Series 2400 SourceMeter®

User's Manual

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KEITHLEY

A GREATER MEASURE OF CONFIDENCE

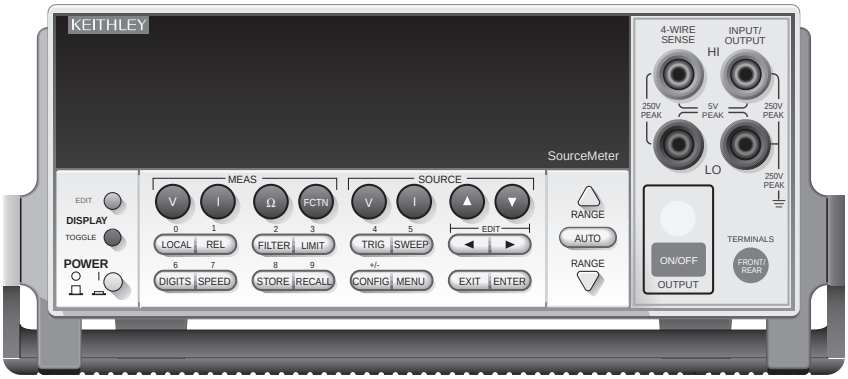
Front and rear panel familiarization

NOTE The SourceMeter models covered in this manual are very similar in appearance. Therefore, to avoid redundancy, a generic Model 2400 is used for illustration purposes.

Front panel summary

The front panel of the SourceMeter is shown in Figure 1-1. The following abbreviated information should be reviewed before operating the instrument.

Figure 1-1
SourceMeter 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).
Δ and ∇	Increase/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.
left/right arrows	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:

Δ	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	Rear input/output connectors selected.
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.

Input/output connectors:

INPUT/OUTPUT HI and LOUse to source-measure volts, amps, and ohms.
4-WIRE SENSE HI and LOUse for 4-wire remote sensing.

Input/output controls:

ON/OFF	Turns the source on or off.
FRONT/REAR	Selects front or rear panel input/output connections.

Handle:

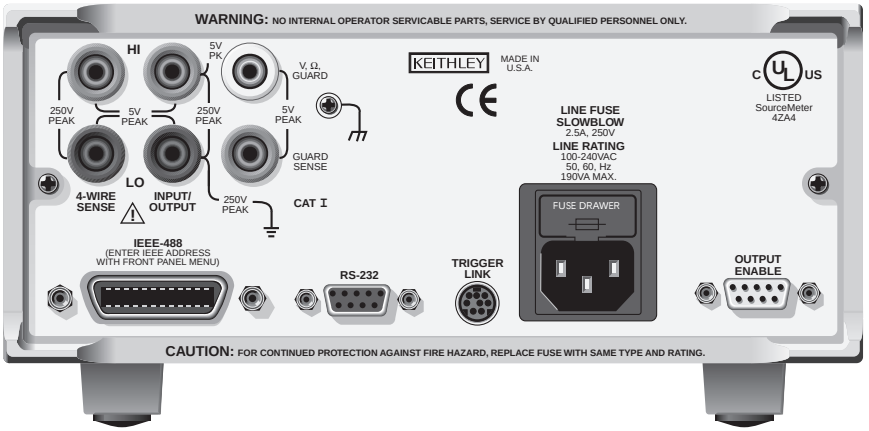
Pull out and rotate to desired position.

Rear panel summary

The rear panel of the Model 2400 SourceMeter is shown in Figure 1-2. (The Models 2410, 2420, 2425, 2430, and 2440 are similar.) The following abbreviated information should be reviewed before operating the instrument.

NOTE Models 2420, 2425, 2430, and 2440 are not UL listed.

Figure 1-2
SourceMeter rear panel



Input/output connectors:

INPUT/OUTPUT HI and LOUse to source-measure volts, amps, and ohms.
4-WIRE SENSE HI and LOUse 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 cannot be allowed to float more than the values shown in Figure 2-1 in Section 2 above chassis ground.**

Output enable and digital input/output port:

OUTPUT ENABLEConnector for digital output lines, output enable, 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.

GPIB connector:

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

Cooling fan

The Models 2410, 2420, 2425, 2430, and 2440 use a cooling fan to help keep them from overheating. The Models 2400 and 2401 do not have a cooling fan. In either case (fan or no fan), proper ventilation must be maintained to prevent overheating. Refer to the "WARNING - CAUTION" located at the beginning of Section 3 for details on maintaining proper ventilation.

Model 2410 — Uses a constant-speed fan that runs continuously while the power is on.

Models 2420, 2425, 2430, and 2440 — Uses a 3-speed fan. With the OUTPUT ON, the fan speed setting is determined by the present current range (source or measure).

2420, 2425, 2430, and 2440 range	Fan speed
10uA, 100uA, 1mA 10mA, 100mA 1A, 3A, 3A/10A (2430) 1A, 5A (2440)	Low (50%) Medium (75%) High (100%) High (100%)

When the OUTPUT is turned OFF, the fan will either run at the low speed or stay at the speed it was at when the output was on (current range dependent). This speed option is set from the FAN selection of the GENERAL MENU. (See "Main menu" in this section.)

NOTE *If the Model 2420, 2425, 2430, or 2440 overheats, the output will trip and the cooling fan will run at high speed (regardless of the speed option setting). See Section 6, "Overheating protection," for details.*

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 as covered below. This feature provides a convenient way to save specific instrument configurations and then recall them as needed. Note that you can also set up the SourceMeter to restore a specific user setup at power-on. See "Power-on configuration," page 1-15.

NOTE *There are two types of setups. Instrument configuration (user) setups (covered here) and source memory sweep setups (Section 10).*

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 1-2, 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 1-2
Factory default settings

Setting	BENCH or GPIB default
A/D Controls:	
Auto-zero	On
Line frequency	No effect
Beeper	On
Contact check mode	Disabled**
Contact check threshold resistance	50ohms**
Contact check event detection	Disabled**
Contact check timeout	0**
Data Store	No effect
Digital output	HI, HI, HI, HI
Digits	5
Fan (2420, 2425, 2430, and 2440)	Output on
FCTN	Power (off)
Filter:	Off
Averaging type	Repeat
Count	10
GPIB address	No effect
Guard	Cable
Limit tests:	
DigOut:	
Size	4-bit
Mode:	Grading
Binning control	Immediate
Auto clear:	Disabled
Delay	0.00001 sec

Table 1-2 (cont.)
Factory default settings

Clear pattern	15**
H/W limits:	
Control	Disabled
Fail mode:	In compliance
Cmpl pattern	15
S/W limits:	
Lim 2, 3, 5-12:	
Control	Disabled
Low limit:	-1.0
Low pattern	15
High limit:	+1.0
High pattern	15
Pass (all tests):	
Pass pattern	15
Source memory location	Next
EOT mode	EOT
Numbers	No effect
Ohms source mode	Auto
Offset compensated ohms	Off
Output	Off
Output enable	Disabled
Off state	Normal*
Auto-off	Disabled
Power-on default	No effect
Pulse Mode (2430 only)	
Pulse delay	0.0s
Pulse width	0.20ms
Ranging (measure):	
Auto range	Enabled
Rel	Off
Value	0.0
RS-232	No effect
Sense mode	2-wire
Source delay	1ms
Auto-delay	Enabled
Source shape (2430 only):	DC mode
Speed	Normal (1 PLC)
Sweep	Linear staircase
Start	0V or 0A
Stop	0V or 0A
Step	0V or 0A
Sweep count	1
Sweep Pts	2500
Source ranging	Best fixed
Abort on compliance	Off

Table 1-2 (cont.)
Factory default settings

Voltage protection	NONE
Triggered source:	
Control	Disabled
Scale factor	+1.0
Triggering:	
Arm layer:	
Event	Immediate
Count	1
Output trigger	Line #2, Off
Trigger layer:	
Event	Immediate
Count	1
Output triggers	Line #2, All off
Delay	0.0 sec

* Model 2410 default off state is guard.
** For instruments with contact check option (denoted by a -C in model number).

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 16).
- Restore GPIB defaults using *RST (Section 16).
- Restore bench defaults using :SYSTem:PRESet (Section 18).
- Save the power-on configuration using :SYSTem:POSetup (Section 18).

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 Complete rules to edit source and compliance values are found in the Basic source-measure procedure in Section 3. See "Editing source and compliance values" below for an overview.

- 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 EDIT Δ and ∇ 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 Δ or ∇ or RANGE Δ 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 Δ or ∇ or RANGE Δ 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.

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.

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 and Current — Table 3-1 lists the source and measure limits for the voltage and current functions.

The full range of operation is explained in Section 6, "Overheating protection" and "Operating boundaries."

NOTE *Output transient recovery — The time required for the V-source to recover to its original value (within 0.1% plus load regulation errors) after a step change in load current is <250µsec. This does not include the response time of autoranging or the second order effects on loads that are not purely resistive.*

Load regulation — The voltage specification for V-source mode load changes is 0.01% +1mV. 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% x 0.2V) + 1mV = 1.02mV

Assuming a 0 to 1A change in current, the output impedance equates to 1.02mΩ(1.02mV/1A = 1.02mΩ). This level can only be achieved using 4-wire remote sensing.

Table 3-1
Source-measure capabilities

2400/2400-LV/2401			2410		
Range	**Source**	**Measure**	**Range**	**Source**	**Measure**
200mV	±210mV	±211mV	200mV	±210mV	±211mV
2V	±2.1V	±2.11V	2V	±2.1V	±2.11V
20V	±21V	±21.1V	20V	±21V	±21.1V
200V*	±210V	±211V	1000V	±1.1kV	±1.1kV
1µA	±1.05µA	±1.055µA	1µA	±1.05µA	±1.055µA
10µA	±10.5µA	±10.55µA	10µA	±10.5µA	±10.55µA
100µA	±105µA	±105.5µA	100µA	±105µA	±105.5µA
1mA	±1.05mA	±1.055mA	1mA	±1.05mA	±1.055mA
10mA	±10.5mA	±10.55mA	20mA	±21mA	±21.1mA
100mA	±105mA	±105.5mA	100mA	±105mA	±105.5mA
1A	±1.05A	±1.055A	1A	±1.05A	±1.055A
(*2400 only) Max Power = 22W			Max Power = 22W		
2420			**2425/2430**		
Range	**Source**	**Measure**	**Range**	**Source**	**Measure**
200mV	±210mV	±211mV	200mV	±210mV	±211mV
2V	±2.1V	±2.11V	2V	±2.1V	±2.11V
20V	±21V	±21.1V	20V	±21V	±21.1V
60V	±63V	±63.3V	100V	±105V	±105.5V
10µA	±10.5µA	±10.55µA	10µA	±10.5µA	±10.55µA
100µA	±105µA	±105.5µA	100µA	±105µA	±105.5µA
1mA	±1.05mA	±1.055mA	1mA	±1.05mA	±1.055mA
10mA	±10.5mA	±10.55mA	10mA	±10.5mA	±10.55mA
100mA	±105mA	±105.5mA	100mA	±105mA	±105.5mA
1A	±1.05A	±1.055A	1A	±1.05A	±1.055A
3A	±3.15A	±3.165A	3A/10A	*	**
Max Power = 66W			2425 and 2430 Max Power DC Mode: 110W (105V, 1.05A) 66W (21V, 3.15A) Pulse Mode: 1.1kW (2430 only)		

Table 3-1 (cont.)
Source-measure capabilities

2440		
Range	**Source**	**Measure**
200mV	±210mV	±211mV
2V	±2.1V	±2.11V
10V	±10.5V	±10.5V
40V	±42V	±42V
10µA	±10.5µA	±10.55µA
100µA	±105µA	±105.5µA
1mA	±1.05mA	±1.055mA
10mA	±10.5mA	±10.55mA
100mA	±105mA	±105.5mA
1A	±1.05A	±1.055A
5A	±5.25A	±5.25A
Max Power = 66W		

* ±3.15A (DC mode; 2425 and 2430)
±10.5A (Pulse mode; 2430 only)
** ±3.165A (DC mode; 2425 and 2430)
±10.55A (Pulse mode; 2430 only)

Compliance limit

When sourcing voltage, the SourceMeter can be set to limit current. Conversely, when sourcing current, the SourceMeter can be set to limit voltage. The SourceMeter output will not exceed the compliance limit. Table 3-2 summarizes compliance limits according to range. See Section 6 for more details on compliance limit.

Table 3-2
Compliance limits

2400/2400-LV/2401		2410		2420	
Measure range	**Maximum compliance value**	**Measure range**	**Maximum compliance value**	**Measure range**	**Maximum compliance value**
200mV 2V 20V 200V*	±210mV ±2.1V ±21V ±210V	200mV 2V 20V 1000V	±210mV ±2.1V ±21V ±1.1kV	200mV 2V 20V 60V	±210mV ±2.1V ±21V ±63V
1µA 10µA 100µA 1mA 10mA 100mA 1A	±1.05µA ±10.5µA ±105µA ±1.05mA ±10.5mA ±105mA ±1.05A	1µA 10µA 100µA 1mA 20mA 100mA 1A	±1.05µA ±10.5µA ±105µA ±1.05mA ±21mA ±105mA ±1.05A	10µA 100µA 1mA 10mA 100mA 1A 3A	±10.5µA ±105µA ±1.05mA ±10.5mA ±105mA ±1.05A ±3.15A

2425/2430		2440	
Measure range	**Maximum compliance value**	**Measure range**	**Maximum compliance value**
200mV 2V 20V 100V	±210mV ±2.1V ±21V ±105V	200mV 2V 10V 40V	±210mV ±2.1V ±10.5V ±42V
10µA 100µA 1mA 10mA 100mA 1A 3A/10A	±10.5µA ±105µA ±1.05mA ±10.5mA ±105mA ±1.05A **	10µA 100µA 1mA 10mA 100mA 1A 5A	±10.5µA ±105µA ±1.05mA ±10.5mA ±105mA ±1.05A ±5.25A

* 2400 only
** ±3.15A (2425 and 2430 DC mode)
±10.5A (Pulse mode; 2430 only)

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. See Section 18, "SYSTem subsystem." 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 functions 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 -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 Section 10, "Performing a source memory sweep.")

V-source protection

Use V-source protection to select the maximum voltage level the SourceMeter can output. Available settings are listed as follows:

SourceMeter	V-Source protection limit settings
2400	20V, 40V, 60V, 80V, 100V, 120V, 160V, NONE (>160V)
2401	20V, NONE (>20V)
2410	20V, 40V, 100V, 200V, 300V, 400V, 500V, NONE (>500V)
2420	6V, 12V, 18V, 24V, 30V, 36V, 48V, NONE (>48V)
2425/2430	10V, 20V, 30V, 40V, 50V, 60V, 80V, NONE (>80V)
2440	4V, 8V, 12V, 16V, 20V, 24V, 32V, NONE (>40V)

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, 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.

Use caution when floating the SourceMeter >30V rms.

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 18, "Set voltage limit," for details. For example, the following command sets the protection value for the Model 2400 or 2410 to 20V:

:SOUR:VOLT:PROT 20

Source delay

NOTE For the Model 2430 Pulse Mode, source delay is not used. The following information assumes that the Model 2430 is in the DC Mode of operation ("Vpls" or "Ipls" displayed). To select the DC Mode, press CONFIG and then SOURCE V or I, select SHAPE from the available menu items, and then select DC.

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 (SDM) cycle. See Section 6. The auto delay option is used to automatically set the delay. The delay period is range dependent (Table 3-4).

The delay option is used to manually set the delay from 000.00000 seconds to 9999.99900 seconds. Manually setting the delay disables auto delay.

Table 3-4
Auto source delay

2400/2400-LV/2401 I-range	2410 I-range	2420 I-range	2425/2430 I-range	2440 I-range	Auto delay (Source V)	Auto delay (Source I)
1µA	1µA	10µA	10µA	10µA	3msec	3msec
10µA	10µA	100µA	100µA	100µA	2msec	1msec
100µA	100µA	1mA	1mA	1mA	1msec	1msec
1mA	1mA	10mA	10mA	10mA	1msec	1msec
10mA	20mA	100mA	100mA	100mA	1msec	1msec
100mA	100mA	1A	1A	1A	1msec	1msec
1A	1A	3A	3A/10A*	5A	1msec	2msec

*10A range only on Model 2430.

Front panel source delay

To set the manual source delay from the front panel:

1. Press CONFIG then SOURCE V.
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.
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 18, "Set delay," for details.) For example, the following command sets the source delay to 500ms:

:SOUR:DEL .5

Similarly, send the following command to enable auto delay:

:SOUR:DEL:AUTO ON

Basic source-measure procedure

Front panel source-measure procedure

Use the following procedure to perform the basic source-measure operations of the SourceMeter. See Section 4, "Ohms Measurements," to measure ohms.

NOTE *For the Model 2430, the following procedure pertains to the DC Mode of operation. Pulse Mode operation is covered in Section 5. If the Model 2430 is in the Pulse Mode (Vpls or Ipls displayed in the source field), you can select the DC Mode from the source/pulse configuration menu. Press CONFIG SOURCE V or I, select the SHAPE menu item, then select DC. Use the EXIT key to return to the normal display. In the DC Mode, Vsrc or Isrc is displayed in the source field.*

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

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. Note that the "OFF" message is displayed to indicate that the source is off (ON/OFF indicator off).

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 acts as a power limiter to the DUT and 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 6, "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 EDIT arrow 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. MANUAL OHMS allows you to edit source and compliance. See Section 4.

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 arrow keys to select a range that will accommodate the value you want to set. (See Section 7 for range information.) 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 arrow 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.

For the Models 2400, 2400-LV, 2401, and 2410, the lowest compliance levels that can be set are 0.00100µA (1nA) and 000.200mV (200µV). For the Models 2420, 2425, 2430, and 2440, the levels are 00.0100µA (10nA) 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.

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.

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 3-5 summarizes basic source-measure commands. See Section 18 for more information on using these commands.

NOTE *The first command in Table 3-5 (SOURce:FUNCtion:SHAPe DC) applies only to the Model 2430. It is not valid for Models 2400, 2410, 2420, 2425, and 2440.*

Table 3-5
Basic source-measure commands

Command	Description
:SOURce:FUNCtion:SHAPe DC	Select DC Mode of operation (Model 2430 only).
:SOURce:FUNCtion[:MODE] <name>	Select source function (name = 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 3-6 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 and range: volts, 20V
- Source mode: fixed
- Source output level: 10V
- Current compliance: 10mA
- Measure function and range: current, 10mA

Table 3-6
Basic source-measure programming example

Step[1]	Action	Commands[2,3]	Comments
		*RST	Restore GPIB defaults.
1	Select source function, mode	:SOUR:FUNC VOLT	Select voltage source.
		:SOUR:VOLT:MODE FIXED	Fixed voltage source mode.
2	Set source range, level, compliance	:SOUR:VOLT:RANG 20	Select 20V source range.
		:SOUR:VOLT:LEV 10	Source output = 10V.
		:SENS:CURR:PROT 10E-3	10mA compliance.
3	Set measure function, range	:SENS:FUNC "CURR"	Current measure function.
		:SENS:CURR:RANG 10E-3	10mA measure range.
		:FORM:ELEM CURR	Current reading only.
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 the 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 (0.00000µA 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 arrow 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. (Figure 2-2).
5. Turn output on. Press the ON/OFF key to turn the output on.
6. Take reading from display.
7. When finished, turn output off.

Remote command measure only

Table 3-7 summarizes the basic command sequence for measure only. The steps outlined correspond to those in the "Front panel measure only" sequence above.

Table 3-7
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	0A source level.
		:SENS:VOLT:PROT 25	25V compliance.
3	Select volts measure range	:SENS:VOLT:RANG 20	20V range.
		:FORM:ELEM VOLT	Volts only.
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."
2. Commands must be sent in order given.
3. Instrument must be addressed to talk after :READ? to acquire data.

Sink operation

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 6, "Operating boundaries."

Battery charging/discharging

WARNING **To prevent personal injury or damage to the SourceMeter, do not attempt to charge non-rechargeable batteries.**

Some of the common batteries than can be charged with a SourceMeter are:

Nickel Cadmium (Ni-Cd)

Nickel Metal Hydride (Ni-MH)

Lithium Ion (Li-ion)

Rechargeable Alkaline

Lead Acid

If you are working with a battery type that is not listed here, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-348-3735 (U.S and Canada only) to obtain technical assistance.

WARNING **Always follow the battery manufacturers requirements for charging or discharging batteries using a SourceMeter. Failure to properly charge or discharge batteries may cause them to leak or explode resulting in personal injury and property damage. Over voltage and current protection should be provided in the charge circuit, external to the SourceMeter, when charging batteries without built-in protection.**

Do not attempt to charge or discharge batteries exceeding the current or voltage requirements listed below:

Model 2400, 2400-C: 21V @ 1.05A or 210V @ 105mA

Model 2400-LV, 2401: 21V @ 1.05A

Model 2410, 2410-C: 21V @ 1.05A or 1100V @ 21mA

Model 2420, 2420-C: 21V @ 3.15A or 63V @ 1.05A

Model 2425, 2425-C: 21V @ 3.15A or 105V @ 1.05A

Model 2430, 2430-C: 105V @ 1.05A or 105V @ 10.5A (pulse mode)

Model 2440, 2440-C: 10.5V @ 5.25A or 42V @ 1.05A

When charging a battery, the SourceMeter is operating as a source. When discharging a battery, the SourceMeter is operating as a sink. Use the V-Source to charge and discharge batteries. Perform the following steps for both charging and discharging:

1. Connect Input/Output HI to the positive (+) terminal of the battery and Input/Output LO to the negative (-) terminal of the battery.
2. Configure the SourceMeter to source voltage and measure current.
3. Set I-compliance to the current level at which the battery is to be charged or discharged.
4. Select an appropriate current measurement range or use AUTO range. Battery charging — To charge the battery, program the SourceMeter to output a voltage that is equivalent to the voltage rating of the battery. For example, to charge a 10V battery, set the SourceMeter to source 10V. As the battery fully charges, current will decrease until it reaches zero or near zero (battery charged).

CAUTION **When the SourceMeter goes into compliance, the V-source becomes an I-source (or the I-source becomes a V-source). For this reason, make sure the voltage compliance is higher than the battery voltage. See Section 6 for more details.**

Battery discharging — To discharge the battery, program the SourceMeter to output 0V. In this configuration, the SourceMeter operates as a sink to discharge the battery. Current from the battery flows into the HI terminal of the SourceMeter resulting in negative current measurements. As the battery discharges, current will gradually decrease until it reaches zero (battery discharged).

NOTE When using the V-Source to charge and discharge batteries, use the HIGH-IMPEDANCE output-off state (Section 13). This output-off state opens the output relay when the OUTPUT is turned off. This open circuit

condition keeps the external battery from discharging while the output is off.

CAUTION **If using the I-Source to charge and/or discharge batteries, the following precautions must be observed. Failure to observe these precautions could result in damage to the SourceMeter that is not covered by the warranty.**

Make sure the external voltage NEVER exceeds the voltage compliance setting of the I-Source. This will cause excessive current to be drawn from the external battery or source.

Make sure the output off state of the I-Source is set for HIGH-IMPEDANCE. This setting opens the output relay when the OUTPUT is turned OFF. With the NORMAL output off state selected, turning the output off sets voltage compliance to zero. This 0V compliance condition will cause excessive current to be drawn from the external battery or source. See Section 13, "Front panel output configuration" to select the high-impedance output off state.

Sink programming example

Table 3-8 lists a command sequence to program the SourceMeter for sink operation.

Table 3-8
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

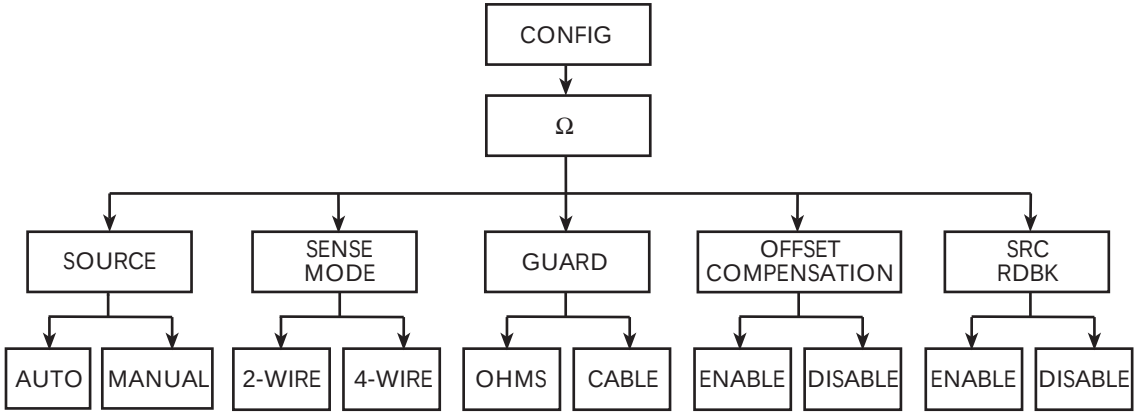
NOTE For the Model 2430 Pulse Mode, offset-compensated ohms cannot be enabled from the ohms configuration menu. However, offset-compensated ohms is available as a math function (Section 8, "Math operations").

To access the ohms configuration menu, press CONFIG then OHMS. Use Section 1, "Rules to navigate menus," 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.
- SENSE MODE — Select 2-WIRE or 4-WIRE sense mode.
- GUARD — Choose OHMS or CABLE guard.
- OFFSET COMPENSATION — Enable or disable offset-compensated ohms (not valid for Model 2430 Pulse Mode).
- SRC RDBK — Enable or disable source readback mode.

The following paragraphs discuss each of these aspects in detail.

Figure 4-1
Ohms configuration menu tree



Ohms measurement methods

NOTE For the Model 2430, the following ohms measurement procedures assume that the DC Mode of operation is selected ("Vsrc" or "Isrc" displayed in the source field). If in the Pulse Mode ("Vpls" or "Ipls" displayed), you can select the DC Mode by pressing CONFIG V or I, selecting the SHAPE menu item, and then selecting DC. Pulse Mode operation is covered in Section 5.

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 or DMM. 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.

Table 4-1
Auto ohms default test currents

Auto ohms range	2400, 2400-LV, 2401, and 2410 default test current	2420, 2425, 2430, and 2440 default test current
2Ω	-	1A
20Ω	100mA	100mA
200Ω	10mA	10mA
2kΩ	1mA	1mA
20kΩ	100µA	100µA
200kΩ	10µA	10µA
2MΩ	1µA	10µA
20MΩ	1µA	1µA
200MΩ	100nA	-

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 the 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.

Ohms measurement procedure

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, "Connections."*

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 by pressing MEAS Ω
2. Select the ohms measurement method (AUTO or MANUAL).

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

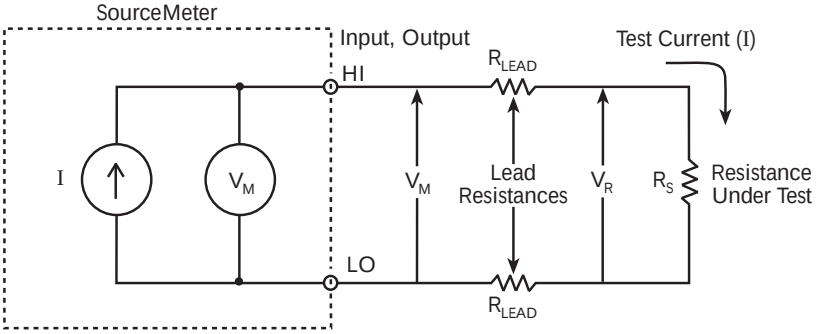
3. For manual ohms, configure source.
   For manual ohms, you can Source I or Source V at the user-programmed output level. The lowest allowable compliance limit is based on the load and the source value. For example, if sourcing 1V to a 1kΩ resistor, the lowest allowable current compliance is 1mA (1V/1kΩ = 1mA). Setting a limit lower than 1mA will place the source in compliance.
4. Select measurement range.
   Use the RANGE 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.
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 will go into compliance if you exceed the maximum ohms measurement range.
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 information on connections and sensing methods.) Note that resistance measurement accuracy specifications are based on using 4-wire sensing.

The 2-wire sensing method has the advantage of requiring only two test leads. However, as shown in Figure 4-2, test lead resistance can seriously affect the accuracy of 2-wire resistance measurements, particularly with lower resistance values. The 4-wire sensing method shown in Figure 4-3 minimizes or eliminates the effects of lead resistance by measuring the voltage across the resistor under test with a second set of test leads. Because of the high input impedance of the SourceMeter voltmeter, the current through the sense leads is negligible, and the measured voltage is essentially the same as the voltage across the resistor under test.

Figure 4-2
2-wire resistance sensing

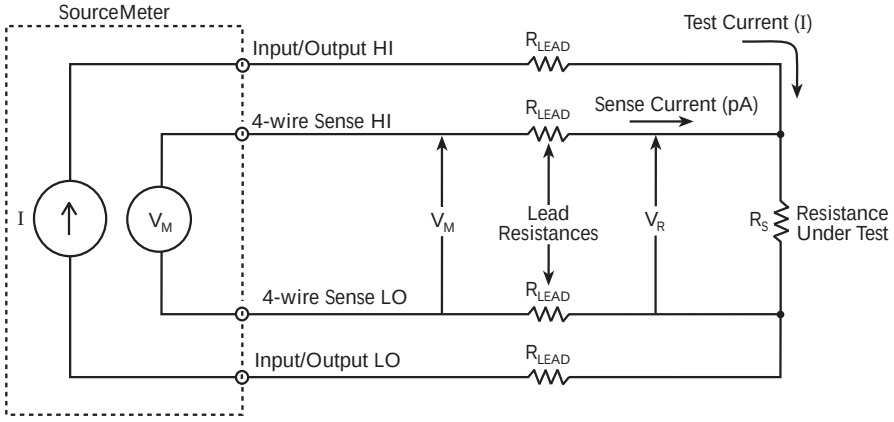


I = Current sourced by SourceMeter
V_M = Voltage measured by SourceMeter
V_R = Voltage across resistor

$$\text{Measured resistance} = \frac{V_M}{I} = R_S + (2 \times R_{LEAD})$$

$$\text{Actual resistance} = \frac{V_R}{I} = R_S$$

Figure 4-3
4-wire resistance sensing



I = Current sourced by SourceMeter
V_M = Voltage measured by SourceMeter
V_R = Voltage across resistor

Because sense current is negligible, $V_M = V_R$

and measured resistance = $\frac{V_M}{I} = \frac{V_R}{I}$

Sense selection

To select sensing mode, press CONFIG then Ω, select SENSE MODE, then choose 2-wire or 4-wire.

Offset-compensated ohms

NOTE For the Model 2430, the following offset-compensated ohms method is not valid in the Pulse Mode. However, offset compensated ohms is available as a math function (Section 8, "Math operations").

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.

Enabling/disabling offset-compensated ohms

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

Ohms accuracy calculations

Example accuracy calculations for various combinations of source readback, offset compensation, and normal/enhanced mode are shown below. See Appendix A for detailed specifications.

Ohms accuracy of 100mΩ@ 5mA source current, normal mode

Source readback OFF, Offset Compensation OFF

Ohms accuracy = Isource accuracy + Vmeas accuracy:

I source accuracy = (5mA) (0.045%) + 2µA
2.25µA + 2µA = 4.25µA
4.25µA / 5mA = 0.085%

Vmeasure accuracy for (100mΩ) (5mA) = 500µV:

(500µV)(0.012%) + 300µV
60nV + 300µV = 300.06µV
300.06µV / 500µV = 60.01%

Total Ohms Uncertainty
60.01% + 0.085% = 60.09%
100mΩ ± 60.09% = 39.9mΩ to 160.09mΩ

Ohms accuracy of 100mΩ@5mA source current, normal mode

Source Readback ON

Ohms accuracy = Imeas accuracy + Vmeas accuracy:

Imeasure accuracy = (5mA) (0.035%) + 600nA
1.75µA + 600nA = 2.35µA
2.35µA / 5mA = 0.047%

Vmeasure accuracy = (500µV)(0.012%) + 300µV
60nV + 300µV = 300.06µV
300.06µV / 500µV = 60.01%

Total Ohms uncertainty:
60% + 0.047% = 60.06%
100mΩ ± 60.06% = 39.94mΩ to 160.06mΩ

Ohms accuracy of 100mΩ@ 5mA source current, enhanced mode

Source Readback ON, Offset Compensation ON

Ohms accuracy = [Imeas % Rdg accuracy + Vmeas % Rdg accuracy] + System noise*

Imeasure accuracy = (5mA)(0.035%)
1.75µA
Measured system noise: 00.0000mA

1.75µA+ 00.0000mA = 1.75µA
1.75µA / 5mA = 0.035%

Vmeasure gain accuracy for (100mΩ) (5mA) = 500µV
(500µV) (0.012%) =60nV
Measured system noise: 000.002mV

60nV + 2µV = 2.06µV
2.06µV / 500µV = 0.412%

.035% + 0.412% = 0.447%
100mΩ +/- 0.447%
99.55mΩ to 100.44mΩ

*System noise includes the external connection to DUT. To determine system noise, the voltage and current noise is measured with test leads connected to the DUT.

For example, with the 100mΩ resistor connected, the noise voltage was measured by pressing V measure, selecting the appropriate 200mV range, pressing the REL button and making note of the systems noise magnitude. In this example, the measurement was 000.002mV or 2µV.

To measure the current source noise, change the measure function to current measure, select the appropriate current range (in this case, 10mA), press REL and note the system noise magnitude. In the example, the system noise current component was measured as 00.0000mA.

Ohms source readback

NOTE For the Model 2430 Pulse Mode, ohms source readback cannot be enabled.

With ohms source readback enabled, the instrument measures the actual source value instead of the programmed value used for ohms measurements and then uses that measured value for reading calculations. Normally, ohms source readback should be left enabled for optimum ohms measurement accuracy because SourceMeter measurement accuracy is better than source programming accuracy. (See specifications in Appendix A.) However, disabling source readback will allow you to make valid ohms measurements with the source in compliance. See Section 6, "Source I measure I and source V measure V," for more details.

Ohms source readback selection

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 2-5C for 6-wire ohms connections. See also Section 2, "Ohms guard," and Section 6, "Guard."*

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

Remote ohms programming

The following paragraphs summarize those basic commands 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 18 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).
:SENSe:VOLTage:PROTection <n>	Set voltage compliance n for manual ohms.
:SENSe:CURRent:PROTection <n>	Set current compliance n for manual ohms.
:SOURce:FUNCtion <name>	Select source function (name = VOLTage or CURRent).
:SYSTem:RSENse <state>	2-wire/4-wire sensing (state = ON, 4-wire; OFF, 2-wire).
: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 auto ohms measurement. These commands set up the SourceMeter as follows:

- Ohms mode and range: auto, 20kΩ
- Offset compensation: off
- Sense mode: 4-wire

Table 4-3
Auto ohms programming example

Step	Action	Command	Description
		*RST	Restore GPIB defaults.
1	Select function	FUNC "RES"	Select ohms measurement function.
2	Select ohms mode	RES:MODE AUTO	Auto ohms mode.
3	Select range	RES:RANG 20E3	Select 20kΩ range.
		:SYST:RSEN ON	Enable 4-wire sensing.
		:FORM:ELEM RES	Resistance reading.
4	Output on	:OUTP ON	Turn on output.
5	Get reading	:READ?	Trigger and acquire reading.
6	Output off	:OUTP OFF	Turn off output.

* Numbers correspond to steps in "Ohms measurement procedure," procedure, page 4-4.

7
Range, Digits, Speed, and Filters

- **Range and digits** — Discusses 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 two types of digital filtering 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.

Maximum readings

The full scale input for each voltage, current, and auto ohms measurement range is defined by 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, and ±2.11kΩ is the full scale reading for the 2kΩ range. Table 3-1 in Section 3 lists the full scale readings for all ranges.

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 (5H 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, while 9.91E+37 will be returned via remote.

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. See Appendix A for ranges.

Manual ranging

For the Source V Measure I, Source I Measure V, and Ohms configurations, the RANGE arrow keys are used to select a fixed range. Note that the highest available range is dependent on the corresponding compliance setting.

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

NOTE For the Model 2430, auto ranging cannot be performed while in the Pulse Mode. Therefore, all the following information on auto ranging is not applicable to the Model 2430 Pulse Mode.

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.

Auto range considerations

If the SourceMeter has to autorange, the SDM (source-delay-measure) cycle is repeated to take the measurement on the new range. This means that any programmed source delay will be applied each time the unit has to autorange. For example, if a 1 second source delay is programmed, the unit could take 2 or more seconds to complete a reading if it has to change ranges.

The autorange algorithm used in the SourceMeters is as follows: If the reading reaches 105% of the present range, the unit will go up 3 ranges, or to the highest range possible if it can't go up 3 ranges. The unit will take another reading, then decide whether it needs to continue going up in range or pick the right range based on the reading. If the reading is 10%, 1%, or 0.1% of the present range, it will go down by 1, 2, or 3 ranges based on the reading.

Auto range change mode

The auto range change mode determines how the instrument performs auto ranging. 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 6, "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 11, "Trigger models.") 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.

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 11-1 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 lower 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 ƒ respectively, then use the ß and © 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.

Limits evaluation

Neither the high limit nor the low limit are evaluated until the unit has switched to the autorange mode. This means that if the unit is already on a range higher than the upper limit, or lower than the lower limit when the limit is set, no range change will occur.

The upper limit is only evaluated if the unit has to upgrade. In other words, if you are on a range higher than the present upper limit, and the unit autoranges down, it can still end up on a range higher than the upper limit. The converse is true for the lower limit.

The upper and lower limits have no meaning until autoranging is turned on, but the limit will not be evaluated unless the unit has to go through an autorange. If you are already on the right range when you turn on autoranging, limits will not be evaluated.

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 5½ digits.*

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

Remote range and digits programming

Table 7-1 summarizes the commands necessary to control range and digits. See Section 18 for more details on these commands.

Range and digits commands

Table 7-1
Range and digits commands

Command	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: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:RESistance:RANGe <n>	Select manual ohms range (n = range).
:SENSe:RESistance:RANGe:AUTO <state>	Enable/disable auto ohms range (state = ON or OFF).
:DISPlay:DIGits <n>	Set display digits (n = 4, 5, 6, or 7).

Note: For the Model 2430, the :AUTO range commands are not valid while in the Pulse Mode.

Range and digits programming example

Table 7-2 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: 5H

Table 7-2
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	10µA range.
:DISP:DIG 5	5H 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 noise rejection. In-between settings are a compromise between speed and noise. The default power-on speed setting is NORMAL (1 PLC).

NOTE *For the Pulse Mode of the Model 2430, the valid NPLC range is 0.01 to 0.1 PLC.*

The speed setting affects both the NMRR (normal mode rejection ratio) and CMRR (common mode rejection ratio). Normal mode noise is the noise signal between the HI and LO input terminals, while common mode noise is the noise signal between LO and chassis ground. See Appendix A for NMRR and CMRR specifications.

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.

NOTE *For the Pulse Mode of the Model 2430, speed is set from Pulse Speed menu. This menu structure is located after the Speed Accuracy menu. Use the "Rules to navigate menus" in Section 1 to check and/or change the speed setting.*

Front panel speed control

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.

PULSE SPEED (NPLC) – Model 2430 Pulse Mode

Press SPEED or CONFIG SPEED to display the speed choices:

0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10

NOTE Display resolution for the Model 2430 Pulse Mode is not affected by the speed setting.

Remote speed programming

Speed commands

Table 7-3 summarizes commands to control speed. See Section 18, "Set measurement speed," for more information.

NOTE The speed setting is global, which means that setting the speed for one function affects the speed for the other functions. However, the speed setting is stored in source memory, and you can use this feature to change speed during a sweep. See Section 10 for details on using source memory.

Table 7-3
Speed commands

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

* For the Model 2430 Pulse Mode, n = PLC, 0.01 to 0.10.

Filters

NOTE For the Pulse Mode of the Model 2430, filtering is not used, and therefore, cannot be enabled. Pressing the FILTER key results in the "Invalid in Pulse Mode" message.

Filter lets you set the filter response to stabilize noisy measurements. The SourceMeter uses a digital filter, which is based on reading conversions. The displayed, stored, or transmitted reading is an average of a number of reading conversions (from 1 to 100).

There are two averaging filter types to choose from: repeating and moving (Figure 7-1). For the repeating filter (which is the power-on default), the stack (filter count) is filled, and the conversions are averaged to yield a reading. The stack is then cleared, and the process starts over. Choose this filter for sweeping so readings for other source levels are not averaged with the present source level.

The moving average filter uses a first-in, first-out stack. When the stack (filter count) becomes full, the measurement conversions are averaged, yielding a reading. For each subsequent conversion placed into the stack, the oldest conversion 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 filtered reading is not yielded until the stack is full. The first reading conversion is placed in the stack and is then copied to the other stack locations in order to fill it. Thus, the first filtered reading is the same as the first reading conversion. Now the normal moving average filter process can continue. Note that a true average is not yielded until the stack is filled with new reading conversions (no copies in stack). For example, in Figure 7-1A, it takes ten filtered readings to fill the stack with new reading conversions. The first nine filtered readings are calculated using copied reading conversions.

NOTE Sweeping with moving average filter enabled is not recommended as it may yield incorrect results. The desired readings may be changing with the sweep source values and these changes can be skewed by the averaging technique.

Response time considerations

The filter averaging mode and count affect the overall reading speed. The moving averaging filter is much faster than the repeat averaging filter because the unit does not have to refill the filter stack for each reading. Also, the number of readings averaged will affect reading speed; as the number of readings averaged increases, the reading speed decreases.

Front panel filter control

Configuring filter

Filter type and count is configured from the CONFIGURE FILTERING menu and is structured as shown in Figure 7-2. Use Section 1, "Rules to navigate menus," to check and/or change the filter configuration.

CONFIGURE FILTERING menu

Press CONFIG and then FILTER to display the menu.

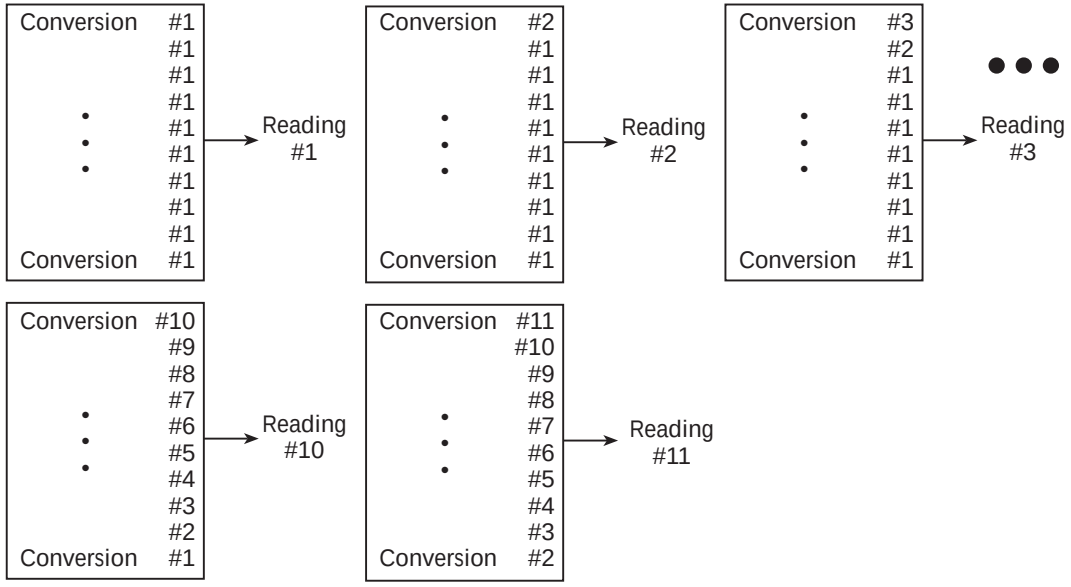
- AVERAGING MODE — Use this menu item to select filter type (MOVING or REPEAT).
- AVERAGE COUNT — Use this menu item to specify filter count (1 to 100 readings).

NOTE The configured filter is the same for all measurement functions.

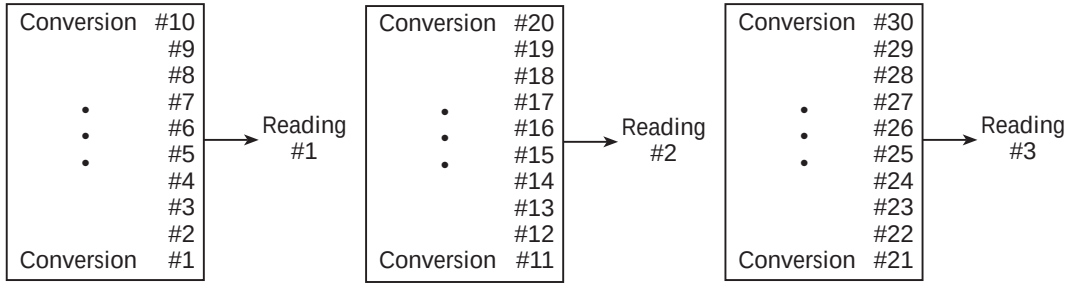
Enabling filter

The filter is enabled by pressing the FILTER key. The "Filter Enabled" message and the filter count are briefly displayed. The FILT annunciator is on while the filter is enabled. Pressing FILTER a second time disables filter.

Figure 7-1
Moving average and repeating filters



A. Type - Moving Average, Readings = 10

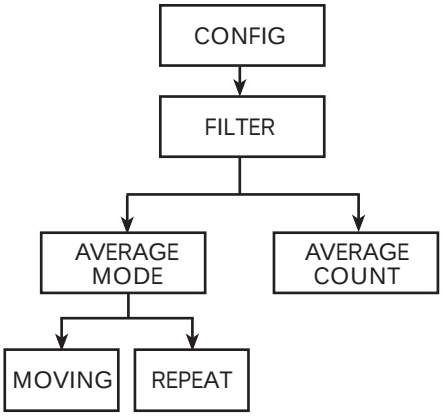


B. Type - Repeating, Readings = 10

Response time

The filter parameters have speed and accuracy trade-offs for the time needed to display, store, or output a filtered reading. These affect the number of reading conversions for speed versus accuracy and response to input signal changes.

Figure 7-2
Filter configuration menu tree



Remote filter programming

Filter commands

Table 7-4 summarizes filter commands. See Section 18, "SENSe1 subsystem," "Configure and control filter," for more details.

Table 7-4
Filter commands

Command	Description
:SENSe:AVERage:TCONtrol <type> :SENSe:AVERage:COUNt <n> :SENSe:AVERage <state>	Select filter type (type = REPeat or MOVing). Set filter count (n = count, 1 to 100). Enable/disable filter (state = ON or OFF)*.

* For the Model 2430 Pulse Mode, the filter cannot be enabled.

10
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.
- **Pulse Mode sweeps (Model 2430 only)** — Covers sweep operation for the Pulse Mode of the Model 2430.

Sweep types

Sweeps allow you to program the instrument to step through specific voltage and current values and perform measurements at each source value. The four basic sweep types, which are described in the following paragraphs, include:

- Linear staircase
- Logarithmic staircase
- Custom
- Source memory

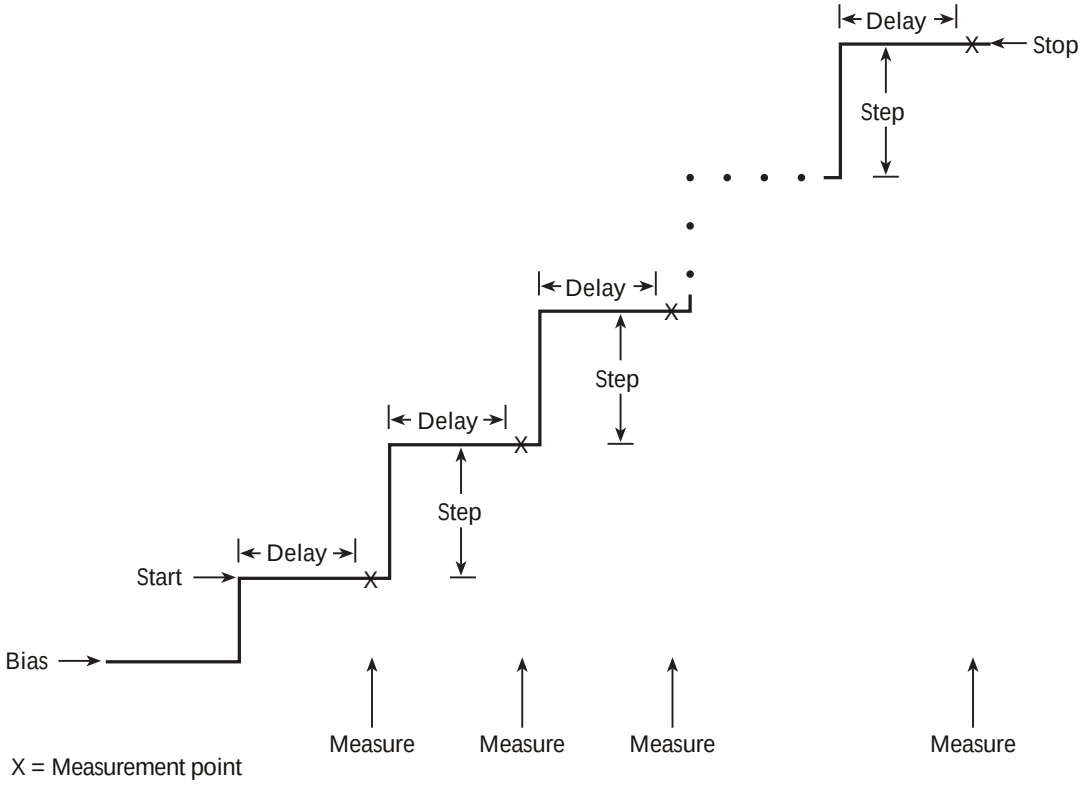
NOTE *Only voltage or current sweeps can be performed. Sweep readings are automatically stored in the buffer. See Section 9 for details on the data store (buffer).*

Linear staircase sweep

As shown in Figure 10-1, 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.

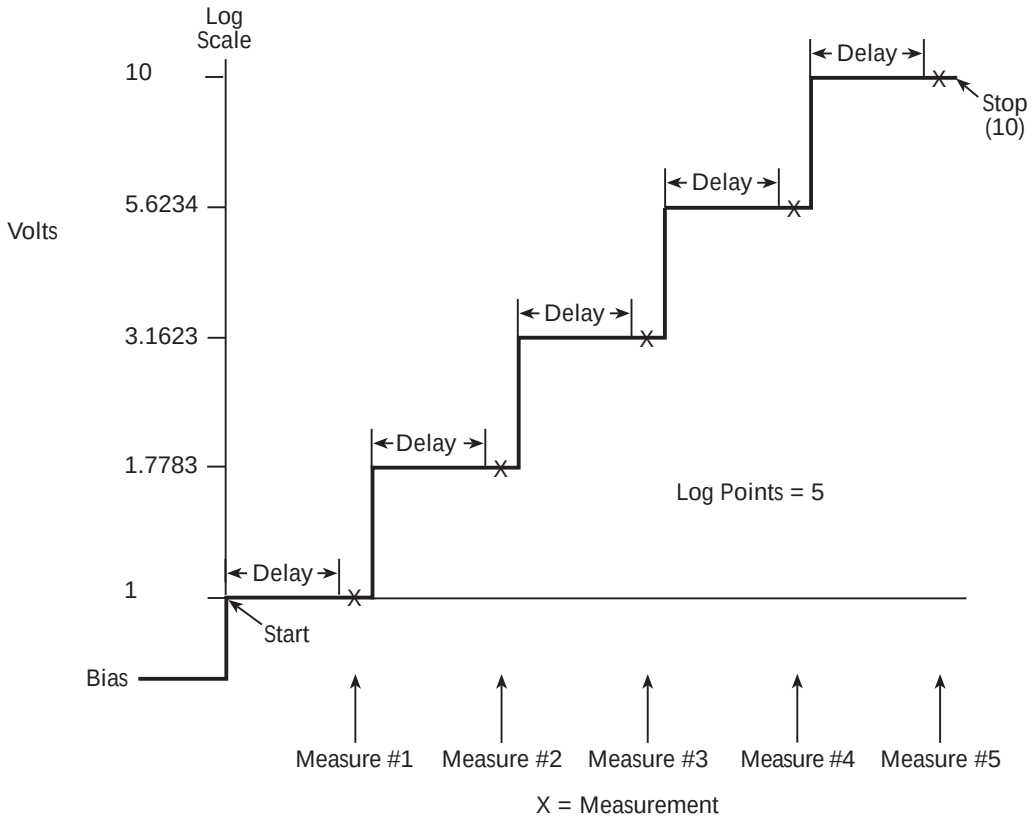
Figure 10-1
Linear staircase sweep



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 10-2. 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 10-2
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 10-2 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 10-1 (the V-Source level is the anti-log of the log step).

Table 10-1
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).

Abort on compliance

This feature aborts a sweep in progress if compliance is detected. There are three modes, never, early, and late. Never turns off the feature, early will abort as soon as compliance is detected at the beginning of the SDM cycle, and late aborts at the end of the SDM cycle. See "Configuring and running a sweep" on page 10-12.

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.

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.

NOTE NPLC caching can be used to speed up source memory sweeps. See Section 3, "NPLC caching," for details.

Current range holdoff

Current range holdoff adds the ability to speed up low-current measurements when sourcing voltage and measuring current. This feature is only available when doing source memory sweeps. It will momentarily set the measure range to the compliance range to overcome the effects of capacitance by quickly charging the capacitance on the higher range, but return to the lower measurement range to obtain a good low-current measurement. This avoids being limited by range compliance, which would require either a longer delay time, or having to take the measurement on a higher current range. This feature is available only by remote, but both parameters are saved for each memory location.

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. The default and typical scenario is starting the source memory sweep at location 1.

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.

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 SOURCE arrow 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 10-2 summarizes the configurations that are saved at each source memory location along with the equivalent remote command. See Section 18 for more details on these remote commands. The SCPI command reference tables, Table 18-1 through Table 18-11, also list source memory parameters.

Table 10-2
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
2430 pulse function	SOURce[1]:FUNCtion:SHAPe
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
2430 pulse width	SOURce[1]:PULSe:WIDTh
2430 pulse delay	SOURce[1]:PULSe:DELay
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

Table 10-2 (cont.)
Source memory saved configurations

Mode	Remote command
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
Guard type	SYSTem:GUARd

* X = CURRent or VOLTage.
** Limit X = Limit 2, 3, 5-12.
† Not available when the Model 2430 is in the Pulse Mode.

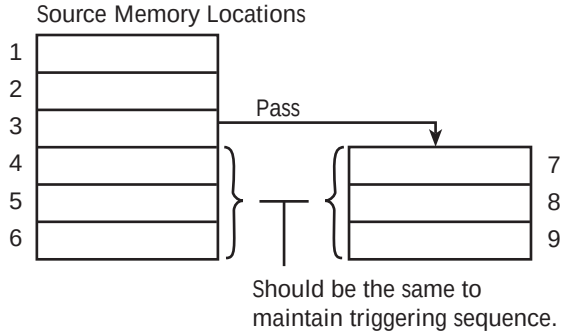
Sweep branching

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 10-3 shows a six-point sweep branching example. In this case, the unit is programmed to branch to location 7 when a pass conditions occurs at location 3.

Figure 10-3
Six-point test branching example



Caution must be used when branching since infinite memory loops can inadvertently be created. Also, 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 12, "Limit Testing" and "Configuring limit tests," for details.) Via remote, use the :CALCulate2:CLIMits:PASS:SMLocation command. (See "Configuring and running a sweep" in this section.)

NOTE Branch on fail is available via remote only with CALC2:CLIM:FAIL:SML. See Section 18 for details.

Configuring and running a sweep

Front panel sweep operation

Sweep configuration menu

The sweep configuration menu is structured as follows and shown in Figure 10-4. 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.

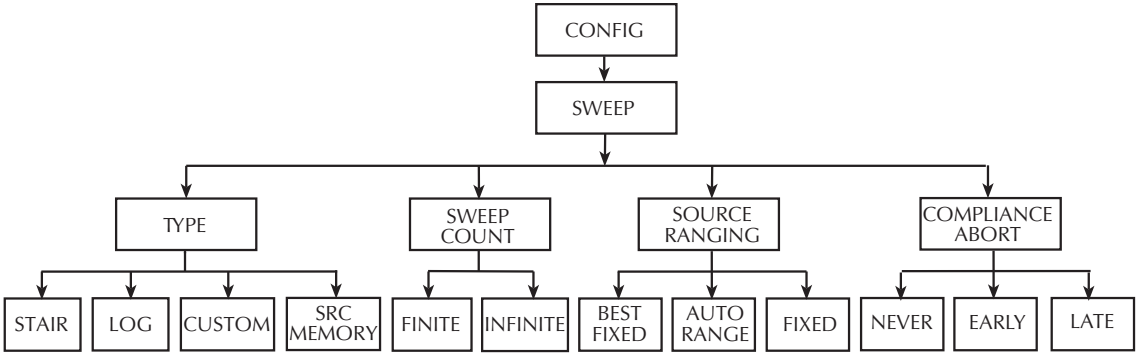
CONFIGURE SWEEPS menu:

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 for the Model 2400 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.
- COMPLIANCE ABORT — Use this option to control abort on compliance, which will abort a sweep in progress if compliance is detected:
  - NEVER — This selection disables abort on compliance.
  - EARLY — Abort sweep if compliance is detected at the beginning of the SDM cycle.
  - LATE — Abort sweep if compliance is detected at the end of the SDM cycle.

Figure 10-4
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).

NOTE *For the Model 2430 Pulse Mode, source delay is not used. Instead, pulse width (for the on-time) and pulse delay (for the off-time) are the delays that are set by the user. Pulse Mode sweeps are covered later in this section.*

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 6, "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 11, "Trigger models" 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 11 for details on trigger count.

Performing sweeps

Procedures for the various sweep types are covered below.

NOTE *For the Model 2430, the following procedure assumes that the DC mode of operation is selected ("Vsrc" or "Isrc" displayed in source field). If in the Pulse Mode ("Vpls" or "Ipls" displayed), you can return to the DC Mode*

by pressing CONFIG V or I, selecting the SHAPE menu item, and then selecting PULSE. Use the EXIT key to back out of the menu.

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 terminal when performing fast pulse sweep operations. 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.**

Performing a 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 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 9, "Data Store.")

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 10-2 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 ƒ 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 10-3 summarizes remote commands used for linear and log staircase sweep operation. See Section 18, "Configure voltage and current sweeps," for more details on these commands.

Table 10-3
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).
:SOURce:SWEep:CABort <name>	Abort on compliance. Name = NEVer (disable), EARLy (start of SDM cycle), or LATE (end of SDM cycle).

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.

Table 10-4 lists the command sequence for the diode programming example.

Table 10-4
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 10-5 summarizes remote commands used for custom sweep operation. See Section 18, "Configure list," for more details on these commands.

Table 10-5
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

Table 10-6 summarizes the basic remote command sequence for performing a custom sweep.

Table 10-6
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 10-7 summarizes remote commands used for custom sweep operation. See Section 18, "Configure memory sweep," for more details on these commands.

Table 10-7
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).
:SENSe:CURRent:RANGe:HOLDoff <b>	Enable (ON), disable (OFF) current range holdoff.
:SENSe:CURRent:RANGe:HOLDoff:DELay <NRf>	Set holdoff delay in seconds.

Source memory sweep programming example

Table 10-8 summarizes the basic remote command sequence for performing the basic source memory sweep.

Table 10-8
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.

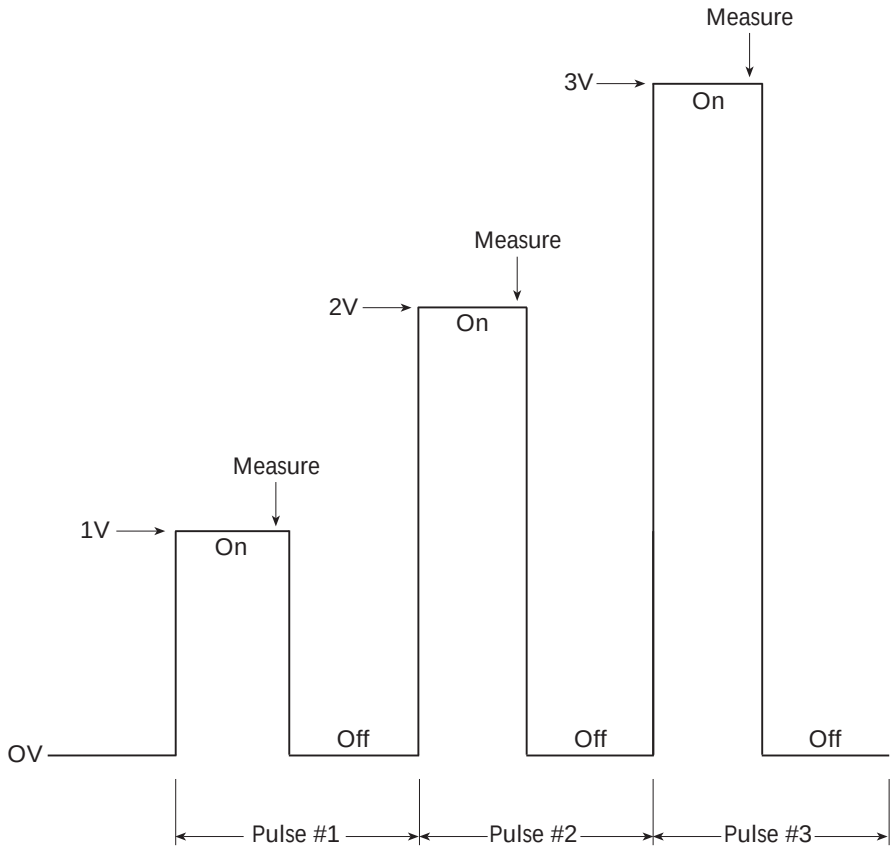
Pulse Mode sweeps (Model 2430 only)

When performing a sweep with the Model 2430 in the Pulse Mode, each step or point of the sweep is made up of a pulse period. In general, a pulse period consists of the pulse width (output on-time) and the output off-time. Figure 10-5 shows an example of a 3-step linear staircase sweep for the Pulse Mode (start = 1V, stop = 3V, step = 1V). A measured reading is performed for each of the three pulse steps. Readings are not performed for the output off-times.

For normal (DC Mode) sweep operation, the time duration spent on each step consists of the set source delay and the time it takes to perform the measurement. For the Pulse Mode, source delay is not used. The pulse width consists of the pulse width delay, internal overhead time and the pulse signal measurement. The output off-time typically consists of zero and reference measurements (used to calculate accurate pulse readings), internal overhead time, and an optional pulse delay.

NOTE Details on Pulse Mode operation for the Model 2430 are provided in Section 5.

Figure 10-5
Pulse Mode linear staircase sweep



Front panel Pulse Mode sweep procedure

The procedure to perform a Pulse Mode sweep is summarized as follows:

NOTE The following procedure assumes that the Model 2430 is already connected to the DUT as explained in Section 2.

WARNING **Hazardous voltages (≥30V rms) can appear on the selected INPUT/OUTPUT LO terminal when performing fast pulse sweep operations. 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.**

Step 1: Select and configure pulse mode

Basic parameters for the Pulse Mode include pulse width, pulse delay, pulse measurement speed, and pulse count. Refer to Section 5, "Pulse Mode configuration," to select the Pulse Mode and set the pulse parameters.

Step 2: Set compliance limit, and select measurement function and range.

Configure the Model 2430 for these aspects of operation as explained in steps 1 through 3, Section 3, "Basic source-measure procedure."

Note that the AUTO measurement range is not valid in the Pulse Mode. Make sure the fixed measurement range that you select can accommodate every measurement point in the sweep.

Step 3: Configure sweep.

Select and configure the sweep as explained in "Configuring and running a sweep."

Step 4: Run sweep.

To run the sweep, press the SWEEP key. After the last pulse in the sweep is sourced, the output will turn off and stay off. A sweep that is in progress can be stopped at any time by pressing the ON/OFF OUTPUT key or the EXIT 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. (See Section 9, "Data Store.")

Remote Pulse Mode sweep operation

The commands for Pulse Mode operation are provided in Section 5, while the staircase sweep commands are provided in Table 10-3.

Table 10-9 provides a typical remote command sequence for performing the 3-point Pulse Model linear staircase sweep shown in Figure 10-5.

Table 10-9
Pulse Mode linear staircase sweep programming example

Command	Description
*RST	Restore GPIB default conditions.
:SOUR:FUNC PULS	Select Pulse Mode.
:SOUR:PULS:WIDT 0.005	5ms pulse width.
:SOUR:PULS:DEL 0.003	3ms pulse delay.
:SENS:VOLT:NPLC 0.1	Measure speed = 0.1 PLC.[1]
:TRIG:COUN 3	Pulse count = # sweep points.[2]
:SOUR:FUNC VOLT	Volts source function.[1]
:SENS:FUNC 'CURR'	Current sense function.[1]
:SENS:CURR:PROT 0.1	100mA current compliance.
:SOUR:VOLT:START 1	1V start voltage.
:SOUR:VOLT:STOP 3	3V stop voltage.
:SOUR:VOLT:STEP 1	1V step voltage.
:SOUR:VOLT:MODE SWE	Select volts sweep mode.[3]
:READ?	Trigger sweep, request data.

1. These commands are not required in this case, since unit assumes these operating states after *RST but are included to demonstrate complete programming steps.
2. 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.
3. This command should normally be sent after START, STOP, and STEP to avoid delays caused by rebuilding sweep when each command is sent.

12
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 condition for the grading and sorting modes.
- **Binning systems** — Details the handler interface, as well as single-element and multiple-element binning and digital output clear pattern that occurs after a binning operation.

NOTE *The Model 2401 does not use the digital output lines of the Digital I/O port. The Model 2401 does not have a handler interface and therefore cannot be used with a component handler to perform binning operations.*

- **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

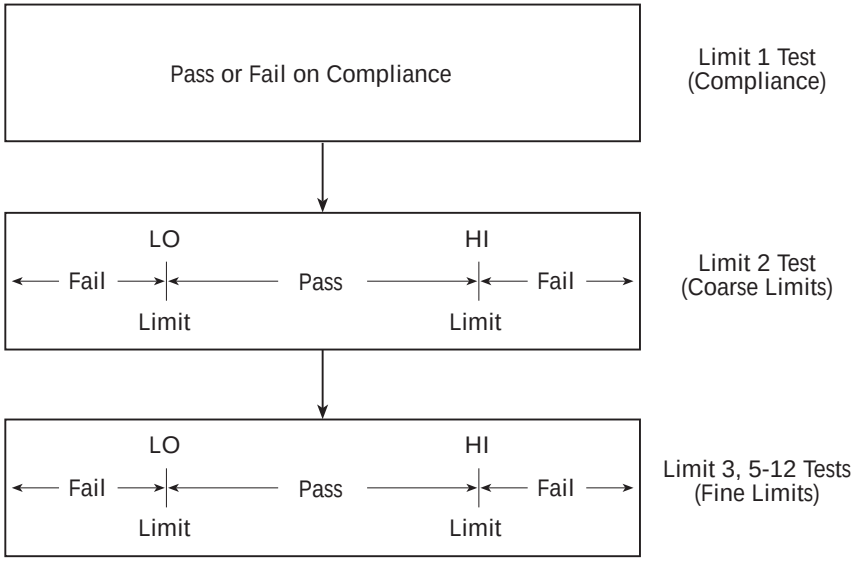
As shown in Figure 12-1, there are 11 limit tests that can be performed on a DUT. These limits include:

- Limit 1: compliance test
- Limit 2: course limits
- Limits 3, 5-12: fine limits

NOTE *Limit 4 is reserved for the contact check option. See Appendix F for details.*

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 12-1
Limit 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," page 12-10, and Section 13, "Digital I/O port," for more information.

NOTE The Model 2401 does not have a handler interface and therefore cannot be used with a component handler to perform binning operations.

- With the :CALCulate2:LIMit<n>:FAIL? query via remote, where <n> is the limit test number (Section 18, "CALCulate2").
- By reading various status bits (Section 15, "Status Structure," and Section 18, "FORMat subsystem").
- By noting a "P" or "F" preceding buffer location numbers (Section 9, "Recalling readings").

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.

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.

Limit 4

This hardware test is only available for instruments equipped with the optional contact check feature. See / for details about the contact check option. Distinct Digital I/O bit patterns can be set for each limit and each high/low pass or fail condition.

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, a component handler can be interfaced to the SourceMeter Digital I/O port to perform binning operations. After the testing process, the DUT will be placed in an assigned bin.

NOTE The Model 2401 does not have a handler interface. Therefore it cannot be used with a component handler to perform binning operations.

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," page 12-10, for more information on using component handlers and scanners to perform binning operations.

Operation overview

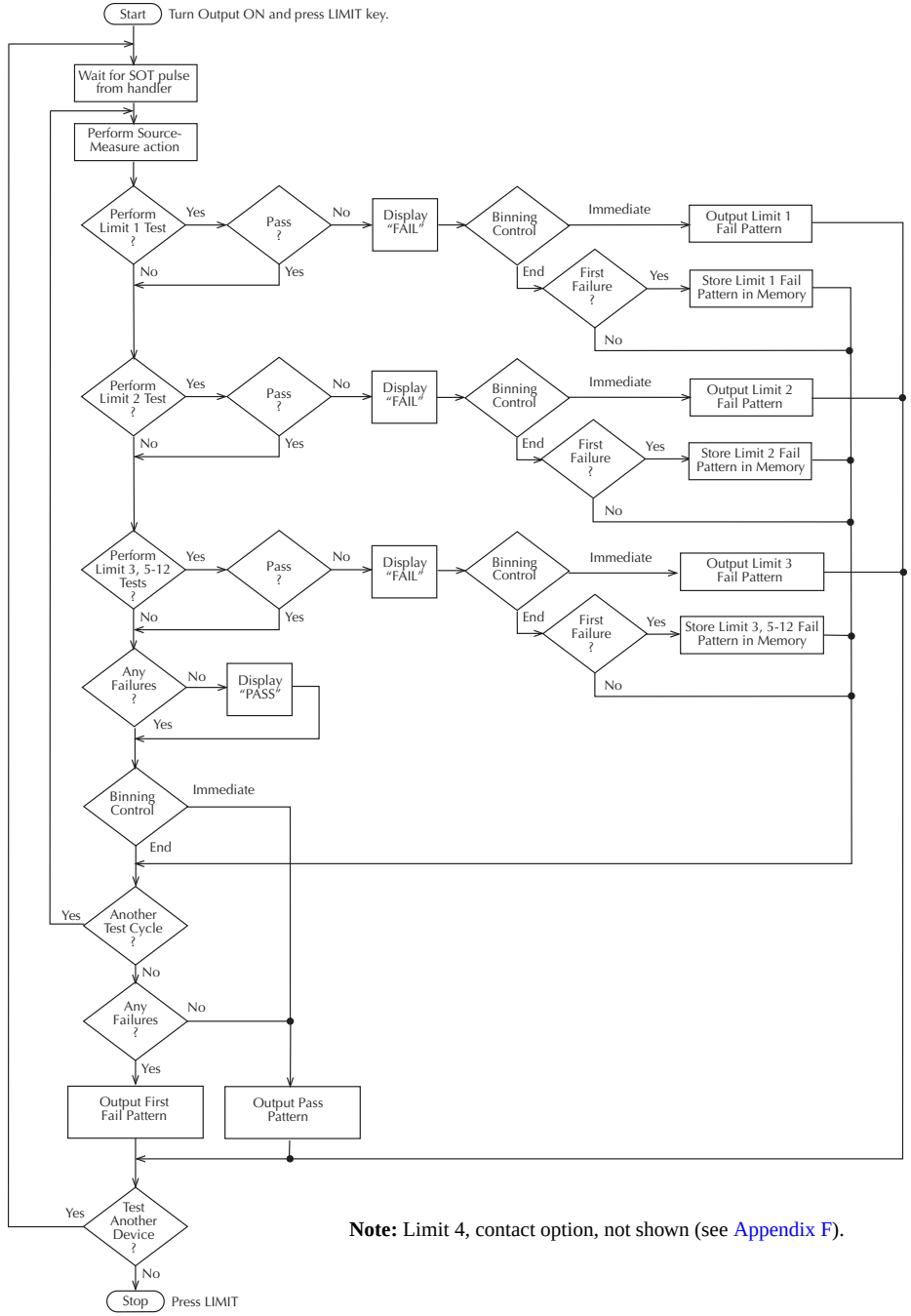
Grading mode

Grading mode limits operation is detailed by the flowchart in Figure 12-2. 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," page 12-10.) If a handler is not used, ignore digital input/output (handler interface) actions.

NOTE The Model 2401 does not have a handler interface. Therefore it cannot be used with a component handler to perform binning operations.

With the limit tests properly configured, turn the SourceMeter output on and press the LIMIT key. In this example, the testing process will start when the component handler sends the start-of-test (SOT) 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 12-2
Grading mode limit testing



Note: Limit 4, contact option, not shown (see Appendix F).

NOTE If using the contact check option, see flowchart, Figure F-4, in Appendix F.

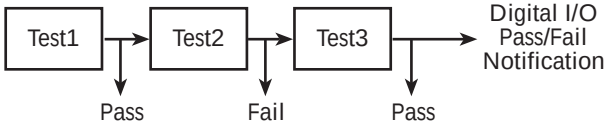
Binning control

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," page 12-10.) There are two types of binning control for the grading mode: immediate and end.

NOTE Binning affects contact check tests. See Appendix F for details.

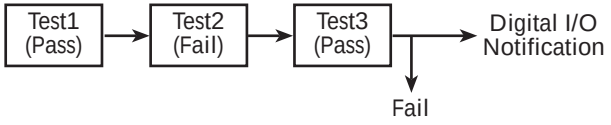
Immediate binning — Use immediate binning when you want to stop all testing after the first failure occurs. Any pending tests will be cancelled, and the DUT will be placed in the bin assigned to that test failure. If no failures occur, all enabled tests will be performed, and the DUT will be placed in the assigned pass bin. This process is demonstrated in
Figure 12-3.

Figure 12-3
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 12-4.)

Figure 12-4
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 via the Digital I/O port to the component handler to perform the binning operation.

End binning — For end binning, operation drops down to 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, the operation loops back to the top of the flowchart and waits for the start-of-test (SOT) 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 when a failure occurs, and the fail pattern for that particular failure is sent to the component handler to perform the binning operation. Triggering is maintained for other instruments or components in the test system.

End binning — For end binning, the fail pattern for the first failure is stored in memory and operation proceeds to 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 completed, the SourceMeter outputs the fail pattern stored in memory on the Digital I/O port. 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 start-of-test (SOT) pulse from the component handler.

Sorting mode

Sorting mode limits operation is detailed by the flowchart in Figure 12-5. 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," page 12-10.)

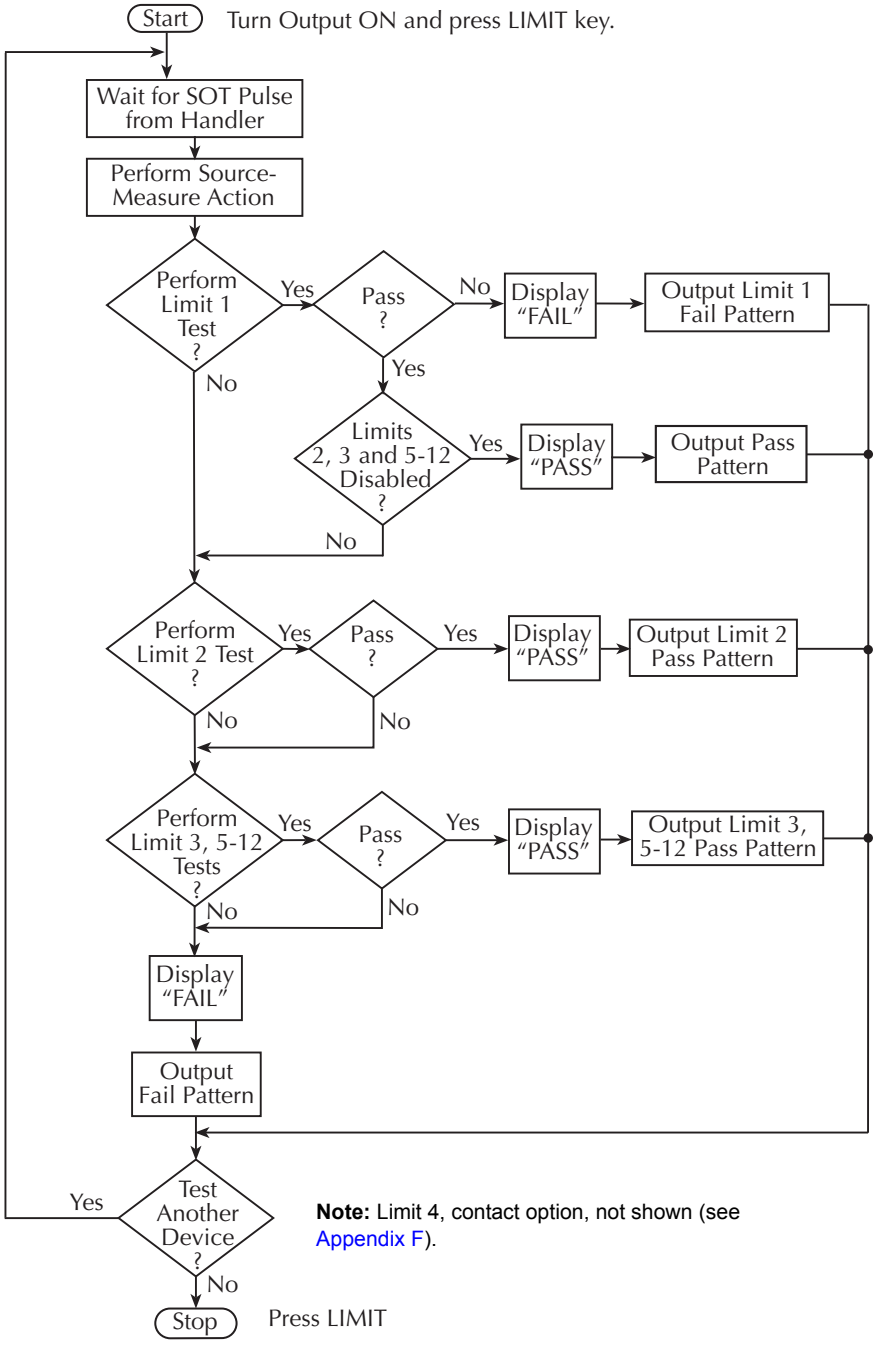
NOTE The Model 2401 does not have a handler interface. Therefore it cannot be used with a component handler to perform binning operations.

NOTE If using the contact check option, see flowchart, Figure F-4, in Appendix F.

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?.)

Figure 12-5
Sorting mode limit testing



Binning systems

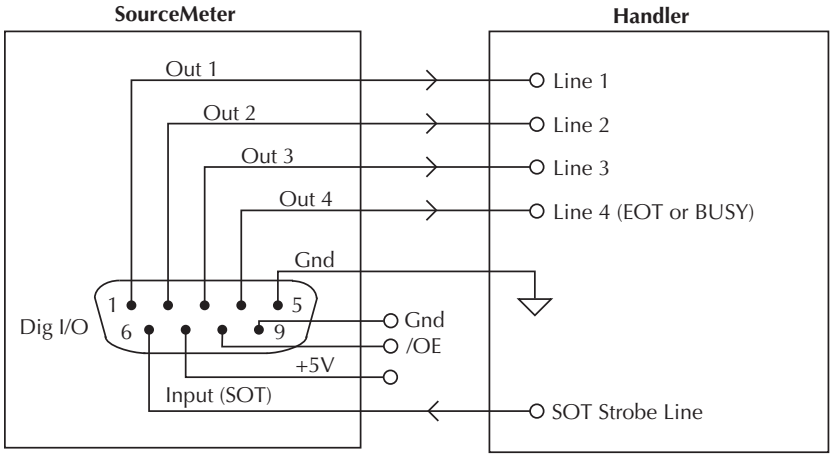
NOTE The Model 2401 does not have handler interface. Therefore it cannot be used with a component handler to perform binning operations.

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 Multiple-element device binning.

Handler interface

The SourceMeter is interfaced to a handler via the Digital I/O port as shown in Figure 12-6. The I/O port has four lines for output signals (Out 1 through Out 4) as well as input lines for start-of-test (SOT) and /OE (output enable) signals. The output lines are used to send the limit test pass/fail signal(s) to the handler to perform the binning operation.

Figure 12-6
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 Section 13, "Digital I/O port," 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," page 12-2.) In the 3-bit output mode, Line 4 can also be used either as an end-of-test (EOT) or BUSY signal depending on the END OF TEST mode. (See "Configuring limit tests," page 12-16.)

EOT or Busy Line

In the 3-bit mode, line 4 can be used to flag the handler when the digital I/O lines may be read. Depending on the type of handler present, either BUSY or end-of-test (EOT) may be used. These signals are defined as follows:

BUSY — The BUSY signal indicates the time from which the start-of-test (SOT) signal is received until all measurements, limit testing, and digital I/O operations have been completed. When /BUSY is selected, line 4 goes LO during this time period.

NOTE The arm source must be set to SOT in order to use BUSY.

EOT — The end-of-test strobe signals to the handler that the digital I/O lines may be read. This pulse occurs approximately 10us after the SourceMeter(c) has updated the digital I/O lines and ends approximately 10us before the digital I/O lines actually clear. The EOT pulse width is specified by the digital auto clear delay. EOT is HI when the digital I/O is updated. /EOT goes LO after the digital I/O lines are updated.

NOTE Digital auto-clear myst be enabled in order to use EOT.

SOT line

The input line (SOT) of the Digital I/O is used to control the start of the testing process. For remote operation with ⇓STEST selected as the 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 selected, testing will start when SOT is pulsed either high or low. For front panel operation with the IMMEDIATE arm event selected, the testing process will start as soon as the LIMIT key is pressed (assuming the output is ON). See Section 11, "Triggering," 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.

/OE line

The /OE (output enable) line of the Digital I/O can be used if the component handler is equipped with a switch. With proper use, power is removed from the DUT

when the lid of the handler is opened to eliminate a possible shock hazard. See Section 13, "Digital I/O port" and "Output enable line," for operation details on the output enable line.

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 Source-Meter 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 end-of-test (EOT) 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 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 LIMITS MENU. See "Configuring limit tests," page 12-16.

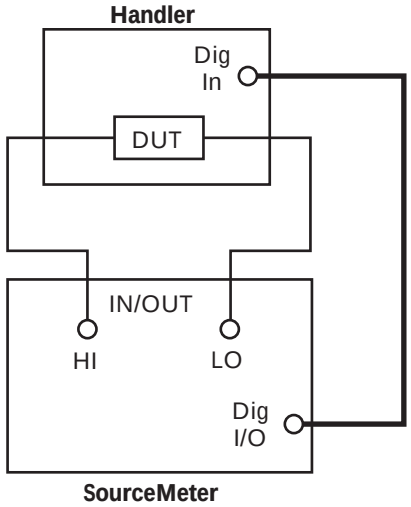
Basic binning systems

Two basic binning systems are shown in Figure 12-7 and Figure 12-8. 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 12-7 shows a basic binning system for single-element devices (i.e., resistors). After all programmed testing on the DUT is completed, the pass/fail 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 12-7
Binning system single-element devices

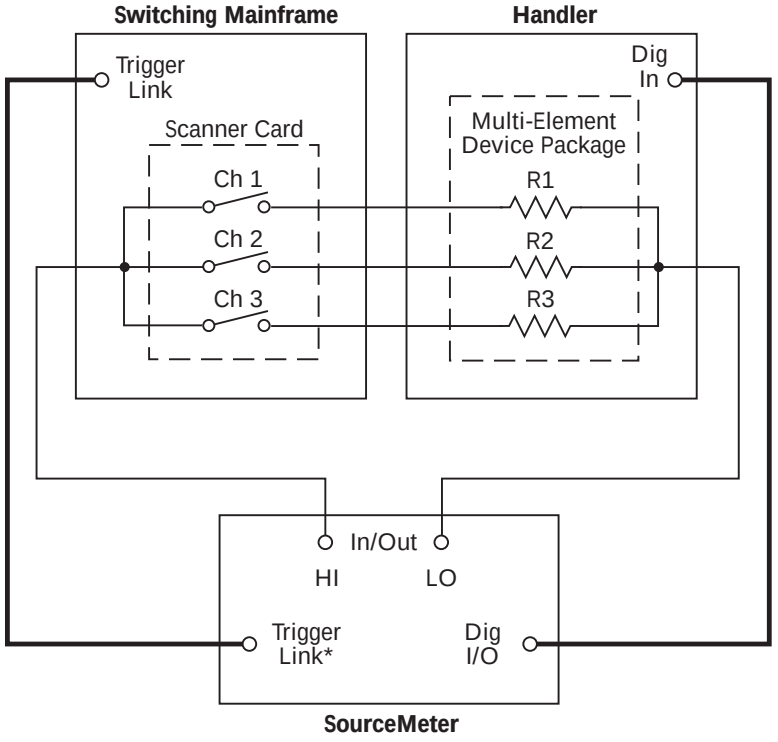


Multiple-element device binning

Figure 12-8 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 main-

frame. 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.

Figure 12-8
Binning system multiple-element devices



*Trigger layer configured to output trigger pulse after each measurement.

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 enabled, you can specify the required pulse width (delay) for the pass or fail pattern. (The default auto-clear pulse width is 10µs.) 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

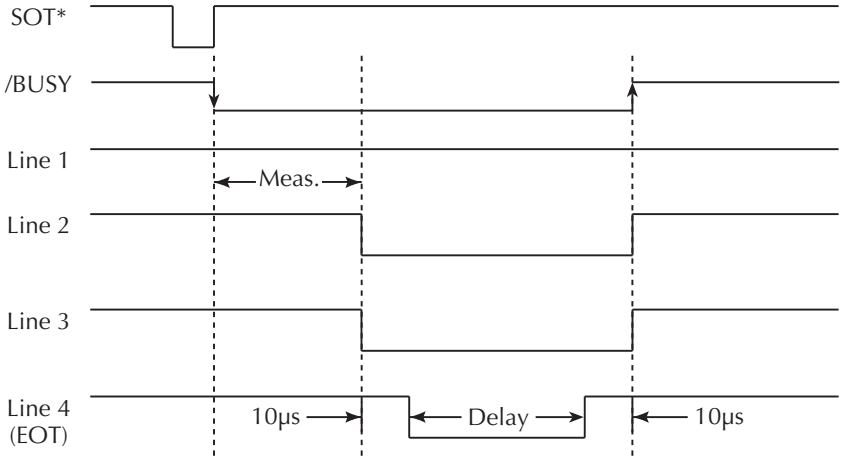
To enable auto-clear:

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 timing diagram example (Figure 12-9) and discussion explain the relationship between the digital output lines for auto-clear.

Figure 12-9
Digital output auto-clear timing example



* With the SOT line being pulsed low (as shown),↓ STEST must be the selected event for the trigger model. If the SOT line is instead pulsed high by the handler, ↑ STEST must be the selected arm event. For high or low pulses, select ↑↓STEST.

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 pass/fail pattern can be set from 0 to 60sec (10µsec 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 with auto-clear enabled.

Configuring and performing limit tests

Configuring limit tests

NOTE The Model 2401 does not use the digital output lines of the Digital I/O port. Therefore it cannot be used with a handler to perform binning operations. If using a Model 2401 for limit testing, ignore all actions and information that pertain to binning.

Press CONFIG and then LIMIT to display the CONFIG LIMITS MENU. The limits configuration menu is structured shown below and in Figure 12-10. Note that bullets indicate the primary items of the limit menu and dashes indicate the options of each menu or submenu 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. 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-BIT mode, 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 Contact Check (contact check option only) and Compliance tests first. The Digital I/O will be driven with the first pattern of the first Contact Check, 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 optional Contact Check Test, the Compliance Test, or is not within any of the Digital I/O Bands. If the tests pass and only Limit 1 or 4 (optional contact check test) 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 or 4 fails, their 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).

- **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).

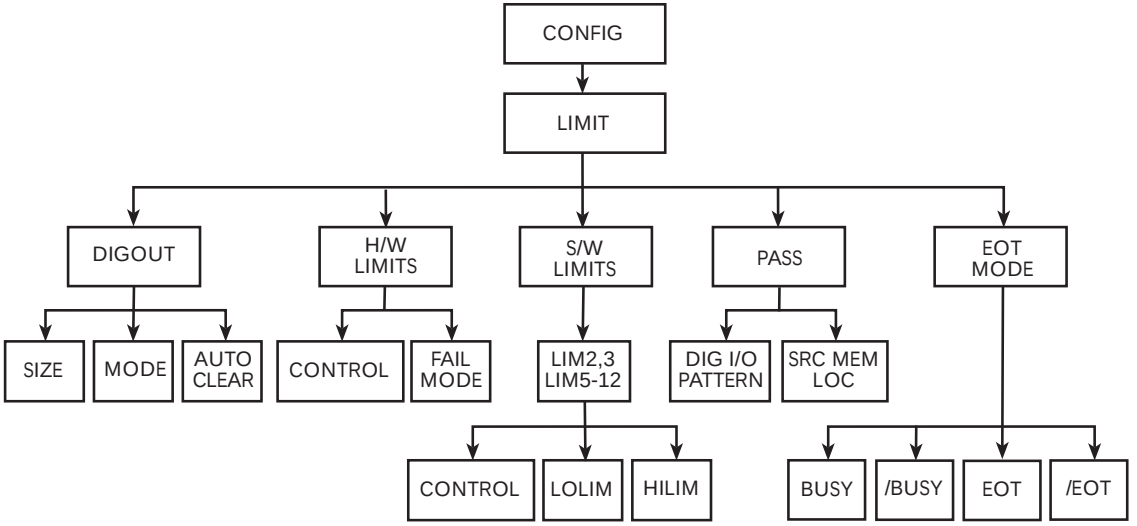
NOTE *If the contact check option is installed, the H/W LIMITS selection will also set options for the Contact Check Test (Limit 4). See Appendix F for contact check details.*

- **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).
  - **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).
- **PASS** — Use this menu item to dictate actions upon a PASS condition:
  - **DIG I/O PATTERN** — Use this option item to define the digital output bit pattern (0 to 7, 3-bit; 0 to 15, 4-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).

  - **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 end-of-test (EOT) or BUSY signal:
  - **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. Requires SOT as the arm source.
  - **/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. Requires SOT as the arm source.
  - **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. Requires digital auto-clear to be enabled.
  - **/EOT** — In 3-bit mode, automatically output a LO pulse on Digital I/O line 4 at end-of-test. In 4-bit mode, EOT is not automatically controlled. Requires digital auto-clear to be enabled.

Figure 12-10
Limits configuration menu tree



Performing front panel limit tests

Perform the basic steps below to run limit tests from the front panel. See "Remote limit testing," page 12-20, for remote commands and a programming example.

NOTE The Model 2401 does not use the digital output lines of the Digital I/O port. Therefore it cannot be used with a handler to perform binning operations. If using a Model 2401 for limit testing, ignore all actions and information that pertain to binning.

Step 1: Configure test system.

As previously explained, your test system could be as simple as connecting a DUT to the SourceMeter (Section 2, "Connections") 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).

Step 2: Configure source-measure functions.

Configure the SourceMeter for the desired source-measure operations.

Step 3: Configure limit tests.

Select and configure the following limit tests parameters as explained in "Configuring limit tests," page 12-16:

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, HIGH IMPEDANCE, 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 over-voltage protection (OVP) 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 12-1 summarizes remote commands to control limit testing parameters, while *Table 12-2* summarizes commands to control the Digital I/O port bit parameters for limit testing. See Section 18, "CALCulate2" and "SOURce2," for more details on these commands.

NOTE The Model 2401 does not use the digital output lines of the Digital I/O port and does not have a component handler interface. The commands in Table 12-2 and Table 12-3 are not valid for the Model 2401 and will cause undefined header errors.

NOTE For instruments with the contact check option, see Appendix F for more information.

Table 12-1
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, 5-12 (n = limit).

Table 12-1 (cont.)
Limit commands

Command*	Description*
: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:CLIMitis: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).

* LIMitX = LIMit2, LIMit3, LIMit5 through LIMit12. LIMit4 (Contact check option) not shown (see Table 18-1 and Appendix F).

Table 12-2
Commands to control Digital I/O port for limit testing (not valid for the Model 2401)

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?	Query actual output pattern.
: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).

Table 12-3
Invalid limit commands for the Model 2401

Command*	Description*
: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: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).

* LIMitX = LIMit2, LIMit3, LIMit5 through LIMit12. LIMit4 (Contact check option) not valid for the Model 2401.

The programming example in Table 12-4 tests a diode for two sets of upper and lower limits for a diode. This example is not valid for the Model 2401.

Table 12-4
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).

13
Digital I/O Port, Output Enable, & 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.

NOTE *The Model 2401 does not use the digital output lines of the Digital I/O port. Since the Model 2401 does not have a handler interface it cannot be used with a component handler to perform binning operations.*

- **Output enable** — Describes how to use the Digital I/O Port as output enable cable.
- **Front panel output configuration** — Details configuration of the Digital I/O Port as an output enable as well as configuring main output off states.
- **Remote output configuration** — Summarizes the remote commands used to control the Digital I/O Port output enable 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.

NOTE The Model 2401 does not use the digital output lines of the Digital I/O port. If using the Model 2401, ignore all information that pertains to binning operations.

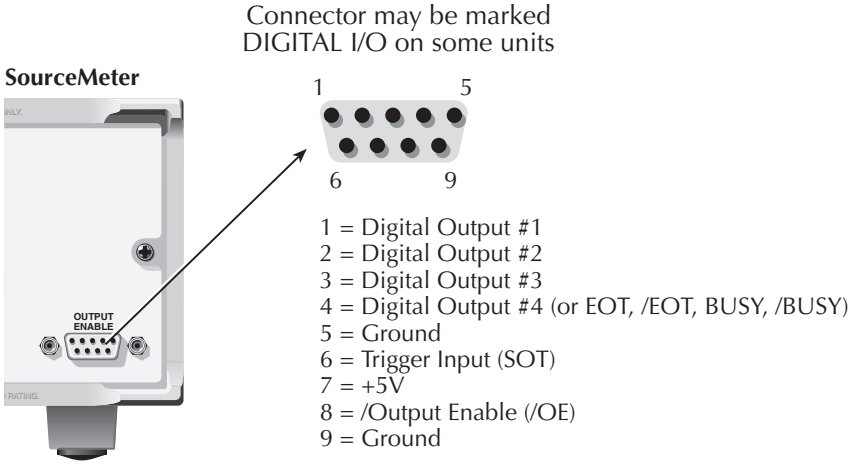
Port configuration

The Digital I/O Port is located on the rear panel and is shown in Figure 13-1.

NOTE The four digital output lines and the SOT line are primarily intended for limit testing with a device handler. See Section 12, "Limit Testing," for details on performing limit tests and interfacing to handlers and Section 11, "Triggering," for information on programming the SourceMeter to respond to the start-of-test (SOT) pulse from a handler.

NOTE The Model 2401 does not use pins 1 through 4 of the Digital I/O port. If using the Model 2401, ignore all information and actions pertaining to the digital output lines.

Figure 13-1
Digital I/O port



Digital output lines

The port provides four output lines. 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 end-of-test (EOT) or BUSY pulse. This pulse from the SourceMeter signals the handler to perform the binning operation, or indicates a busy condition. (See Section 12, "Configuring limit tests.")

SOT line

The input line (SOT) is used by the handler to start limit testing. With the ⇓STEST arm event selected (Section 11, "Configuring triggering"), 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, which starts the testing process. With ↑ ⇓STEST selected, either a high or low SOT pulse starts the testing process.

Output enable line

The output enable line (/OE) is intended for use with an output enable circuit on a device handler or test fixture. See"Output enable," page 13-5), for more details.

+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).

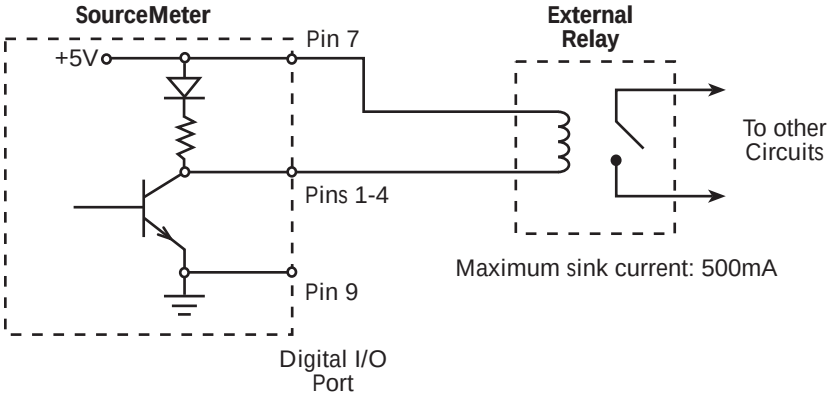
Digital output configuration

There are two basic methods to connect external components to the digital output lines, sink operation and source operation.

Sink operation

Figure 13-2 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.

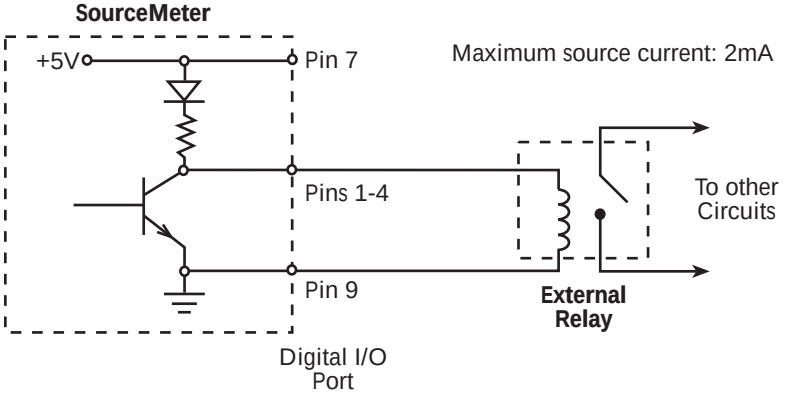
Figure 13-2
Sink operation



Source operation

Figure 13-3 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 13-3
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 covered below.

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 13-1). 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 :SOURce2:TTL <NRf> command to control the digital output line logic levels, where <NRf> is the decimal value shown in Table 13-1. For example, send the following command to set the output lines to L, H, L, H:

:SOUR2:TTL 5

Table 13-1
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 12.) 0-65535 with 2499-DIGIO 16-bit option.

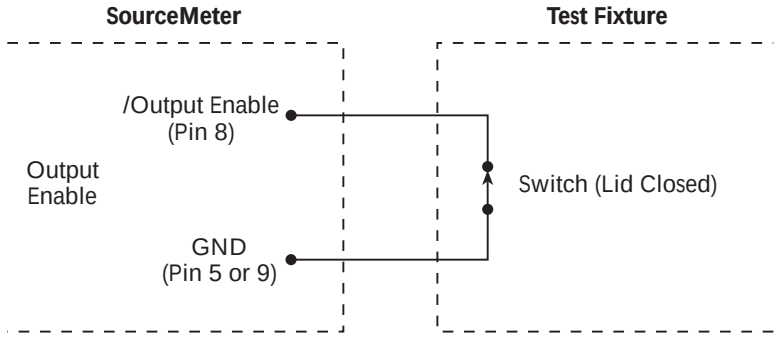
Output enable line

NOTE The output enable line can be used by all Series 2400 SourceMeters.

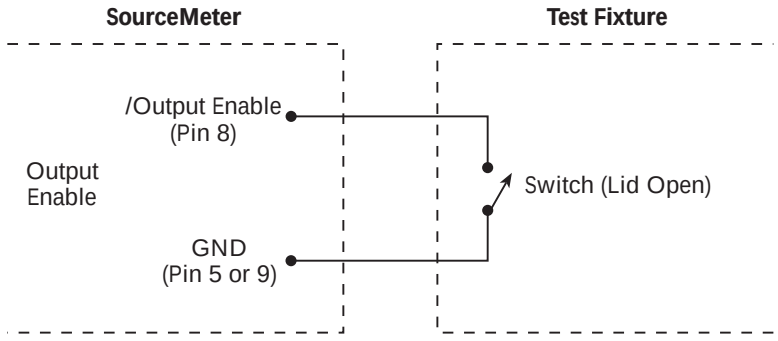
The digital I/O port provides an output enable line for use with a test fixture output enable switch. When properly used, the OUTPUT of the SourceMeter will turn OFF when the lid of the test fixture is opened. See Section 2, "Connections," for important safety information when using the test fixture switch.

When the output enable is turned on (see "Front panel output configuration," page 13-7), the output of the SourceMeter cannot be turned on unless the output enable line is pulled low through a switch to ground as shown in Figure 13-4A. If the lid of the test fixture opens (Figure 13-4B), the switch opens, and the output enable 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 13-4
Using test fixture output enable



A. SourceMeter OUTPUT can be turned on.



B. SourceMeter OUTPUT turns off.

NOTE Output enable can be driven by Digital I/O. Allow 100µs settling and response time. The Digital I/O lines are edge-sensitive, open-collector, and signals should be debounced 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

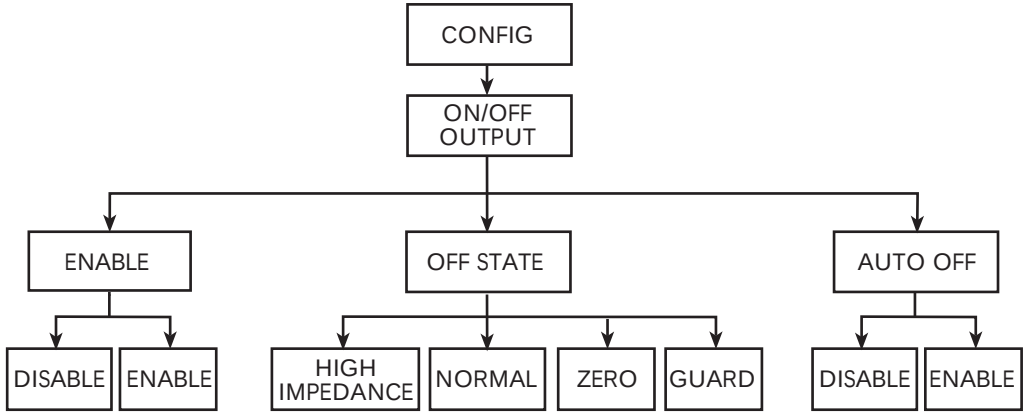
Press CONFIG and then ON/OFF OUTPUT to display the menu. Figure 13-5 shows the overall menu structure.

NOTE *For the Model 2430 Pulse Mode, ENABLE is the only menu item that is displayed. For the Pulse Mode, the output-off state is always set to NORMAL, and auto output-off is always enabled.*

- **ENABLE** — Use to ENABLE or DISABLE the output enable line of the Digital output. This line is used as an output enable for a test fixture. See "Digital I/O port," page 13-2.
- **OFF STATE** — Use to select the OFF state of the output. See "Output-off states," page 13-9, for details.
  - **HIGH IMPEDANCE** — When the OUTPUT is turned OFF, the output relay opens. This disconnects external circuitry from the input/output of the SourceMeter.
  - **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.
  - **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.

NOTE Enabling auto output off with auto zero turned off may result in readings that are not fully settled because the source may not have settled when the A/D signal phase measurement is taken. Turning auto zero on may improve the readings because it adds a 450µs delay after the output is turned on, but before the A/D measurement is taken. If the readings have not settled, it will be necessary to increase the source delay.

Figure 13-5
Output configuration menu tree



Output-off states

NOTE For the Model 2430 Pulse Mode, output-off is always set to NORMAL.

HIGH IMPEDANCE

With this output-off state, the output relay opens when the OUTPUT is turned OFF. This disconnects external circuitry from the input/output of the SourceMeter. To prevent excessive wear on the output relay, do not use this output off state for tests that turn the output off and on frequently (such as the Output Auto-Off mode). Note that there is a ~ 15msec settling time for the relay when the output is turned on.

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 SourceMeter 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.

On power-up, the SourceMeter will momentarily be in the HIGH IMPEDANCE output-off state before going to the selected power-on output-off state.

If an Over-Temperature condition or an output enable line violation occurs, the SourceMeter will go into the HIGH IMPEDANCE output-off state.

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 possibly 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 13-2 summarizes output configuration commands. These commands include those to enable and disable the output enable line as well as commands to control output offstates. See Section 18, "OUTPut subsystem" and "SOURce subsystem" for more information

Output configuration programming example

Table 13-2
Output configuration commands

Command	Description
:OUTPut:ENABle:[STATe] <state>	Enable/disable output enable (state = ON or OFF).
:OUTPut:ENABle:TRIPped?	Query output enable line tripped state (1 = tripped).
:OUTPut:SMODe <name>	Select output-off mode (state = HIMPedance, NORMal, ZERO, or GUARd).[1]
:SOURce:CLEar	Turn output source off when in idle state.
:SOURce:CLEar:AUTO <state>	Enable/disable auto output-off. State = OFF (output off after measurement) or ON (output stays on).[2]
: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).

1. For the Model 2430 Pulse Mode, the output-off mode is always NORMal. Selecting one of the other output-off states causes error +831.
2. For the Model 2430 Pulse Mode, auto output-off is always enabled. You can set auto output to be off, but it will not disable until the DC Mode of operation is selected.

Table 13-3 lists the command sequence for output configuration.

Table 13-3
Output configuration programming example

Command	Description
*RST	Restore GPIB defaults.
:SOUR:VOLT 10	Output 10V.
:OUTP:ENAB:STAT ON	Enable output enable line.*
:OUTP:SMOD HIMP	Select high impedance 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 switch.

14
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 18, "SENSe1 subsystem," for details.

NOTE *For the Model 2430, concurrent measurements cannot be performed while in the Pulse Mode. See Section 5 for details on Pulse Mode operation.*

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.

An interface is selected and configured from the COMMUNICATIONS option of the Main Menu (Section 1, "Main menu"). For details on the programmable aspects of the interfaces, see "Primary address," page 14-4, and "RS-232 interface operation," page 14-13.

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.

To allow many parallel connections to one instrument, stack the connectors. Two screws are located on each connector to ensure that connections remain secure.

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.

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 option of the Main Menu (Section 1, "Main menu").

General bus commands

General commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. Table 14-1 lists the general bus commands.

Table 14-1
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.

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

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. 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.

LSTN

This indicator is on when the SourceMeter is in the listener active state.

SRQ

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 15, "Status Structure," 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 will still be active 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 16 and Section 18 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 ONEnable 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 11Press 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 0.1Sets timer to 100 msec.

:ARM:TIMer DEFaultSets timer to 0.1 sec.

:ARM:TIMer MINimumSets timer to 1 msec.

:ARM:TIMer MAXimumSets 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 18 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; :stat:oper:enab <NRf>

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 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. However, 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 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 multiple 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 (see "Multiple command messages," page 14-11), 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. This clears any pending operation and discards any pending output.

Baud rate

The baud rate is the rate at which the SourceMeter and the programming terminal communicate. Choose one of 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 Ifull, 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 14-1 shows the rear panel connector for the RS-232 interface, and Table 14-2 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 14-1
RS-232 interface connector

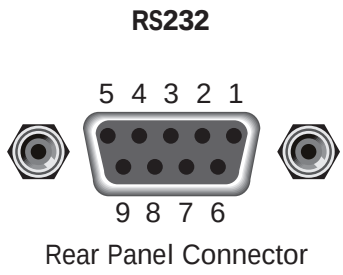


Table 14-2
RS-232 connector pinout

Pin numbezr	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: CTA and RTS are tied together.

Table 14-3 provides pinout identification for the 9-pin (DB-9) or 25-pin (DB-25) serial port connector on the computer (PC).

Table 14-3
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.

15
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.

16
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, discussed in Section 15.

Command summary

Common commands (summarized in Table 16-1) 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 15: *CLS, *ESE, *ESE?, *ESR?, *SRE, *SRE?, and *STB?.*

Table 16-1
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.
*OPT?	Options Query	Queries installed options. Response message indicates the prescence or absence of options. For example, if response message reads "0", then no options are present. If the response message reads CONTACT CHECK, then a Contact-Check option is present.
*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 15.

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 nnnn, xxxxxxx, yyyyy/zzzzz /a/d

Where: nnnn is the model number.
xxxxxxx is the serial number.
yyyyy/zzzzz is the firmware revision level 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.

*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.

**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 (see "Default" column of SCPI tables in Section 18).
- 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 11.

**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 com-

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.

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.**

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
32	FRONT/REAR 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:

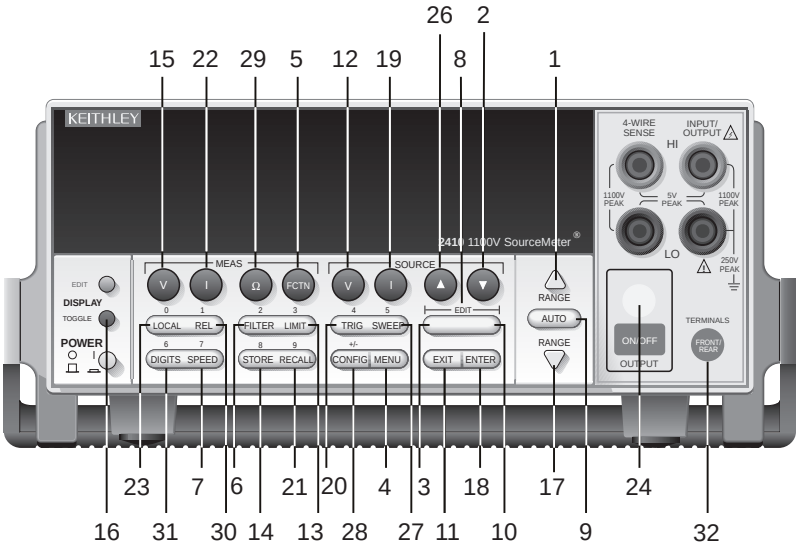
:syst:key 15

The parameter listing provides the key-press code in numeric order. Figure 18-3 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 18-3
Key-press codes



Parameters

<NRf> =

1	RANGE up arrow key	17	RANGE down arrow key
2	SOURCE down arrow key	18	ENTER key
3	Left arrow key	19	I (SOURCE) key
4	MENU key	20	TRIG key
5	FCTN key	21	RECALL key
6	FILTER key	22	I (MEAS) key
7	SPEED key	23	LOCAL key
8	EDIT key	24	ON/OFF key
9	AUTO key	25	- (not used)
10	Right arrow key	26	SOURCE up arrow key
11	EXIT key	27	SWEEP key
12	V (SOURCE) key	28	CONFIG key
13	LIMITS key	29	Ω key
14	STORE key	30	REL key
15	V (MEAS) key	31	DIGITS key
16	TOGGLE key	32	FRONT/REAR key

A
Specifications

Accuracy calculations

The information below 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)
= ±[$(0.015\% \times 10\text{V})$ + 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% x 0.7mA) + 200nA)]
= ±(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 Source-Meter 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.

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 15 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
-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

Table B-1 (continued)
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
-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
-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		

Table B-1 (continued)
Status and error messages

	Error message	Event[1]	Status register[2]	Bit
	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
+110	Limit 4 failed	SE*	Measurement Event	10
+111	OUTPUT enable 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
+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

* Contact check option only.

Table B-1 (continued)
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
	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
	Additional command execution errors: Illegal with storage active			
+800	Insufficient vector data	EE	Standard Event	4
+801	OUTPUT blocked by output enable	EE	Standard Event	4
+802	Not permitted with OUTPUT off	EE	Standard Event	4
+803	Expression list full	EE	Standard Event	4
+804	Undefined expression exists	EE	Standard Event	4
+805	Expression not found	EE	Standard Event	4
+806	Definition not allowed	EE	Standard Event	4
+807	Expression cannot be deleted	EE	Standard Event	4
+808	Source memory location revised	EE	Standard Event	4
+809	OUTPUT blocked by Over Temp	EE	Standard Event	4
+810		EE	Standard Event	4

Table B-1 (continued)
Status and error messages

Number	Error message	Event[1]	Status register[2]	Bit
+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
+828	Invalid on 1 amp range	EE	Standard Event	4
+829	Invalid on 1kV range	EE	Standard Event	4
+830	Invalid with INF ARM:COUNT	EE	Standard Event	4
+831	Invalid in Pulse Mode	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 100Correct
- *Improper short or long form.* Check the command list in Section 18 of this manual.
- *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 be 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 SourceMeter 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 SourceMeter will discard the second program message unit :SENS:FUNC? even though it is a valid query.