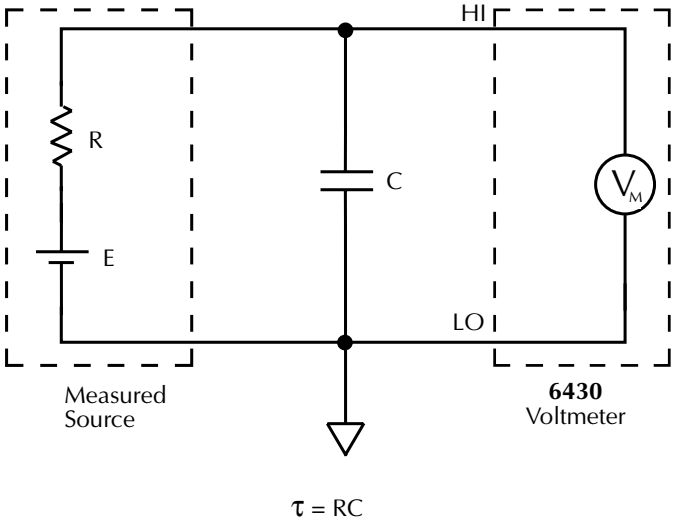
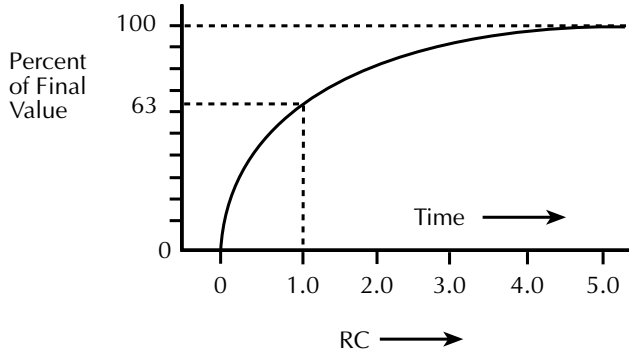


Figure F-7
Settling time



High resistance measurements

Ohms measurement methods

The SourceMeter can make ohms measurements by either sourcing current, measuring voltage (constant-current method), or sourcing voltage, measuring current (constant-voltage method). After the appropriate voltage and current readings are acquired, the resistance reading is calculated using Ohms Law (R = V/I).

When using the constant-current method, the SourceMeter outputs a precise current and then measures the voltage across the DUT. For high-impedance DUT, the considerations for "High-impedance voltage measurements" apply.

When using the constant-voltage method, the SourceMeter outputs a precise voltage and then measures the current through the DUT. For high-impedance DUT, the considerations and techniques for "Low current measurements" apply.

Characteristics of high-valued resistors

Resistors with values of 1GΩ or more are often referred to as megohm resistors. Because of their high resistances, these components are very unusual devices; accordingly, there are a number considerations to take into account when measuring these devices: voltage and temperature coefficients, the effects of mechanical shock, and contamination.

Two types of high-megohm resistors are widely used: carbon-film and metal-oxide. Although other types are available, experience has shown that these two are the most useful. Compared to conventional resistors, carbon-film high-megohm resistors are noisy, unstable, have high temperature coefficients, display high voltage coefficients, and are very fragile. Recent developments in metal-oxide types have resulted in resistors with much lower voltage coefficients, as well as improved temperature and time stability. Modern devices exhibit voltage coefficients less than 5ppm/V and no significant drift after five years of tests. Temperature coefficients are on the order of 0.01%/˚C at 100MΩ, 0.025%/˚C at 100GΩ.

Such delicate devices require extreme care in handling. Mechanical shock may significantly alter the resistance by dislodging particles of the conductive material. It is also important that the resistance element or the glass envelope that surrounds it not be touched; doing so could change its resistance due to the creation of new current paths or small electrochemically generated currents.

The resistors are coated to prevent water films from forming on the surface. Therefore, if it is suspected that the resistor has acquired surface films from careless handling or deposits from air contaminants, it should be cleaned with a cotton swab and methanol. After cleaning, the resistor should be dried in a low-humidity atmosphere for several hours to allow any static charges to dissipate.

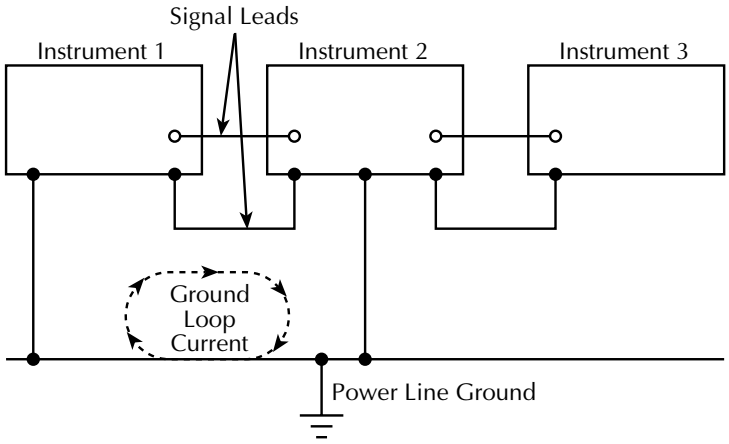
General measurement considerations

The following measurement considerations apply to all precision measurements.

Ground loops

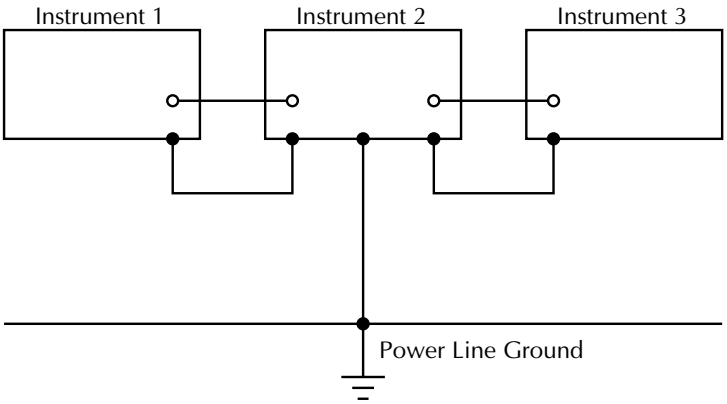
Ground loops that occur in multiple-instrument test setups can create error signals that cause erratic or erroneous measurements. The configuration shown in Figure F-8 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances, either in the wires, or at the connecting points. This small resistance results in voltage drops that can affect the measurement. Even if the ground loop currents are small, magnetic flux cutting across the large loops formed by the ground leads can induce sufficient voltages to disturb sensitive measurements.

Figure F-8
Power line ground loops



To prevent ground loops, instruments should be connected to ground at only a single point, as shown in Figure F-9. Note that only a single instrument is connected directly to power line ground. Experimentation is the best way to determine an acceptable arrangement. For this purpose, measuring instruments should be placed on their lowest ranges. The configuration that results in the lowest noise signal is the one that should be used.

Figure F-9
Eliminating ground loops



Light

Some components, such as semiconductor junctions and MOS capacitors on semiconductor wafers, are excellent light detectors. Consequently, these components must be tested in a light-free environment. While many test fixtures provide adequate light protection, others may allow sufficient light penetration to affect the test results. Areas to check for light leaks include doors and door hinges, tubing entry points, and connectors or connector panels.

Electrostatic interference

Electrostatic interference occurs when an electrically charged object is brought near an uncharged object, thus inducing a charge on the previously uncharged object. Usually, effects of such electrostatic action are not noticeable because low impedance levels allow the induced charge to dissipate quickly. However, the high impedance levels of many measurements do not allow these charges to decay rapidly, and erroneous or unstable readings may result. These erroneous or unstable readings may be caused in the following ways:

- DC electrostatic field can cause undetected errors or noise in the reading.
- AC electrostatic fields can cause errors by driving the input preamplifier into saturation, or through rectification that produces DC errors.

Electrostatic interference is first recognizable when hand or body movements near the experiment cause fluctuations in the reading. Means of minimizing electrostatic interference include:

1. Shielding. Possibilities include: a shielded room, a shielded booth, shielding the sensitive circuit, and using shielded cable. The shield should always be connected to a solid connector that is connected to signal low. If circuit low is floated above ground, observe safety precautions, and avoid touching the shield. Meshed screen or loosely braided cable could be inadequate for high impedances, or in strong fields. Note, however, that shielding can increase capacitance in the measuring circuit, possibly slowing down response time.
2. Reduction of electrostatic fields. Moving power lines or other sources away from the experiment reduces the amount of electrostatic interference seen in the measurement.

Magnetic fields

A magnetic field passing through a loop in a test circuit will generate a magnetic EMF (voltage) that is proportional to the strength of the field, the loop area, and the rate at which these factors are changing. Magnetic fields can be minimized by following these guidelines:

- Locate the test circuit as far away as possible from such magnetic field sources as motors, transformers and magnets.
- Avoid moving any part of the test circuit within the magnetic field.
- Minimize the loop area by keeping leads as short as possible and twisting them together.

Electromagnetic Interference (EMI)

The electromagnetic interference characteristics of the Model 6430 comply with the electromagnetic compatibility (EMC) requirements of the European Union as denoted by the CE mark. However, it is still possible for sensitive measurements to be affected by external sources. In these instances, special precautions may be required in the measurement setup.

Sources of EMI include:

- Radio and TV broadcast transmitters.
- Communications transmitters, including cellular phones and handheld radios.
- Devices incorporating microprocessors and high-speed digital circuits.
- Impulse sources as in the case of arcing in high-voltage environments.

The effect on instrument performance can be considerable if enough of the unwanted signal is present. The effects of EMI can be seen as an unusually large offset, or, in the case of impulse sources, erratic variations in the displayed reading.

The instrument and experiment should be kept as far away as possible from any EMI sources. Additional shielding of the instrument, experiment and test leads will often reduce EMI to an acceptable level. In extreme cases, a specially constructed screen room may be required to sufficiently attenuate the troublesome signal.

External filtering of the input signal path may be required. In some cases, a simple one-pole filter may be sufficient. In more difficult situations, multiple notch or band-stop filters, tuned to the offending frequency range, may be required. Connecting multiple capacitors of widely different values in parallel will maintain a low impedance across a wide frequency range. Keep in mind, however, that such filtering may have detrimental effects (such as increased response time) on the measurement.

G
GPIB 488.1 Protocol

Introduction

The Model 6430 supports two GPIB protocols: SCPI and 488.1. The 488.1 protocol is included to significantly increase speed over the GPIB.

When using the 488.1 protocol, throughput is enhanced up to 10 times for data sent to the Model 6430 (command messages) and up to 20 times for data returned by the Model 6430 (response messages). The speed of readings sent over the GPIB is also increased; see *GPIB reading speed comparisons* at the end of this Appendix for details.

NOTE *With the 488.1 protocol selected, you will still use SCPI commands to program the Model 6430. Operation differences between the two protocols are discussed in this appendix.*

Selecting the 488.1 protocol

Perform the following steps to select the 488.1 protocol:

1. Press MENU to display the MAIN MENU.
2. Place the cursor on COMMUNICATION, and press ENTER to display the COMMUNICATIONS SETUP menu.
3. Place the cursor on GPIB, and press ENTER to display the present GPIB address.
4. Press ENTER to display the GPIB PROTOCOL menu.
5. Place the cursor on 488.1, and press ENTER.
6. Use the EXIT key to back out of the menu structure.

When switching between the SCPI protocol and 488.1 protocol, the instrument does not reset. The GPIB protocol setting is saved in EEPROM, and the unit will power up with that selected protocol.

The GPIB protocol cannot be changed over the bus. However, there is a query command to determine the presently selected protocol. When the 488.1 protocol is selected, the message exchange protocol (MEP) disables. Therefore, if you use the following query to request the state of MEP, you will know which protocol is enabled:

:SYSTem:MEP[:STATe]?

If a “1” is returned, MEP is enabled, and the SCPI protocol is selected. A “0” indicates that MEP is disabled, and the 488.1 protocol is enabled. To summarize:

1 = SCPI protocol
0 = 488.1 protocol

Protocol differences

The following information covers the differences between the 488.1 protocol and the SCPI protocol.

Message exchange protocol (MEP)

When the 488.1 protocol is selected, the MEP is disabled to speed up GPIB operation.

The following guidelines/limitations must be followed when using the 488.1 protocol:

- If a query is sent, it must be the only command on the line (this limitation also means no multiple queries can be sent). Otherwise, full SCPI command syntax is still supported including long-form and short form commands, multiple commands, and MIN/MAX/DEF parameter definitions.

  For example, the following command strings are invalid:
  :VOLT:RANG 10;*OPC?
  :RES:RANG?;:READ?
  :READ?;:READ?

  The following command strings are valid:
  :SOUR1:VOLTage:STARt 1;STOP 10;step 1
  :volt:nplc 1.0;:curr:rang min
  :RES:RANG? MAX
  :READ?
- When a query is sent, either the data must be read back or a Device Clear (DCL) or Interface Clear (IFC) must be performed to reset the query.
- When sending a command or query, do not attempt to read data from the Model 6430 until the terminator has been sent (usually Line Feed with EOI). Otherwise, a DCL or IFC must be sent to reset the input parser.
- When receiving data, all data, up to and including the terminator (LF with EOI), must be accepted. Otherwise, a DCL or IFC must be sent to reset the output task.
- Empty command strings (terminator only) should not be sent.

Using SCPI-based programs

In general, an existing SCPI-based program will run properly and faster in the 488.1 protocol as long as it meets the above guidelines and limitations.

NRFD hold-off

*OPC, *OPC?, and *WAI are still functional but are not needed for the 488.1 protocol. When sending commands, the GPIB is automatically held off when it detects a terminator. The hold-off is released when all the commands have finished executing, or if there is some parser or command error. An exception is an initiate command, which releases the hold-off immediately and does not wait for all of the readings to be acquired. This immediate release of bus hold-off is done to support GET, SDC, IFC, *TRG, *RCL, *RST, SYSTem:PRESet and ABORt during data acquisition.

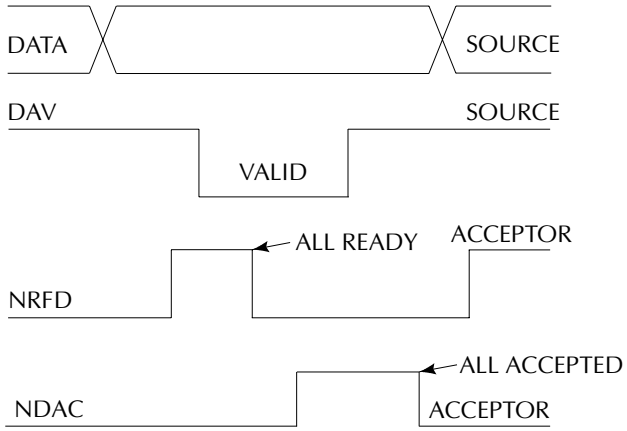
NDAC hold-off

NDAC is included with the GPIB 488.1 protocol mode to allow a single instrument to hold off all others on the bus until it is finished executing a command. The following command controls NDAC hold-off:

SYSTem:MEP:HOLDoff ON | OFF

The default is OFF, but NRFD hold-off will still be enabled and will prevent an instrument from accepting further commands. See Figure G-1 for the complete IEEE-488 handshake sequence.

Figure G-1
IEEE-488 handshake sequence



Trigger-on-talk

Trigger-on-talk functionality has been added for the 488.1 protocol. If a query has not been received by the instrument, the Model 6430 will automatically assume a READ? command has been sent when it is addressed to talk. This technique increases GPIB speed by decreasing the transmission and parser times for the command.

Trigger-on-talk is extremely useful in the single-shot reading mode (*RST default) and is the main reason for a >2x speed improvement over the SCPI protocol. Remember that the output must be on (:OUTput:STATe ON) before you can take readings.

The ARM:SOUR BUS and ARM:COUN INF commands are not supported by READ? with the 488.1 protocol selected. If you send one of these commands, a DCL or IFC may be required to reset the GPIB.

Message available

The MAV (message available) bit in the Serial Poll byte will be set when the query is finished being processed, not when there is data available in the output buffer (as with the SCPI protocol). For the 488.1 protocol, output data will not be formatted until the first request for data is received. This delay may cause unexpected time-outs when using SRQ on MAV for queries that take a long time to execute.

General operation notes

- The TALK, LSTN, and SRQ annunciators are not functional in the 488.1 protocol. This speeds up data through-put greatly. The REM annunciator still operates since it is critical to fundamental GPIB operation.
- If the unit is in REMote, the GTL command may not put the Model 6430 into the local mode. Only the front panel LOCAL key is guaranteed to operate, if not in local lockout (LLO). GTL will still disable LLO.
- IEEE-488 bus commands and features (GET, IFC, SDC, DCL, LLO, Serial Poll, and SRQ) are still fully supported.
- Multiple TALKs on the same query are supported as in the SCPI protocol. This feature is useful when reading back long ASCII strings.

GPIB reading speed comparisons

The tables that follow compare the differences in reading speed for the SCPI and 488.1 protocols. Included in all tables is the percentage improvement achieved with the 488.1 protocol compared to the SCPI protocol. The most significant speed improvements are shown in the shaded areas of the tables.

Sweep operation

Tables G-1 through G-4 show bus reading rates for measure-only, source-measure, source-measure-limit test, and source-memory sweep operation respectively. Note that the reading rate for sweep operation can be increased by almost 50%.

Table G-1
SCPI/488.1 reading speed comparisons for measure-only sweep operation (rdgs/sec)

Speed	NPLC/Trig. origin	SCPI	488.1	Improvement
Fast	0.01/internal	1198.7	1759.6	46.78%
	0.01/external	1079.3	1254.7	16.25%
Medium	0.10/internal	509.6	511.5	0.37%
	0.10/external	438.4	440.2	0.41%
Normal	1.00/internal	59.0	59.0	0.00%
	1.00/external	57.9	57.9	0.00%

Table G-2
SCPI/488.1 reading speed comparisons for source-measure sweep operation (rdgs/sec)

Speed	NPLC/Trig. origin	SCPI	488.1	Improvement
Fast	0.01/internal	999.9	1369.3	36.94%
	0.01/external	916.0	1035.2	13.02%
Medium	0.10/internal	470.2	471.6	0.29%
	0.10/external	409.3	409.8	0.12%
Normal	1.00/internal	58.4	58.4	0.00%
	1.00/external	57.3	57.3	0.00%

Table G-3
SCPI/488.1 reading speed comparisons for source-measure-limit test sweep operation (rdgs/sec)

Speed	NPLC/Trig. origin	SCPI	488.1	Improvement
Fast	0.01/internal	809.5	981.1	21.19%
	0.01/external	756.2	886.9	17.28%
Medium	0.10/internal	388.9	398.0	2.35%
	0.10/external	374.6	383.9	2.47%
Normal	1.00/internal	56.9	57.1	0.41%
	1.00/external	56.6	56.9	0.48%

Note: Pass/Fail test performed using one high limit and one low math limit.

Table G-4
SCPI/488.1 reading speed comparisons for source-memory sweep operation (rdgs/sec)

Speed	NPLC/Trig. origin	SCPI	488.1	Improvement
Fast	0.01/internal	164.8	165.2	0.23%
	0.01/external	162.6	163.0	0.23%
Medium	0.10/internal	132.8	133.0	0.15%
	0.10/external	131.4	131.4	0.00%
Normal	1.00/internal	44.4	44.4	0.00%
	1.00/external	44.2	44.2	0.00%

Note: Pass/Fail test performed using one high limit and one low math limit.

Single-shot operation

Tables G-5 through G-7 show reading rates for measure-only, source-measure, and source-measure-limit test single-shot operation respectively. Note that the reading rate can be increased by >100%.

Table G-5
SCPI/488.1 reading speed comparisons for measure-only single-shot operation (rdgs/sec)

Speed	NPLC/Trig. origin	SCPI	488.1	Improvement
Fast	0.01/internal	256.0	537.8	110.08%
Medium	0.10/internal	167.3	294.3	75.86%
Normal	1.00/internal	49.2	53.9	9.47%

Table G-6
SCPI/488.1 reading speed comparisons for source-measure single-shot operation (rdgs/sec)

Speed	NPLC/Trig. origin	SCPI	488.1	Improvement
Fast	0.01/internal	79.5	140.0	76.15%
Medium	0.10/internal	72.9	116.9	60.27%
Normal	1.00/internal	34.9	42.3	21.20%

Note: Includes time to re-program source to a new level before making measurement.

Table G-7
SCPI/488.1 reading speed comparisons for source-measure-limit test single-shot operation (rdgs/sec)

Speed	NPLC/Trig. origin	SCPI	488.1	Improvement
Fast	0.01/internal	79.3	135.9	71.44%
Medium	0.10/internal	69.9	113.9	62.81%
Normal	1.00/internal	35.0	41.7	19.33%

Notes:
1. Pass/Fail test performed using one high limit and one low math limit.
2. Includes time to re-program source to a new level before making measurement.

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Printed in the U.S.A.

No. 2193
4/2001