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Safety Supplement

Introduction

This supplement provides you with basic installation, front panel, and rear panel information to help you start using your Keithley Instruments 2601B-PULSE instrument safely.

For detailed information about these topics, refer to the *Model 2601B-PULSE Reference Manual*, available from the [Keithley Instruments website \(tek.com/keithley\)](http://Keithley Instruments website (tek.com/keithley)).

Power and environmental ratings

The 2601B-PULSE power and environmental ratings and connections are listed in the following tables.

Category	Specification
Power supply	100 V ac to 240 V ac, 50 Hz or 60 Hz (autosensing). 240 VA maximum
Input and output connections	See Front panel (on page 3) and Rear panel (on page 6)
Environmental conditions	For indoor use only. Operating altitude: Maximum 2000 meters (6562 feet) above sea level Operating temperature: 0 °C to 35 °C at up to 70% relative humidity; at 35 °C to 50 °C, derate 3% relative humidity per °C Storage: -25 °C to 65 °C Pollution degree: 1 or 2

	Source input electrical ratings
Voltage	40 V dc maximum
Current	3 A maximum at 6 V dc, 1 A maximum at 40 V dc

	Pulser feature output, region 4
Region maximums	10 A at 20 V
Maximum pulse width	1.8 ms
Maximum duty cycle	1%

	Measure input electrical ratings
Measurement category	O
Voltage	40 V dc maximum HI to LO
Current	3 A maximum at 6 V dc, 1 A maximum at 40 V dc
Impedance	Variable



Supply connection and grounding requirements

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

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

Assembly, location, and mounting requirements

The 2601B-PULSE can be mounted in a standard 19-inch rack (horizontal mountings only; mounting vertically may impede the cooling mechanisms).

When rack mounting the 2601B-PULSE, make sure there is adequate airflow around at least one side to ensure proper cooling. Adequate airflow enables air temperatures within approximately one inch of the 2601B-PULSE surfaces to remain within specified limits under all operating conditions. The cooling specifications state:

- Forced air
- Side intake, rear exhaust
- One side must be unobstructed when rack mounted

Ventilation requirements

To prevent damaging heat build-up and ensure specified performance, observe the following precautions.

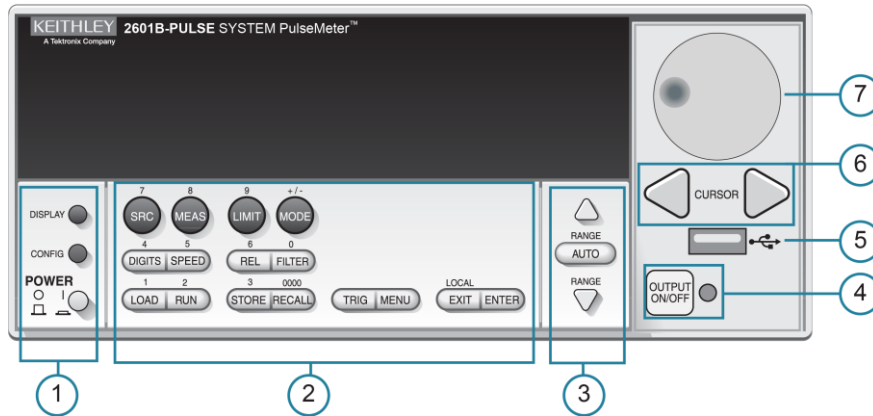
The rear exhaust vent and at least one side vent must be kept free of any obstructions. Even partial blockage could impair proper cooling.

- Do not position any devices adjacent to the 2601B-PULSE that force air (heated or unheated) into or onto its cooling vents or surfaces. This additional airflow could compromise accuracy performance.
- When rack mounting the 2601B-PULSE, make sure there is adequate airflow around at least one side to ensure proper cooling. Adequate airflow enables air temperatures within approximately one inch of the 2601B-PULSE surfaces to remain within specified limits under all operating conditions.
- Do not rack-mount high power-dissipation equipment adjacent to the 2601B-PULSE that could cause excessive heating to occur. The specified ambient temperature must be maintained around the surfaces of the 2601B-PULSE to maintain specified accuracies.


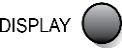
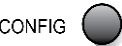
Front panel

The front panel of the 2601B-PULSE is shown below. The descriptions of the front-panel controls, USB port, and indicators follow the figure.

Figure 1: 2601B-PULSE front-panel controls



1. Power switch, display and configuration keys

- 
 POWER
 Power switch. The in position turns the 2601B-PULSE on (I); the out position turns it off (O).
- 
 DISPLAY
 Toggles between the various source-measure displays and the user message mode.
- 
 CONFIG
 Configures a function or operation.

2. SMU setup, performance control, special operation, and numbers

SMU (source-measure unit) setup



- | | |
|--------------|---|
| SRC | Selects the source function (voltage or current) and places the cursor in the source field for editing. |
| MEAS | Cycles through measure functions (V, A, Ω , or W). |
| LIMIT | Places the cursor in the compliance limit field for editing. Also selects the limit value to edit (V, A, or W). |
| MODE | Selects a meter mode (I-METER, V-METER, OHM-METER, or WATT-METER). |

Performance control



DIGITS	Sets the display resolution (4½, 5½, or 6½ digits).
SPEED	Sets the measurement speed (FAST, MEDium, NORMAL, HI-ACCURACY, or OTHER). Speed and accuracy are set by controlling the measurement aperture.
REL	Controls relative measurements, which allows a baseline value to be subtracted from a reading.
FILTER	Enables or disables the digital filter. You can use this filter to reduce reading noise.

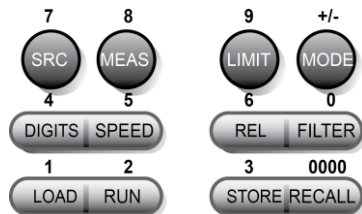
Special operation



LOAD	Loads test for execution (FACTORY, USER, or SCRIPTS).
RUN	Runs the last selected factory or user-defined test.
STORE	Accesses reading buffers and takes readings. TAKE_READINGS: Use to take readings and store them in a reading buffer. SAVE: Use to save a reading buffer to nonvolatile memory or to a user-installed flash drive (USB1) in CSV or XML format. Readings include measurements, source values, and timestamp values, if configured.
RECALL	Recalls information (DATA or STATISTICS) stored in a reading buffer: DATA includes stored readings, and if configured, source values and timestamp values; STATISTICS includes MEAN, STD DEV, SAMPLE SIZE, MINIMUM, MAXIMUM, PK-PK.
TRIG	Triggers readings.
MENU	Accesses the main menu. The main menu can be used to configure many functions and features.
EXIT	Cancels the selection and returns to the previous menu or display. Also used as a LOCAL key to take the instrument out of remote operation.
ENTER	Accepts the selection and moves to the next choice or exits the menu.

Numbers

Number keys When enabled and in EDIT mode, the number keys (0-9, +/-, 0000) allow direct numeric entry. Press the navigation wheel to enter EDIT mode.



3. Range keys



Selects the next higher source or measure range.



Enables or disables source or measure autorange.



Selects the next lower source or measure range.

In addition to selecting range functions, the up and down range keys change the format for non-range numbers (as an example, when editing the limit value).

4. Output control



Turns the source output on or off.


5. USB port



Use the USB port to connect a USB flash drive to the instrument. You can use the USB flash drive to store reading buffer data, scripts, and user setups. You can also use it to upgrade the firmware.

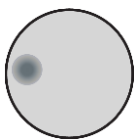
6. Cursor keys




Use the CURSOR keys to move the cursor left or right. When the cursor is on the source or compliance value digit, press the navigation wheel  to enter edit mode, and turn the navigation wheel to edit the value. Press the navigation wheel again when you finish editing.

Use the CURSOR keys or the navigation wheel to move through menu items. To view a menu value, use the CURSOR keys for cursor control, and then press the navigation wheel to view the value or sub-menu item.

7. Navigation wheel



Turn the navigation wheel  to:

- Move the cursor to the left and the right (the cursor indicates the selected value or item)
- While in edit mode, increase or decrease a selected source or compliance value

Push the navigation wheel  to:

- Enable or disable edit mode for the selected source or compliance value
- Open menus and submenu items
- Select a menu option or a value

8. Display indicators (not shown)

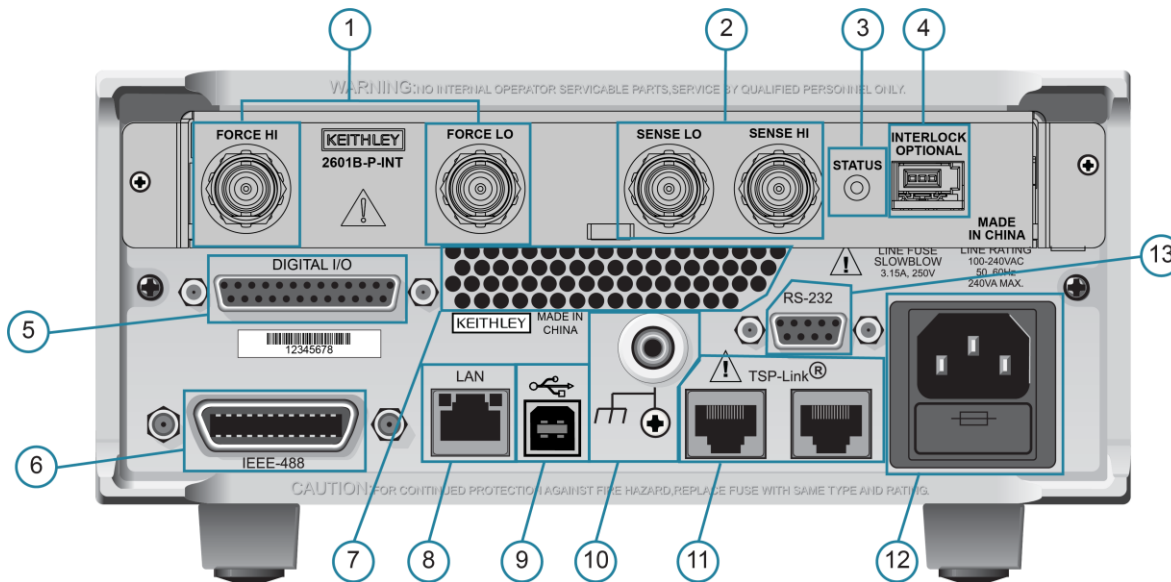
The items listed below represent the possible display indicators and their meanings.

Indicator	Meaning
4W	Remote (4-wire) sense selected
AUTO	Source or measure autorange is selected
EDIT	Instrument is in editing mode
ERR	Questionable reading or invalid calibration step
FILT	Digital filter is enabled
LSTN	Instrument is addressed to listen
REL	Relative mode is enabled
REM	Instrument is in remote mode
SRQ	Service request is asserted
TALK	Instrument is addressed to talk
* (asterisk)	Readings are being stored in the buffer

Rear panel

The rear panel of the 2601B-PULSE is shown below. The descriptions of the rear-panel components follow the figure.

Figure 2: Rear panel

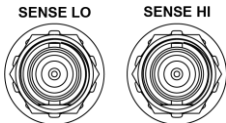


1. FORCE HI and FORCE LO connectors



These connectors provide connections for FORCE HI and FORCE LO.

2. SENSE LO and SENSE HI connectors



These connectors provide connections for SENSE LO and SENSE HI.

3. STATUS indicator



This LED indicates the status of the interlock. When the interlock is not asserted, the indicator is off. When the interlock is asserted, the indicator is on.

4. INTERLOCK connector



This connector provides a connection for the optional interlock. Refer to "Using the interlock" in the *Model 2601B-PULSE Reference Manual* for information on setting up and connecting the interlock.

5. Digital I/O



Female DB-25 connector. Use a cable equipped with a male DB-25 connector (Keithley Instruments part number CA-126-1).

Pins provided:

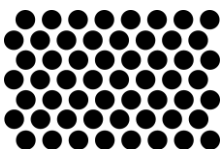
- Fourteen digital input or output pins
- Seven GND pins
- Three +5 V pins

6. IEEE-488



Connector for IEEE-488 (GPIB) operation. Use a shielded cable, such as the Keithley Instruments Model 7007-1 or Model 7007-2.

7. Cooling exhaust vents



Exhaust vent for the internal cooling fan. Keep the vent free of obstructions to prevent overheating. Also see [Cooling vents](#) (on page 8).

8. LAN



RJ-45 connector for a local area network (LAN). The LAN interface supports Auto-MDIX, so either a CAT-5e crossover cable (provided), or a normal CAT-5e straight-through cable (not provided) can be used.

9. USB port



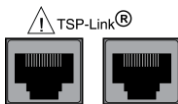
This USB-2.0 receptacle (Type B) located on the rear panel is used to connect the instrument to a computer. You can use this connection to send commands to the instrument.

10. Ground



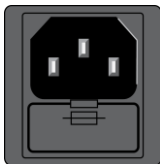
Ground terminal for connection output HI or LO to chassis ground.
Ground screw for connections to chassis ground.

11. TSP-Link



Expansion interface that allows a 2601B-PULSE and other TSP-enabled instruments to trigger and communicate with each other. Use a category 5e or higher LAN crossover cable.

12. Power module



Contains the AC line receptacle and power line fuse. The instrument can operate on line voltages of 100 V to 240 VAC at line frequencies of 50 Hz or 60 Hz.

13. RS-232



Female DB-9 connector. For RS-232 operation, use a straight-through (not null modem) DB-9 shielded cable (Keithley Instruments Model 7009-5) for connection to the computer.

Cooling vents

The 2601B-PULSE has side and top intake and rear exhaust vents. One side must be unobstructed to dissipate heat.

Excessive heat could damage the 2601B-PULSE and degrade its performance. Only operate the 2601B-PULSE in an environment where the ambient temperature does not exceed 50 °C.

Do not place a container of liquid (water or coffee, for instance) on the top cover. If it spills, the liquid may enter the case through the vents and cause severe damage.

CAUTION

To prevent damaging heat build-up and ensure specified performance, use the following guidelines.

The rear exhaust vent and either the top or both side intake vents must be unobstructed to properly dissipate heat. Even partial blockage could impair proper cooling.

Do not position any devices adjacent to the 2601B-PULSE that force air (heated or unheated) toward its cooling vents or surfaces. This additional airflow could compromise accuracy.

When rack mounting the 2601B-PULSE, make sure there is adequate airflow around both sides to ensure proper cooling. Adequate airflow enables air temperatures within approximately one inch of the 2601B-PULSE surfaces to remain within specified limits under all operating conditions.

If you rack mount high power-dissipation equipment next to the 2601B-PULSE, it could cause excessive heating. To produce specified 2601B-PULSE accuracies, maintain the specified ambient temperature around the surfaces of the 2601B-PULSE. In rack configurations with convection cooling only, proper cooling practice places the hottest non-precision equipment (for example, the power supply) at the top of the rack away from and above precision equipment (such as the 2601B-PULSE).

Mount precision equipment as low as possible in the rack, where temperatures are coolest. Adding space panels above and below the 2601B-PULSE will help provide adequate airflow.

Starting up your instrument

The following topics describe how to power your instrument on and off, place the instrument in standby, configure the line frequency, and replace the line fuse.

Turning the instrument on and off

The 2601B-PULSE operates from a line voltage of 100 V to 240 V at a frequency of 50 Hz or 60 Hz. Line voltage is automatically sensed (there are no switches to set). Make sure the operating voltage in your area is compatible.

Follow the procedure below to connect the 2601B-PULSE to line power and turn on the instrument.

CAUTION

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

To turn a 2601B-PULSE on and off:

1. Before plugging in the power cord, make sure that the front panel POWER switch is in the off (O) position.
 2. Connect the female end of the supplied power cord to the AC receptacle on the rear panel.
 3. Connect the other end of the power cord to a grounded AC outlet.
-

WARNING

The power cord supplied with the 2601B-PULSE contains a separate protective earth (safety ground) wire for use with grounded outlets. When proper connections are made, the instrument chassis is connected to power-line ground through the ground wire in the power cord. In addition, a chassis ground connection is provided through a screw on the rear panel. This terminal should be connected to a known protective earth. In the event of a failure, not using a properly grounded protective earth and grounded outlet may result in personal injury or death due to electric shock.

Do not replace detachable mains supply cords with inadequately rated cords. Failure to use properly rated cords may result in personal injury or death due to electric shock.

WARNING

Hazardous voltages may be present on all measurement terminals. To prevent electrical shock that could cause injury or death, remove power from the instrument or test system and discharge any energy storage components (for example, capacitors or cables) before changing any connections that might allow contact with an uninsulated conductor.

NOTE

On some sensitive or easily damaged devices under test (DUTs), the instrument power-up and power-down sequence can apply transient signals to the DUT that may affect or damage it. When testing this type of DUT, do not make final connections to it until the instrument has completed its power-up sequence and is in a known operating state. When testing this type of DUT, disconnect it from the instrument before turning the instrument off.

To prevent any human contact with a live conductor, connections to the DUT must be fully insulated and the final connections to the DUT must only use safety-rated safety jack socket connectors that do not allow bodily contact.

4. To turn your instrument on, press the front panel **POWER** switch to place it in the on (I) position.
 5. To turn your instrument off, press the front panel **POWER** switch to place it in the off (O) position.
-

Placing a 2601B-PULSE in standby

WARNING

Placing the 2601B-PULSE in standby does not place the instrument in a safe state (an interlock is provided for this function).

When the instrument is on, the output may be placed in an active output state (output on) or a standby mode (output off). From the front panel, pressing the **OUTPUT ON/OFF** control toggles the output using the present instrument configuration. You can also place the output in standby over the remote interface by sending the following command:

```
smua.source.output = smua.OUTPUT_OFF
```

Even though the instrument is placed in standby, the output may not be actually off.

Warmup period



The 2601B-PULSE must be turned on and allowed to warm up for at least two hours to achieve rated accuracies.

Line frequency configuration

The factory configures the 2601B-PULSE to automatically detect the power line frequency (either 50 Hz or 60 Hz) at each power-up. This detected line frequency is used for aperture (NPLC) calculations.

In noisy environments, you can manually configure the instrument to match the actual line frequency.

To configure the line frequency from the front panel:

1. Press the **MENU** key, then turn the navigation wheel  to select **LINE-FREQ**, and then press the **ENTER** key.
2. Turn the navigation wheel  to select the appropriate frequency and then press the **ENTER** key. To configure the instrument to automatically detect line frequency at each power-up, select **AUTO**.
3. Press the **EXIT (LOCAL)** key to return to the main display.

To configure the line frequency from a remote interface:

Set the `localnode.linefreq` or the `localnode.autolinefreq` attribute. To set the line frequency to 60 Hz, send:

```
localnode.linefreq = 60
```

To configure the instrument to automatically detect line frequency at each power-up:

```
localnode.autolinefreq = true
```

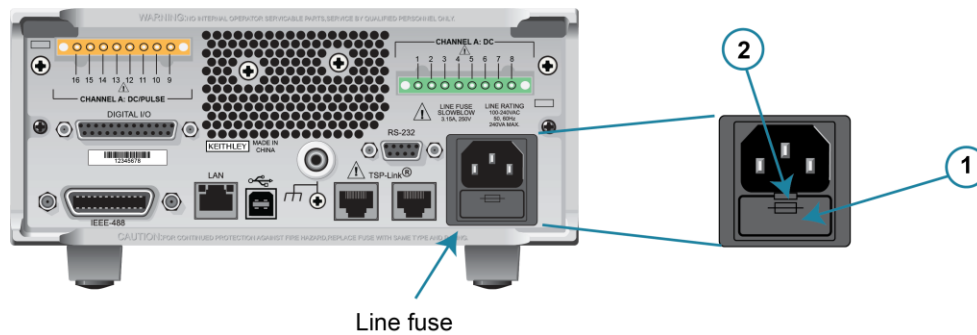
Line fuse replacement

A fuse on the 2601B-PULSE rear panel protects the power line input of the instrument. Follow the below instructions to replace the fuse. You do not need to return your instrument for service if the fuse is damaged.

⚠ WARNING

Disconnect the line cord at the rear panel and remove all test leads connected to the instrument before replacing a line fuse. Failure to do so could expose the operator to hazardous voltages that could result in personal injury or death.

Figure 3: Fuse replacement



⚠ WARNING

To prevent injury, death, or instrument damage, use only the correct fuse type (see table).

To replace the line fuse:

1. Power off the instrument and remove the line cord.
2. The fuse drawer (item 1 in the figure) is located below the AC receptacle. A small tab is on the top of the fuse drawer (item 2). Use a thin-bladed knife or a screwdriver to pry this tab away from the AC receptacle.
3. Slide the fuse drawer out to gain access to the fuse (the fuse drawer does not pull completely out of the power module).
4. Snap the fuse out of the drawer and replace it with the same type (the fuse is specified in the table below).
5. Push the fuse drawer back into the module.

If a fuse continues to become damaged, a circuit malfunction exists and must be corrected. Return the instrument to Keithley Instruments for repair.

Line fuse

Line voltage	Rating	Keithley part number
100 V to 240 V	250 V, 3.15 A, slow blow 5 x 20 mm	FU-106-3.15

System information

You can display serial number, firmware revision, and calibration dates through the front panel by selecting **SYSTEM-INFO** from the main menu.


To view the system information from the front panel:

1. Press the **MENU** key.
2. Select **SYSTEM-INFO**.
3. Select one of the following:
 - **FIRMWARE**
 - **SERIAL#**
 - **CAL**

For remote programming, use the `*IDN?` query to read system information.

Beeper

The 2601B-PULSE includes a beeper. When it is enabled, a beep indicates one of the following actions have occurred:

- A front-panel key was pressed: A short beep, similar to a key click, is issued.
- The navigation wheel  was turned or pressed: A short beep is issued.
- The output source was changed: A longer beep is issued when you select the OUTPUT ON/OFF control (turn the output on or off).

To turn the beeper on or off from the front panel:

1. Press the **MENU** key, and then select **BEEPER**.
2. Select one of the following:
 - **ENABLE**
 - **DISABLE**

To turn the beeper on or off from the TSP command interface:

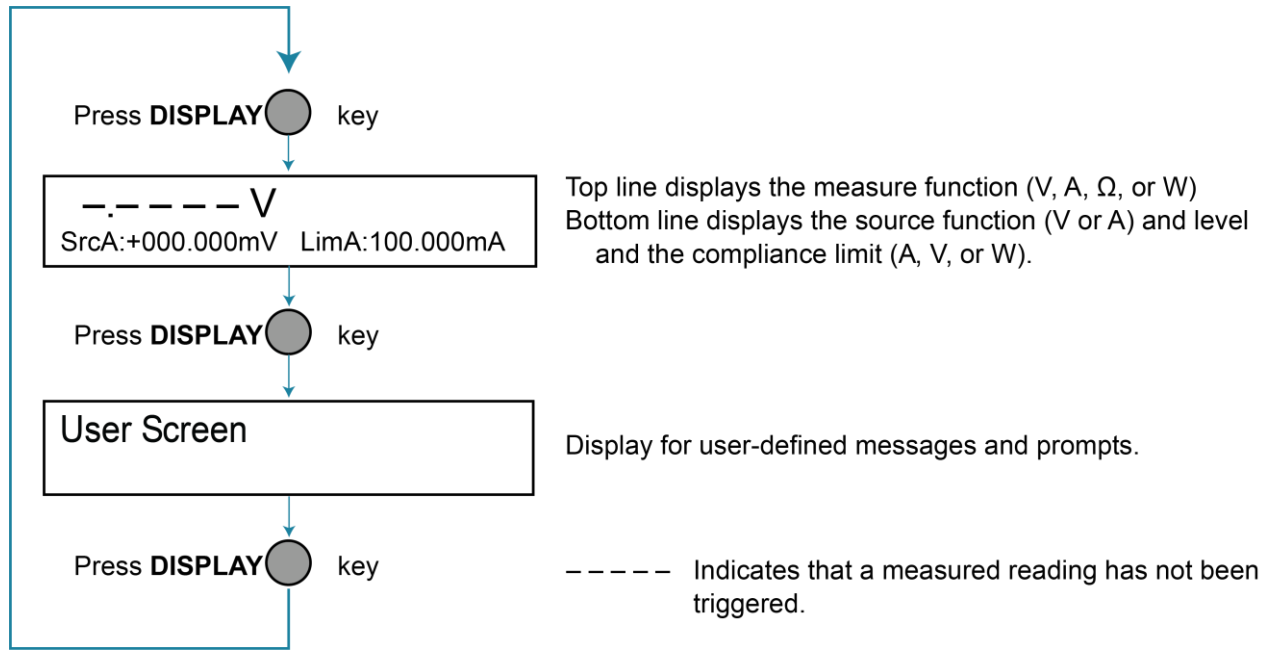
Set the `beeper.enable` attribute. For example, to enable the beeper, send:

```
beeper.enable = 1
```

Display mode

Use the **DISPLAY** key to scroll through the various display modes shown in the figure below.

Figure 4: Display modes



Operation overview

From the front panel, you can configure the instrument to perform the following source-measure operations:

- **Source voltage:** Measure and display current, voltage, resistance, or power
- **Source current:** Measure and display voltage, current, resistance, or power
- **Measure resistance:** Display resistance calculated from voltage and current components of measurement (can optionally specify source voltage or source current value)
- **Measure power:** Display power calculated from voltage and current components of measurement (can optionally specify source voltage or source current value)
- **Measure only (V or I):** Display voltage or current measurement

You can also configure source-measure operations using remote commands.

In addition to source-measure operations, the 2601B-PULSE provides pulser sourcing and measuring. The pulser feature is only available using remote commands.

NOTE

Before you begin any of the following front-panel procedures, make sure that you exit out of the menu structure. Press the **EXIT (LOCAL)** key as many times as needed to return to the main display.

Voltage and current

The following table lists the source and measure limits for the voltage and current functions.

Source-measure capabilities

Range	Source	Measure
100 mV	±101 mV	±102 mV
1 V	±1.01 V	±1.02 V
6 V	±6.06 V	±6.12 V
40 V	±40.4 V	±40.8 V
100 nA	±101 nA	±102 nA
1 µA	±1.01 µA	±1.02 µA
10 µA	±10.1 µA	±10.2 µA
100 µA	±101 µA	±102 µA
1 mA	±1.01 mA	±1.02 mA
10 mA	±10.1 mA	±10.2 mA
100 mA	±101 mA	±102 mA
1 A	±1.01 A	±1.02 A
3 A	±3.03 A	±3.06 A
10 A (only available in pulse mode)	±10.1 A	±10 A
Maximum power = 40.4 W per channel		

Safety concerns

WARNING

This instrument can produce high current, high power outputs that can cause heating of connectors and wires. Always use wires and connectors that are rated for the maximum current ratings of the instrument. Failure to provide correctly rated wires and connectors can result in a fire.

CAUTION

To protect sensitive devices under test, consider using external fuses or other current limiting devices. Failure to provide current limit devices may result in damage to sensitive devices under test.

NOTE

When using 4-wire (sense), if a sense lead becomes disconnected, current in excess of the instrument ratings can flow. Consider using external resistors to connect HI to sense HI and LO to sense LO at the instrument terminals to mitigate this risk. 100 K Ω resistors are recommended.

Contact information

If you have any questions after you review the information in this documentation, please contact your local Keithley Instruments office, sales partner, or distributor. You can also call the corporate headquarters of Keithley Instruments (toll-free inside the U.S. and Canada only) at 1-800-935-5595, or from outside the U.S. at +1-440-248-0400. For worldwide contact numbers, visit the [Keithley Instruments website \(tek.com/keithley\)](http://tek.com/keithley).