



Model 2470

High Voltage SourceMeter Instrument

USER'S MANUAL



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User's Manual

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Cleveland, Ohio, U.S.A.

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

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

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

The types of product users are:

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

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

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

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

Keithley products are designed for use with electrical signals that are measurement, control, and data I/O connections, with low transient overvoltages, and must not be directly connected to mains voltage or to voltage sources with high transient overvoltages. Measurement Category II (as referenced in IEC 60664) connections require protection for high transient overvoltages often associated with local AC mains connections. Certain Keithley measuring instruments may be connected to mains. These instruments will be marked as category II or higher.

Unless explicitly allowed in the specifications, operating manual, and instrument labels, do not connect any instrument to mains.

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

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

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

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

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

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

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


For safety, instruments and accessories must be used in accordance with the operating instructions. If the instruments or accessories are used in a manner not specified in the operating instructions, the protection provided by the equipment may be impaired.


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

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

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


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


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

The  symbol on an instrument means caution, risk of hazard. The user must refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

The  symbol on an instrument means warning, risk of electric shock. Use standard safety precautions to avoid personal contact with these voltages.


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

The  symbol indicates a connection terminal to the equipment frame.

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

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

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

The **CAUTION** heading with the  symbol in the user documentation explains hazards that could result in moderate or minor injury or damage the instrument. Always read the associated information very carefully before performing the indicated procedure. Damage to the instrument may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

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

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

Unless otherwise noted in product-specific literature, Keithley instruments are designed to operate indoors only, in the following environment: Altitude at or below 2,000 m (6,562 ft); temperature 0 °C to 50 °C (32 °F to 122 °F); and pollution degree 1 or 2.

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

Safety precaution revision as of June 2018.

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Introduction

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Welcome

Thank you for choosing a Keithley product. The 2470 High Voltage SourceMeter Instrument is a precise, low-noise instrument that combines a stable DC power supply with a repeatable, high-impedance multimeter. This instrument features intuitive setup and control, enhanced signal quality and range, and better resistivity and resistance capabilities than similar products on the market.

With its 1100 V and 10 fA capability, the 2470 is optimized for characterizing and testing high voltage, low leakage devices, materials, and modules, such as silicon carbide (SiC), gallium nitride (GaN), power MOSFETs, transient suppression devices, circuit protection devices, power modules, and batteries.

SMU instruments offer a highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current measurements. The 2470 instrument can be used as a:

- Precision power supply with voltage and current readback
- True current source
- Digital multimeter (DCV, DCI, ohms, and power with 6½-digit resolution)
- Precision electronic load
- Pulse generator
- Trigger controller

Introduction to this manual

This manual provides detailed applications to help you achieve success with your Keithley 2470. It also provides information about the basics of the front panel to familiarize you with the instrument.

Each application includes an overview, followed by instructions to complete the application using the front panel, Standard Commands for Programmable Instrumentation (SCPI) code or Test Script Processor (TSP™) code.

More information about the commands that are used in these applications is available. Refer to the SCPI and TSP command reference sections of the *Model 2470 Reference Manual*.

This manual is available at tek.com/keithley.

Extended warranty

Additional years of warranty coverage are available on many products. These valuable contracts protect you from unbudgeted service expenses and provide additional years of protection at a fraction of the price of a repair. Extended warranties are available on new and existing products. Contact your local Keithley Instruments office, sales partner, or distributor for details.

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 Tektronix corporate headquarters (toll-free inside the U.S. and Canada only) at 1-800-833-9200. For worldwide contact numbers, visit tek.com/contact-tek.

Organization of manual sections

This manual is organized into the following sections:

- [Installation](#) (on page 2-1): Dimensions, installation, and power up information.
- [Instrument description](#) (on page 3-1): Describes the front panel, rear panel, power on, power off, display, menus, setups, and resets.
- [Making basic front-panel measurements](#) (on page 4-1): An example that demonstrates how to make a basic measurement.
- [Maintenance](#) (on page 5-1): Fuse replacement, cleaning, and firmware upgrade information.
- [Troubleshooting FAQs](#) (on page 6-1): Provides answers to frequently asked questions to help you troubleshoot common problems encountered with the 2470.
- [Next steps](#) (on page 7-1): Provides information about additional resources that can help you use the 2470.

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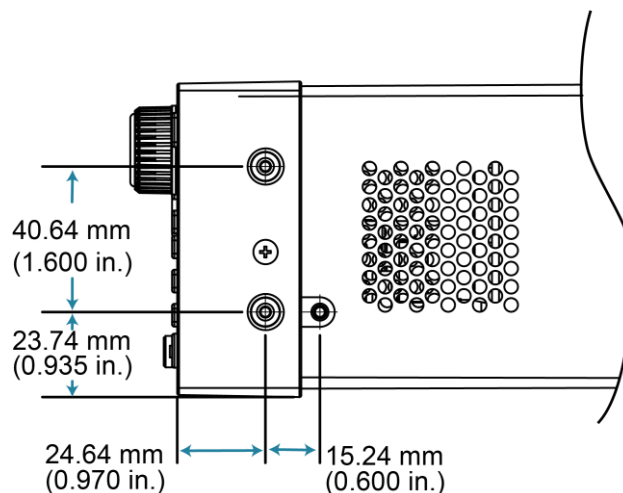
Dimensions

The following figures show the mounting screw locations and the dimensions of the instrument with and without the handle and bumpers.

The instrument weighs 4.54 kg (10.0 lb) with the bumpers and handle and 4.08 kg (9 lb) without them.

Mounting screws must be #6-32 with a maximum screw length of 11.12 mm (0.438 in.) or 7/16 in. The dimensions shown are typical for both sides of the instrument.

Figure 1: 2470 mounting screw locations and dimensions



The following figures show the dimensions when the handle and bumpers are installed.

Figure 2: 2470 dimensions front and rear with handle and bumpers

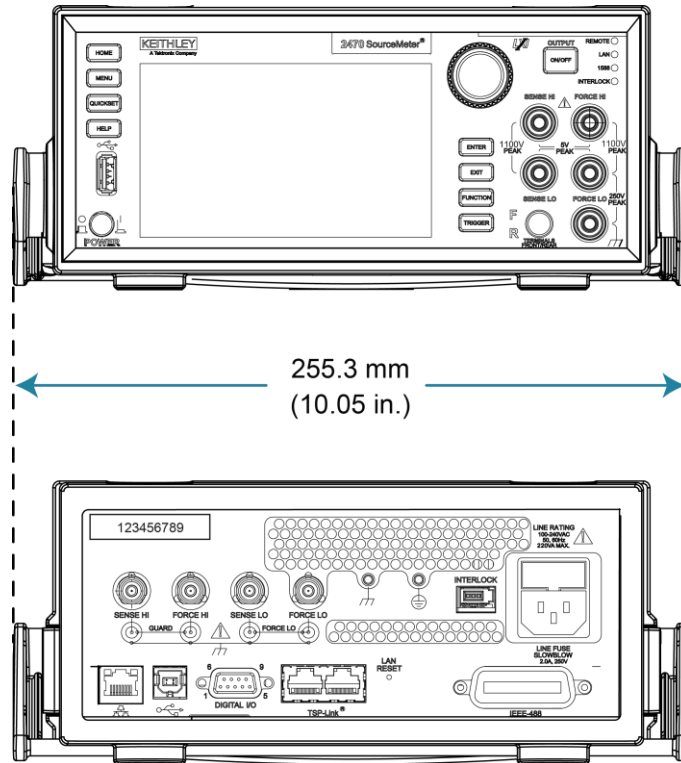
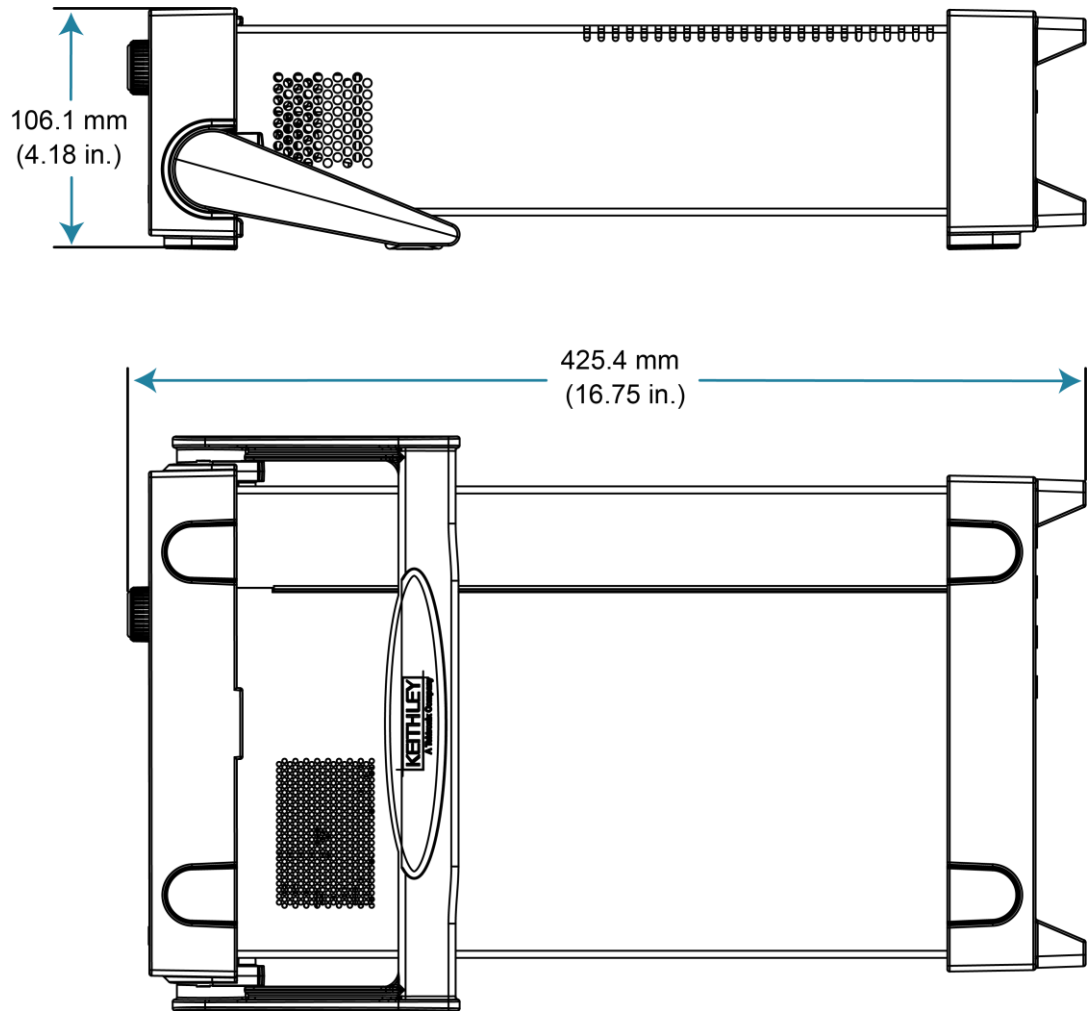


Figure 3: 2470 dimensions side and top with handle and bumpers



The following figures show the dimensions when the handle and bumpers have been removed.

Figure 4: 2470 front and rear panel dimensions with handle and bumpers removed

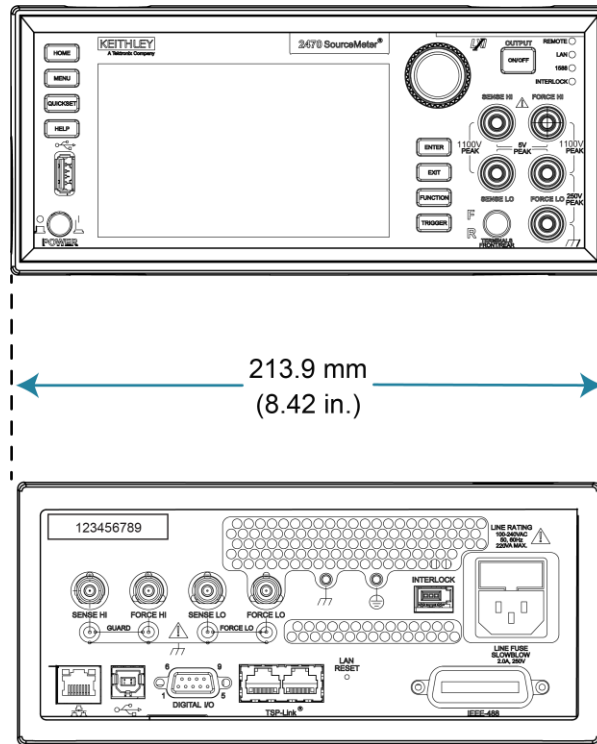
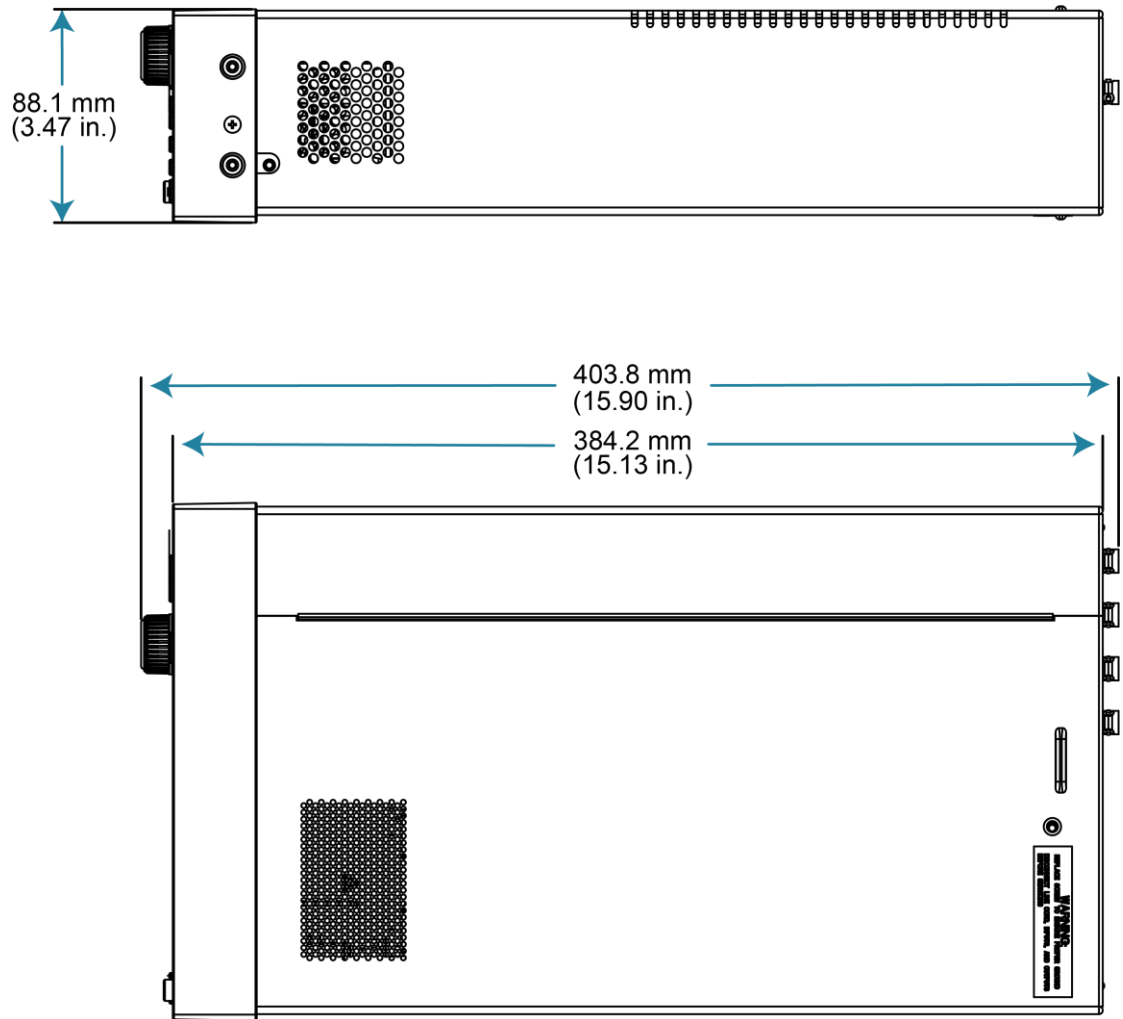


Figure 5: 2470 top and side dimensions with handle and bumpers removed



Handle and bumpers

The 2470 has a handle and front and rear bumpers for using the instrument on a benchtop. The handle rotates so that you can swing it below the bottom surface of the instrument to tilt the instrument up for easier front-panel viewing or carry the instrument.

Removing the handle and bumpers

You can remove the handle and bumpers on the 2470 if you want to mount the instrument in a rack.

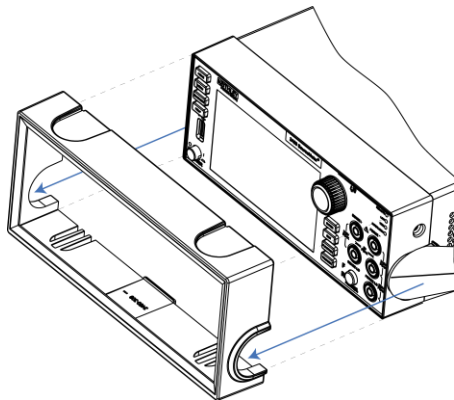
NOTE

If you remove the handle and bumpers, be sure to store them for future benchtop use.

To remove the bumpers:

1. Swivel the handle to a position above or below the instrument so that it will not interfere with the removal of the front bumper.
2. Grasp the front bumper on each side of the 2470 and gently pull it toward you until the bumper comes off the instrument.

Figure 6: Removing the front bumper



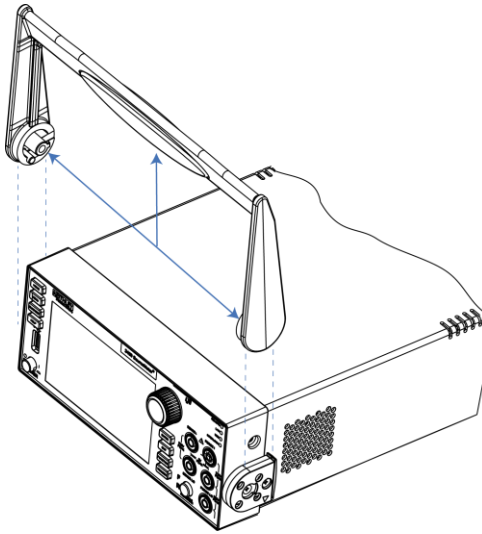
NOTE

Remove all connections to the rear panel of the 2470 before removing the rear bumper.

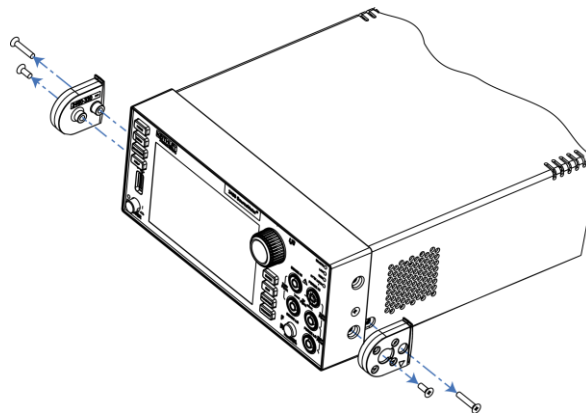
3. To remove the rear bumper, repeat the procedure in step 2.

To remove the handle assembly:

1. Grasp the sides of the handle near where it attaches to the instrument on both sides and gently pull the handle ends apart to widen the handle as you slide it over the instrument case.

Figure 7: Removing the handle

2. Use a Phillips screwdriver to loosen and remove the two screws holding the handle-mount assembly to one side of the 2470. The handle-mount assembly will fall away from the instrument chassis when the screws are removed.

Figure 8: Removing the handle mount

3. Repeat step 2 on the other side of the 2470.
4. Store the handle-mount assembly, screws, and handle together for future use.

Instrument power

Follow the steps below to connect the 2470 to line power and turn on the instrument. The 2470 operates from a line voltage of 100 V to 240 V at a frequency of 50 Hz or 60 Hz. It automatically senses line voltage and frequency. Make sure the operating voltage in your area is compatible.

You must turn on the 2470 and allow it to warm up for at least one hour to achieve rated accuracies.

CAUTION

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

WARNING

The power cord supplied with the 2470 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 redundant protective earth 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.

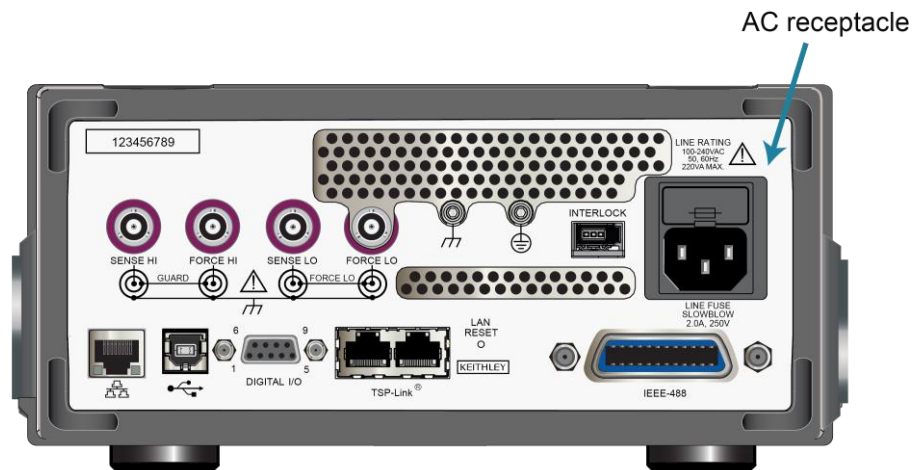
Do not replace detachable mains supply cords with inadequately rated cords. Failure to use properly rated cords may result in personal injury or death due to electric shock.

Connect the power cord

To connect the power cord:

1. Make sure that the front-panel POWER switch is in the off (O) position.
2. Connect the socket of the supplied power cord to the AC receptacle on the rear panel.
3. Connect the plug of the power cord to a grounded AC outlet.

Figure 9: 2470 AC receptacle on rear panel



Power the instrument on or off

Before turning the instrument on, disconnect any devices under test (DUTs) from the 2470.

To turn your instrument on, press the front-panel **POWER** switch to place it in the on (I) position. The instrument displays a status bar as it powers on. The home screen is displayed when power on is complete.

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

Basic connections

WARNING

The front and rear terminals of the instrument are rated for connection to circuits rated Measurement Category O only, with transients rated less than 1500 V_{PEAK} above the maximum rated input. Do not connect the instrument terminals to CAT II, CAT III, or CAT IV circuits. Connection of the instrument terminals to circuits higher than CAT O can cause damage to the equipment and expose the operator to hazardous voltage.

Do not exceed the maximum allowable voltage differentials. Exceeding the voltage differentials can result in electric shock and damage to the equipment.

Common mode voltage must be externally limited to 250 V DC, 1.05 A maximum. Failure to limit the common mode voltage can result in electric shock and damage to the equipment.

You can access the FORCE HI, FORCE LO, SENSE LO, and SENSE HI connections from the front or rear panel of the instrument. The front panel has banana jack connections and the rear panel has triaxial connections.

The front panel of the instrument shows the maximum allowable voltage differentials between terminals. The maximum common mode voltage is the voltage between FORCE LO and chassis ground. You must limit the current from an external common mode voltage source. You can use protective impedance or a fuse to limit the current.

The guard connections are only available from the rear panel of the instrument.

To remove a triaxial cable from the rear panel, turn the cable connector counterclockwise and pull it off the rear panel.

When making or breaking connections, follow these guidelines:

- Power off the 2470 and all other instruments.
- Disconnect any devices that may deliver energy.
- Make connections to the device under test through a test fixture or other safe enclosure.
- Make sure the 2470 is properly connected to protective earth (safety ground).
- If the test fixture is conductive, make sure the test fixture is properly connected to protective earth (safety ground).
- Make sure the test fixture provides proper protection.

- Properly make interlock connections between the 2470, the test fixture, and any other instruments.
- Make sure to follow all warnings and cautions and to take adequate safety precautions for each set of connections.
- Properly terminate any cables. All unterminated cable ends must be in a safe enclosure.
- See [Two-wire local sense connections](#) (on page 2-17) and [Four-wire remote sense connections](#) (on page 2-18) for examples of connections.
- For information about the interlock, see [Using the interlock](#) (on page 2-11).

Using the interlock

The instrument provides an interlock circuit on the rear panel. You must enable this circuit in order for the instrument to set source voltages greater than ± 42 V DC.

When the safety interlock signal is asserted, the following actions occur:

- All voltage ranges of the instrument are available.
- The green front-panel INTERLOCK indicator is on.

The action when the interlock signal is not asserted depends on the Interlock setting. If Interlock is set to Off, if the safety interlock signal is not asserted, the following occurs:

- The nominal output is limited to less than ± 42 V.
- The front-panel INTERLOCK indicator is not illuminated.
- You can output voltages less than ± 42 .

If Interlock is set to On, when the safety interlock signal is not asserted, the following occurs:

- You cannot turn on the source output.
- The front-panel INTERLOCK indicator is not illuminated.
- Whenever the interlock changes state (from asserted to not asserted or vice versa), the output is turned off.

To change the Interlock setting:

- From the front panel, select **MENU**. Select **Source Settings** and set **Interlock** to **ON** or **OFF**.
- Using SCPI commands, refer to `:OUTPut[1]:INTerlock:STATE`.
- Using TSP commands, refer to `smu.interlock.enable`.

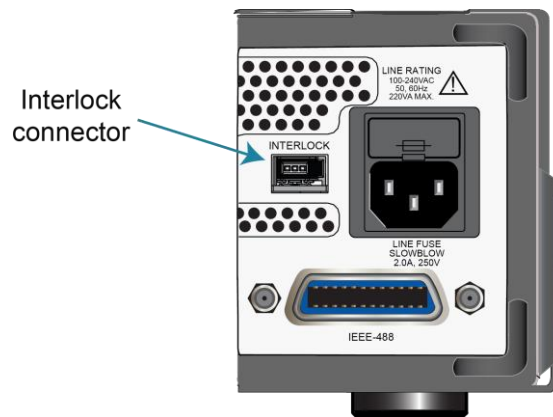
If you try to assign a high-voltage output and turn the source on when the interlock is not asserted, event code 5074, “Output voltage limited by interlock,” is generated. The SOURCE swipe screen displays the value that is selected for the voltage source.

⚠ WARNING

The 2470 is provided with an interlock circuit that must be positively activated for the high voltage output to be enabled. The interlock helps facilitate safe operation of the equipment in a test system. Bypassing the interlock could expose the operator to hazardous voltages that could result in personal injury or death.

Location of the interlock connection

Figure 10: Rear-panel interlock location



Interlock connector pins

An interlock circuit is provided on the rear panel of the instrument. This circuit must be closed to enable the 2470 to produce voltages greater than ± 42 V DC.

The interlock is intended for use through a normally open switch, which may be installed on the lid of a test fixture, on the enclosure of a semiconductor prober or device handler, or on the door or doors of a test equipment rack. The circuit opens when an access door is opened and closes when the door is closed.

When the interlock is asserted, the FORCE and GUARD terminals should be considered hazardous voltages, even if they are programmed to a nonhazardous voltage or current.

⚠ WARNING

Potentially hazardous voltages of up to approximately 1350 V may be present at the High Force, High Sense, and Guard terminals when the interlock circuit is closed.

To prevent electrical shock, do not expose these lines.

You can use the Keithley connector CS-1616-3 Safety Interlock Mating Connector, supplied with the 2470, to make the interlock connection to the rear panel. You must supply connection wire. The recommended wire is:

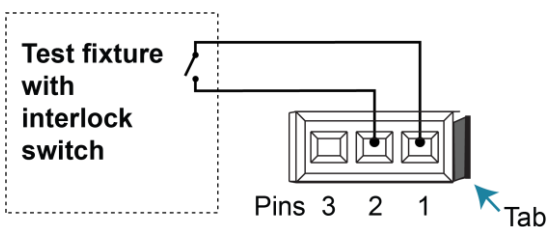
- 20 AWG to 24 AWG copper alloy
- 7 to 19 bare and tinned strands
- 0.25 mm² to 0.50 mm²
- Flexible vinyl, semi-flexible vinyl, polyethylene, x-linked polyethylene, or PTFE

To ensure proper interlock operation, the combined resistance of the external interlock switch and connection wires must be less than 10 Ω when the switch is closed.

The interlock pin locations and connections are shown in the following figure. The pins are:

- Pin 3: Earth and chassis ground
- Pin 2: Interlock
- Pin 1 (next to tab): +6 V DC out (current limited)

Figure 11: 2470 interlock pins



To assemble the interlock:

1. Insert the wire into CS-1616-3.
2. Use a pair of pliers to squeeze the connector sections together.

You cannot disassemble connector and reuse it.

Front-panel or rear-panel test connections

You can use either the front-panel or the rear-panel terminals to make connections to the device under test (DUT). The instrument must be set to use either the front or the rear terminals.

NOTE

You cannot make some connections to the front-panel terminals and some to the rear-panel terminals for the same test setup. All connections for the same test must be made to either the front-panel or the rear-panel terminals.

WARNING

Be aware that hazardous voltages can appear on the LO terminals even if the terminals are not presently selected. The TERMINALS switch selects the active terminals for the measurement. It does not disconnect the terminals.

Determining whether to use front or rear terminals

The terminals on the front panel are banana jack connectors, and the rear-panel terminals are triaxial connectors. Depending on your test setup, the test environment, and the precision of your measurements, you may see different results between measurements made from the front and rear terminals.

For the most precise measurements, use the rear-panel triaxial terminals. You will get the best results with rear-panel connections if you are making measurements or sourcing current in the 10 nA and 100 nA ranges or when making bipolar junction transistor (BJT) measurements.

You may also want to use the rear-panel terminals if the test environment is electrically noisy. The shielding on the triaxial cables will prevent environmental noise from affecting measurements.

Setting the instrument to use the front or rear terminals

NOTE

If the output is on when you change the settings for the terminals that are used, the output turns off.

Using the front panel:

1. Press the **FUNCTION** key.
2. Select the source and measure combination
3. Press the **TERMINALS FRONT/REAR** switch.

When F is lit, the instrument is using the front-panel terminals. When R is lit, the instrument is using rear-panel terminals.

Using SCPI commands:

To change to the front-panel terminals for current measurements, send the command:

```
ROUTE:TERMinals FRONT
```

To change to the rear-panel terminals for current measurements, send the command:

```
ROUTE:TERMinals REAR
```

Using TSP commands:

To change to the front-panel terminals, send the command:

```
smu.terminals = smu.TERMINALS_FRONT
```

To change to the rear-panel terminals, send the command:

```
smu.terminals = smu.TERMINALS_REAR
```


Two-wire compared to four-wire measurements

You can use 2-wire or 4-wire measurement techniques with the 2470.

You should use 4-wire, or remote sense, measurement techniques for the following conditions:

- Low-impedance applications
- When sourcing high current
- When sourcing low voltage
- When sourcing higher currents and measuring low voltages
- When enforcing voltage limits directly at the device under test (DUT)
- When sourcing or measuring voltage in low-impedance (less than 100 Ω) test circuits
- When optimizing the accuracy for low resistance, voltage source, or voltage measurements

Use 4-wire connections when you are concerned about voltage drops because of lead or contact resistance that could affect measurement accuracy. This can occur on low-impedance devices when you are sourcing or measuring voltage, especially in semiconductor device testing. For example, when testing low-impedance devices (less than 100 Ω), usually a higher current is sourced and small voltages are measured.

Sourcing current and measuring voltage drops in a 4-wire configuration is used when measuring resistivity of a material using a 4-point collinear probe.

It is sometimes necessary to use a 4-wire configuration when sourcing small voltages (less than 1 V) and measuring current. This is true when performing I-V tests on semiconductor devices such as diodes.

When you source or measure voltage in a low-impedance test circuit, there can be errors because of lead resistance. Use 4-wire remote sensing to eliminate these errors. If you use 4-wire remote sensing when you source voltage, the programmed voltage is delivered to the DUT. If you use 4-wire remote sensing when you measure voltage, only the voltage drop across the DUT is measured.

The maximum voltage drop between the force and sense leads is 5 V.

NOTE

When the output is off, the remote sense lines are disconnected and 4-wire sensing is disabled. When the output is on, the instrument uses 2-wire sense, regardless of the sense setting. When the output is on, the selected sense setting is used.

You can use 2-wire, or local sensing, measurement techniques for the following source-measure conditions:

- Sourcing and measuring low current.
- Sourcing and measuring voltage in high impedance (more than 1 k Ω) test circuits.
- Measure-only operation (voltage or current).

When you use 2-wire sensing, voltage is sensed at the output connectors.

You should only use 2-wire connections if the error contributed by test-lead IR drop is acceptable.

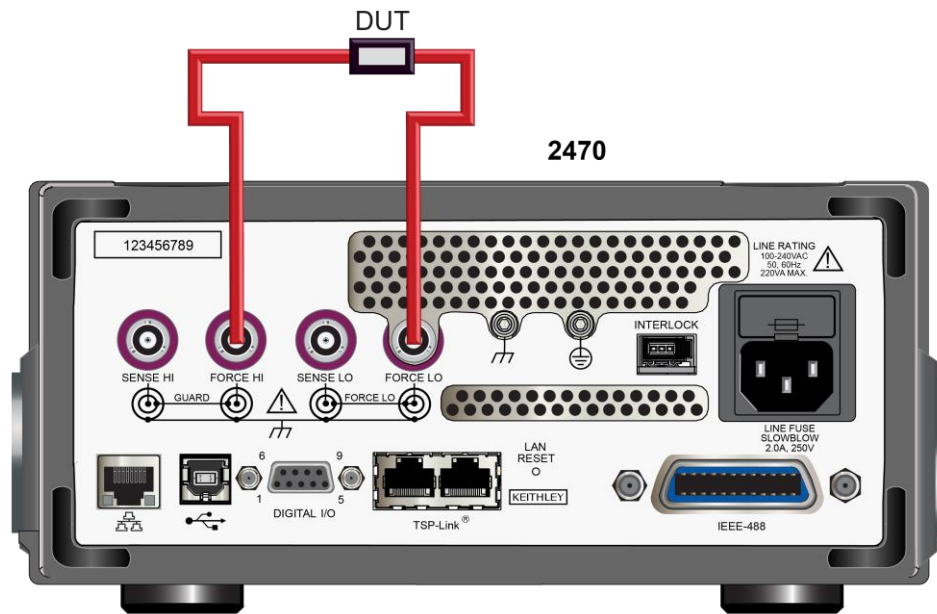
Two-wire local sense connections

Two-wire connections are shown in the following figures.

If your application results in impedances above 1 G Ω , you may also need to use guarding. This prevents leakage current from affecting measurement accuracy. For information, see “Guarding” in the *Model 2470 Reference Manual*.

Figure 12: 2470 2-wire front-panel connections



Figure 13: 2470 2-wire rear-panel connections**Using the front panel:**

1. Press the **FUNCTION** key.
2. Select the source and measure combination.
3. Press the **MENU** key.
4. Under Measure, select **Settings**.
5. Select the button next to Sense and select **2-Wire Sense**.
6. Press the **HOME** key to return to the operating display.

Four-wire remote sense connections

Using 4-wire remote sense connections provides the most accurate low-resistance, voltage source, and measurement accuracy. Specified accuracies for instrument source and measurement capabilities are only guaranteed when you use 4-wire remote sensing.

By default, the 2470 instruments are configured to use 2-wire (local) voltage sensing. If you choose to enable 4-wire (remote) voltage sensing, it is critical that you establish and maintain the proper Kelvin connections between the corresponding force and sense leads to ensure the proper operation of the instrument and to make accurate voltage measurements. Sense HI must be connected to Force HI, and Sense LO must be connected to Force LO.

When sourcing voltage with remote sense, the instrument relies on the voltage detected with the sense lines to provide the proper closed-loop control of its output voltage and to properly limit the voltage across the device-under-test. If a sense line becomes disconnected from its corresponding force line, an erroneous voltage is sensed. The output voltage may be adjusted to a level that is radically different than the programmed voltage level (possibly to hazardous levels). In addition, the voltage across the device may exceed the programmed source limit voltage, possibly causing damage to the device or test fixture.

In both cases, the voltage is not measured correctly if a sense lead becomes disconnected from its corresponding force lead.

WARNING

Even with the overvoltage protection set to the lowest value (20 V), never touch anything connected to the terminals of the 2470 when the instrument is on. Always assume that a hazardous voltage (greater than 30 V_{RMS}) is present when the instrument is on. To prevent damage to the device under test or external circuitry, do not set the voltage source to levels that exceed the value that is set for overvoltage protection.

To prevent unexpected voltages caused by a sense lead that becomes disconnected from its corresponding force lead during remote sense operation, you can enable overvoltage protection (OVP) to restrict the maximum output voltage level of the instrument when either voltage or current is sourced. With OVP enabled, the voltage between the Force HI and the Force LO terminals will not exceed the specified overvoltage limit value regardless of the voltage present on the sense leads. Refer to “Overvoltage protection” in the *Model 2470 Reference Manual* for additional information.

To make 4-wire measurements, you must set the sense mode of the instrument to 4-wire, as described in the following topics.

NOTE

When you are sourcing voltage in 4-wire remote sense, connect the sense leads to the DUT. If a sense lead is disconnected, the instrument senses 0 V, which causes it to increase the output voltage to compensate. To further protect against overvoltage situations, you can set overvoltage protection. Refer to “Overvoltage protection” in the *Model 2470 Reference Manual* for additional information.

Always connect the sense lines as close as possible to the device under test.

Figure 14: 2470 rear-panel 4-wire remote sense connections

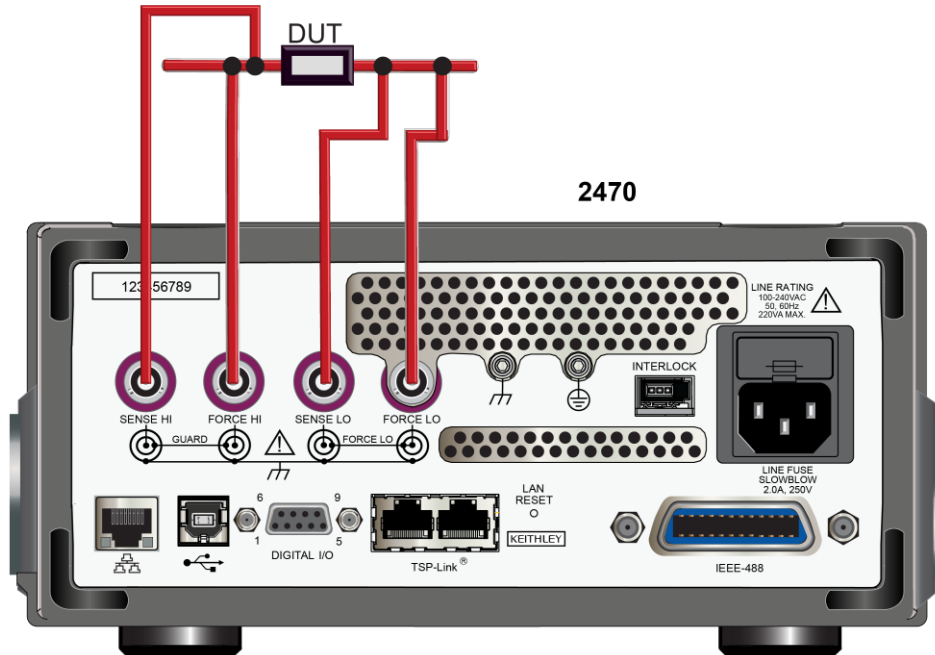
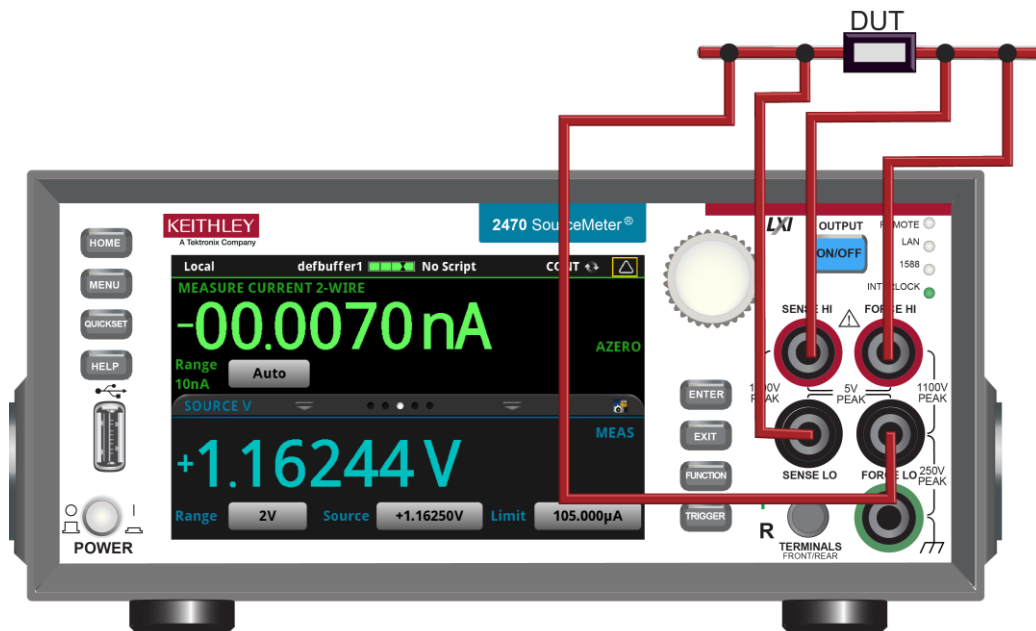


Figure 15: 2470 4-wire sense front-panel connection



Set the instrument to 4-wire sense

To use 4-wire connections, you must set the instrument to 4-wire sense.

When 4-wire sense is selected and the output is turned off, the sense lines are internally disconnected. The sense lines are automatically reconnected when the output is turned on.

NOTE

When you change the sense setting, the output is automatically turned off.

Using the front panel:

1. Press the **FUNCTION** key.
2. Select the source and measure combination.
3. Press the **MENU** key.
4. Under Measure, select **Settings**.
5. Set Sense to **4-Wire Sense**.
6. Select **HOME** to return to the operating display.

Test fixtures

A test fixture can be used to house a device or test circuit. The test fixture can be a metal or nonconductive enclosure and is typically equipped with a lid. When the test fixture is correctly connected using the interlock, the output of the 2470 will be less than $\pm 42 V_{PEAK}$ when the lid of the test fixture is opened.

You mount the test circuit inside the test fixture.

WARNING

To provide protection from shock hazards, an enclosure should be provided that surrounds all live parts.

Nonconductive enclosures must be constructed of materials that are suitably rated for flammability and the voltage and temperature requirements of the test circuit. Connect the enclosure of all metal test fixtures to protective earth (safety ground). See your specific test fixture for information. Nonconductive test fixtures must be rated to double the maximum capability of the test equipment in the system.

For metallic enclosures, the test fixture chassis must be properly connected to protective earth (safety ground). A grounding wire (16 AWG or larger) must be attached securely to the test fixture at a screw terminal designed for safety grounding. The other end of the ground wire must be attached to a known protective earth (safety ground).

When hazardous voltages ($>30 V_{\text{RMS}}$, $42 V_{\text{PEAK}}$) will be present, the test fixture must meet the following safety requirements:

- **Construction material:** A metal test fixture must be connected to a known protective earth (safety ground) as described in the above warning. A nonconductive test fixture must be constructed of materials that are suitable for flammability, voltage, and temperature conditions that may exist in the test circuit. The construction requirements for a nonconductive enclosure are also described in the warning above.
- **Test circuit isolation:** With the lid closed, the test fixture must completely surround the test circuit. A metal test fixture must be electrically isolated from the test circuit. Although the outer layer on a high voltage triaxial cable must be connected to the test fixture's metal chassis, the inner two layers of the cable (input/output connectors) must be isolated from the test fixture. Internally, Teflon standoffs are typically used to insulate the internal printed circuit board or guard plate for the test circuit from a metal test fixture.
- **Interlock switch:** The test fixture must have a normally-open interlock switch. The interlock switch must be installed so that when the lid of the test fixture is opened, the switch will open, and when the lid is closed, the switch will close. The 2470 includes an interlock connector on the rear panel of the instrument. When properly connected to a test fixture, the output of the 2470 is limited to $\pm 42 V$ when the lid of the test fixture is open.

Output-off state

CAUTION

Carefully consider and configure the appropriate output-off state, source, and limits before connecting the 2470 to a device that can deliver energy, such as other voltage sources, batteries, capacitors, or solar cells. Configure the settings that are recommended for the instrument before making connections to the device. Failure to consider the output-off state, source, and limits may result in damage to the instrument or to the device under test (DUT).

When the source of the instrument is turned off, it may not completely isolate the instrument from the external circuit. You can use the Output Off setting to place the 2470 in a known, noninteractive state during idle periods, such as when you are changing the device under test. The output-off states that can be selected for a 2470 are normal, high-impedance, zero, or guard.

When you change the output-off state, the selected output-off state is set immediately. When the instrument is powered on, the instrument is momentarily in the high-impedance output-off state before going to the default output-off state of normal or a setting defined in a power up script.

Regardless of the selected output-off state, if an overtemperature condition occurs, the instrument goes into the high-impedance output-off state.

When the output is off, the SOURCE area of the home screen shows the source value that is set, not the value that is presently being output.

Normal output-off state

When the 2470 is set to the normal output-off state, the following settings are made when the source is turned off:

- The measurement sense is set to 2-wire
- The voltage source is selected and set to 0 V
- The current limit is set to 10% of the full scale of the present measurement function autorange value
- If source readback is off, Output Off is displayed in the home screen Source area
- If source readback is on, the actual measurement is displayed in the home screen Source area
- If measurement is set to resistance, dashes (--.----) are shown in the home screen Source area
- The Source button on the home screen shows the value that will be sourced when the output is turned on again

Even though the voltage source is set to zero, the source value may not be exactly at zero and the instrument may source or sink a small amount of power. In most cases, this source or sink power level is insignificant. For passive devices such as resistors, normal mode should be sufficient to protect your device. However, because the limit current is 10% of range, it may take time to remove charge from large energy storage devices such as capacitors.

For sources, such as batteries, the normal output-off state limits the current to 10% of range. This may be acceptable for devices such as another source-measure instrument or a power supply. However, for devices such as small cell batteries, it can drain the batteries. In situations such as this, use the high-impedance output-off state.

High-impedance output-off state

When the high-impedance output-off state is selected and the output is turned off:

- The measurement sense is set to 2-wire
- The output relay opens, disconnecting the instrument as a load

Opening the relay disconnects external circuitry from the inputs and outputs of the instrument. 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.

The high-impedance output-off state should be used when the instrument is connected to a power source or another source-measure instrument. In some cases, it may also be appropriate for devices such as capacitors.

When the output is turned on again, the relay has a settling time of approximately 15 ms.

When the high-impedance output-off state is selected, you cannot make measurements using 2-wire connections.

Zero output-off state

When the zero output-off state is selected and you turn off the output:

- The measurement sense is changed to 2-wire
- The voltage source is selected and set to 0 V
- The range is set to the presently selected range (turn off autorange)
- If the source is voltage, the current limit is not changed
- If the source is current, the current limit is set to the programmed source current value or to 10% full scale of the present current range, whichever is greater

When the zero output-off state is selected, you can use the instrument as an ammeter because it is outputting 0 V.

The zero mode is ideal for passive devices such as resistors. In most cases, it can also be used with energy storage devices such as capacitors and inductors. This mode will discharge capacitors under test and remove the charge from semiconductor junctions.

Guard output-off state

Use the guard output-off state when you are measuring a load that uses an active source.

When the guard output-off state is selected and the output is turned off, the following actions occur:

- The measurement sense is changed to 2-wire
- The current source is selected and set to 0 A if the source is set to current (amps); otherwise, the output remains a voltage source when the output is turned off
- The voltage limit is set to 10% full scale of the present voltage range

Output-off states and inductive loads

To protect the instrument from inductive energy, you may need to install a spark gap across the HI and LO terminals. The instrument does not have internal spark gap protection.

Setting the output-off state

Before setting the output-off state, set the source function. The output-off state is stored with the source function. If you change the source function, the output-off state changes to the last state you set for that function.

Using the front panel:

1. Press the **MENU** key.
2. Under Source, select **Settings**.
3. Set **Output Off** to the appropriate setting for your application.
4. Select **HOME** to return to the operating display.

Using SCPI commands:

To set the output-off state to normal, send the command:

```
:OUTPut:SMODE NORMal
```

To set the output-off state to zero, send the command:

```
:OUTPut:SMODE ZERO
```

To set the output-off state to high impedance, send the command:

```
:OUTPut:SMODE HIMPedance
```

To set the output-off state to guard, send the command:

```
:OUTPut:SMODE GUARd
```

Using TSP commands:

To set the output-off state to normal, send the command:

```
smu.source.offmode = smu.OFFMODE_NORMAL
```

To set the output-off state to zero, send the command:

```
smu.source.offmode = smu.OFFMODE_ZERO
```

To set the output-off state to high impedance, send the command:

```
smu.source.offmode = smu.OFFMODE_HIGHZ
```

To set the output-off state to guard, send the command:

```
smu.source.offmode = smu.OFFMODE_GUARD
```

Upgrading the firmware

To upgrade the 2470 firmware, you load an upgrade file into the instrument. You can load the file from the front-panel USB port using either a remote interface or the front panel of the instrument. If you are using Test Script Builder (TSB), you can upgrade the firmware from TSB using a file saved to the computer on which TSB is running.

During the upgrade process, the instrument verifies that the version you are loading is newer than what is on the instrument. If the version is older or at the same revision level, no changes are made.

If you want to return to a previous version or reload the present version of the firmware, select **Downgrade to Older**. This forces the instrument to load the firmware regardless of the version.

The upgrade process normally takes about five minutes.

Upgrade files are available on tek.com/keithley.

CAUTION

Disconnect the input and output terminals before you upgrade or downgrade.

Do not remove power from the instrument or remove the USB flash drive while an upgrade or downgrade is in progress. Wait until the instrument completes the procedure and shows the opening display. If you are upgrading an instrument with no front panel (NFP), the LAN and 1588 LEDs on the front panel blink in unison during the upgrade and stop when the upgrade is complete.

Do not initialize or reset TSP-Link before starting the upgrade.

Before upgrading, turn the instrument power off, wait a few seconds, then turn the instrument power on.

Front panel firmware upgrade

CAUTION

Do not turn off power or remove the USB flash drive until the upgrade process is complete.

NOTE

The firmware file must be in the root subdirectory of the flash drive and must be the only firmware file in that location. You can upgrade or downgrade the firmware from the front panel or from the virtual front panel.

From the front panel or virtual front panel:

1. Copy the firmware file (.upg file) to a USB flash drive.
2. Verify that the firmware file is in the root subdirectory of the flash drive and that it is the only firmware file in that location.
3. Disconnect any input and output terminals that are attached to the instrument.
4. Turn the instrument power off. Wait a few seconds.
5. Turn the instrument power on.
6. Insert the flash drive into the USB port on the front panel of the instrument.
7. From the instrument front panel, press the **MENU** key.
8. Under System, select **Info/Manage**.
9. Choose an upgrade option:
 - To upgrade to a newer version of firmware, select **Upgrade to New**.
 - To return to a previous version of firmware, select **Downgrade to Older**.
10. If the instrument is controlled remotely, a message is displayed. Select **Yes** to continue.
11. When the upgrade is complete, reboot the instrument.

A message is displayed while the upgrade is in progress.

System information

You can get the serial number, firmware build, detected line frequency, calibration verify date, calibration adjust date, and calibration adjust count information from the instrument.

To view the version and serial number information from the front panel:

1. Press the **MENU** key.
2. Under System, select **Info/Manage**.

The firmware version and serial number are displayed at the top of the screen.

To view the calibration information from the front panel:

1. Press the **MENU** key.
2. Under System, select **Calibration**.

The adjust date, adjust count, and calibration date are displayed.

To view the line frequency information from the front panel:

1. Press the **MENU** key.
2. Under System, select **Settings**.
3. Scroll down to display the line frequency.

To view system information using SCPI commands:

To retrieve the manufacturer, model number, serial number, and firmware version, send the command:

```
*IDN?
```

To read the line frequency, send the command:

```
SYStem:LFRequency?
```

The firmware build, memory available, and factory calibration date are not available when using SCPI commands.

Verify system information using TSP commands

To view system information using TSP commands:

To read the model number, send the command:

```
print(localnode.model)
```

To read the serial number, send the command:

```
print(localnode.serialno)
```

To read the firmware version, send the command:

```
print(localnode.version)
```

To read the line frequency, send the command:

```
print(localnode.linefreq)
```

The factory calibration date cannot be accessed using TSP commands.

Instrument description

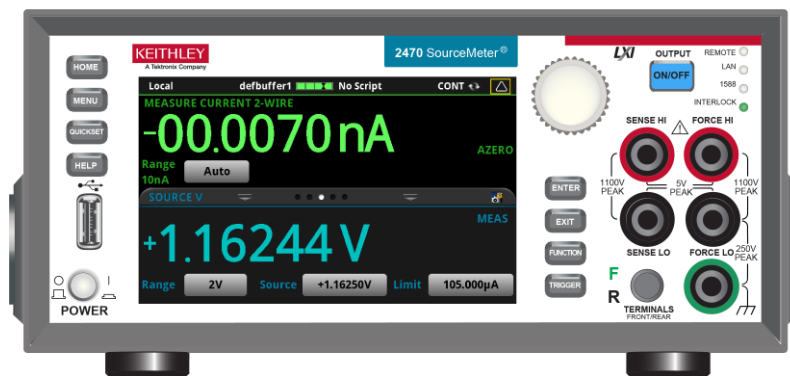
In this section:





Front-panel overview	3-1
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Turn the 2470 output on or off	3-4
Touchscreen display	3-5
Store measurements on a USB flash drive	3-16
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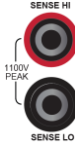

Front-panel overview



The front panel of the 2470 is shown below. Descriptions of the controls on the front panel follow the figure.

Figure 16: 2470 front panel



POWER switch		Turns the instrument on or off. To turn the instrument on, press the power switch so that it is in the on position (I). To turn it off, press the power switch so that it is in the off position (O).
HOME key		Returns the display to the home screen.
MENU key		Opens the main menu. Press the icons on the main menu to open source, measure, views, trigger, scripts, and system screens. For details, refer to Menu overview (on page 3-11).
QUICKSET key		Opens a menu of preconfigured setups, including voltmeter, ammeter, ohmmeter, and power supply. Also allows you to choose source and measure functions and adjust performance for better resolution or speed. For details, see QuickSet menu (on page 3-11).

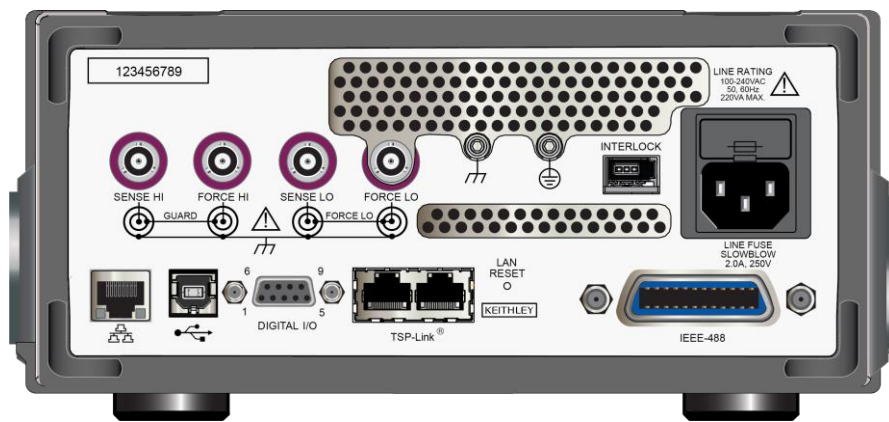
HELP key		Opens help for the area or item that is selected on the display. If there is no selection when you press the HELP key, it displays overview information for the screen you are viewing. To display help, use the navigation control to select the button, then press the HELP key. You can also press and hold the on-screen button while pressing the HELP key.
USB port		Saves reading buffer data and screen snapshots to a USB flash drive. You can also store and retrieve scripts to and from a USB flash drive. The flash drive must be formatted as a FAT or FAT32 drive.
Touchscreen		The 2470 has a high-resolution, five-inch color touchscreen display. The touchscreen accesses swipe screens and menu options. You can access additional screens by pressing the front-panel MENU , QUICKSET , and FUNCTION keys. Refer to Touchscreen display (on page 3-5) for details.
Navigation control		Moves the cursor and makes screen selections. Turning the navigation control: Moves the cursor to highlight a list value or menu item so that you can select it. Turning the control when the cursor is in a value entry field increases or decreases the value in the field. Pressing the navigation control: Selects the highlighted choice or allows you to edit the selected field.
ENTER key		Selects the highlighted choice or allows you to edit the selected field.
EXIT key		Returns to the previous screen or closes a dialog box. For example, press the EXIT key when the main menu is displayed to return to the home screen. When you are viewing a subscreen (for example, the Event Log screen), press the EXIT key to return to the main menu screen.
FUNCTION key		Displays instrument functions. To select a function, touch the function name on the screen.
TRIGGER key		Accesses trigger-related settings and operations. The action of the TRIGGER key depends on the instrument state. For details, see “Switching between measurement methods” in the <i>Model 2470 Reference Manual</i> .
OUTPUT ON/OFF switch		Turns the output source on or off. The switch illuminates when the source output is on.
REMOTE LED indicator	REMOTE 	Illuminates when the instrument is controlled through a remote interface.
LAN LED indicator	LAN 	Illuminates when the instrument is connected to a local area network (LAN).
1588 LED indicator	1588 	1588 functionality is not supported at this time.
INTERLOCK LED indicator	INTERLOCK 	Illuminates when the interlock is enabled.
Sense terminals		Use the SENSE HI and SENSE LO terminal connections to measure voltage at the device under test (DUT). When you use sense leads, measurement of the voltage drop across the force leads is eliminated. This produces more accurate voltage sourcing and measurement at the DUT.
Force terminals		Use FORCE HI and FORCE LO terminal connections to source or sink voltage or current to or from a device under test (DUT).








FRONT/REAR TERMINALS switch		Activates the terminals on the front or rear panel. When the front-panel terminals are active, a green “F” is visible to the left of the FRONT/REAR switch. When the rear-panel terminals are active, a yellow “R” is visible to the left of the switch.
Chassis connection		Banana jack connector that provides a chassis connection.


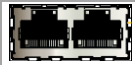


Rear-panel overview

The rear panel of the 2470 is shown below. Descriptions of the options follow the figure.

Figure 17: 2470 rear panel



SENSE and FORCE connectors		These triaxial terminals provide connections for SENSE HI and SENSE LO, FORCE HI and FORCE LO, GUARD, and chassis ground.
Chassis ground		Ground screw for connections to chassis ground. This provides a connection terminal to the equipment frame.
Protective earth (safety ground)		Ground screw for connection to protective earth (safety ground). Connect to protective earth using recommended wire size (#16 AWG or larger).
Interlock connector		Interlock connection for use with an interlock switch, such as a test fixture. When properly connected, the safety interlock of the 2470 places the outputs of the instrument in a safe state. For details, see Using the interlock (on page 2-11).
Line fuse and power receptacle		Connect the line cord to the power receptacle and a grounded AC power outlet. The line fuse, located just above the power receptacle, protects the power line input of the instrument. For safety precautions and other details, see Power the instrument on or off (on page 2-9) and Line fuse replacement (on page 5-1) in the <i>Model 2470 User's Manual</i> .
LAN port		Supports full connectivity on a 10 Mbps or 100 Mbps network. The 2470 is a version 1.5 LXI Device Specification 2016 instrument that supports TCP/IP and complies with IEEE Std 802.3 (ethernet LAN).
USB port		USB-B connection for communications, control, and data transfer.

Digital I/O port		A digital input/output port that detects and outputs digital signals. The port provides six digital I/O lines. Each output is set high (+5 V) or low (0 V) and can read high or low logic levels. Each digital I/O line is an open-drain signal.
TSP-Link ports		TSP-Link™ system expansion interface, which builders of test systems can use to connect multiple instruments in a master and subordinate configuration. TSP-Link is a high-speed trigger synchronization and communications bus.
LAN reset		Reverts the LAN settings and the instrument password to default values. Insert a straightened paper clip into the hole below LAN RESET.
IEEE-488 port		GPIB connection; the default setting for the 2470 is 18.

Turn the 2470 output on or off

You can turn the 2470 output on from the front panel or by sending remote commands.

⚠ WARNING

Turning the 2470 output off does not place the instrument in a safe state (an interlock is provided for this function).

Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never make or break connections to the 2470 while the output is on. Turn off the equipment from the front panel or disconnect the main power cord from the rear of the 2470 before handling cables. Putting the equipment into an output-off state does not guarantee that the outputs are powered off if a hardware or software fault occurs.

When the source of the instrument is turned off, it may not completely isolate the instrument from the external circuit. You can use the Output Off setting to place the 2470 in a known, noninteractive state during idle periods, such as when you are changing the device under test. The output-off states that can be selected for a 2470 are normal, high-impedance, zero, or guard.

See [Output-off state](#) (on page 2-22) for additional details.

Using the front panel:

Press the **OUTPUT ON/OFF** switch. The instrument is in the output-on state when the switch is illuminated. The instrument is in the output-off state when the switch is not illuminated.

Using SCPI commands:

To turn the output on, send the command:

```
:OUTPut:STATe ON
```

To turn the output off, send the command:

```
:OUTPut:STATe OFF
```

Using TSP commands:

To turn the output on, send the command:

```
smu.source.output = smu.ON
```

To turn the output off, send the command:

```
smu.source.output = smu.OFF
```

Touchscreen display

The touchscreen display gives you quick front-panel access to source and measure settings, system configuration, instrument and test status, reading buffer information, and other instrument functionality. The display has multiple swipe screens that you can access by swiping the front panel. You can access additional interactive screens by pressing the front-panel MENU, QUICKSET, and FUNCTION keys.

CAUTION

Do not use sharp metal objects, such as tweezers or screwdrivers, or pointed objects, such as pens or pencils, to touch the touchscreen. It is strongly recommended that you use only fingers to operate the instrument. Use of clean-room gloves to operate the touchscreen is supported.

Select items on the touchscreen

To select an item on the displayed screen, do one of the following:

- Touch it with your finger
- Turn the navigation control to highlight the item, and then press the navigation control to select it

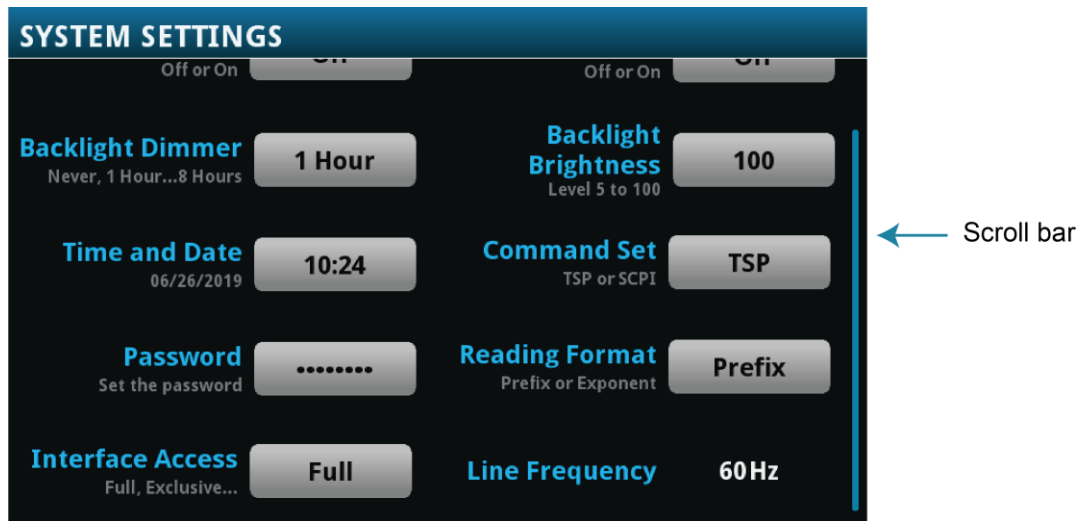
The following topics describe the 2470 touchscreen in more detail.

Scroll bars

Some of the interactive screens have additional options that are only visible when you scroll down the screen. A scroll indicator on the right side of the touchscreen identifies these screens. Swipe the screen up or down to view the additional options.

The following figure shows a screen with a scroll bar.

Figure 18: Scroll bar



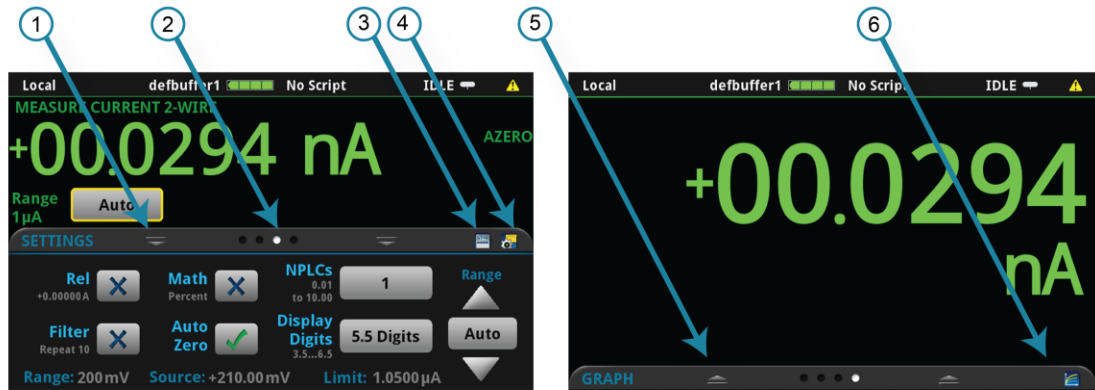
Swipe screens







The 2470 touchscreen display has multiple screens that you can access by swiping left or right on the lower half of the display. The options available in the swipe screens are described in the following topics.

Swipe screen heading bar

The heading bar of the swipe screen contains the following options.

Figure 19: Swipe screens, maximized and minimized



#	Screen element	Description
1	Minimize indicator 	You can swipe down to minimize the swipe screens.
2	Swipe screen indicator 	Each circle represents one swipe screen. As you swipe right or left, a different circle changes color, indicating where you are in the screen sequence. Select a circle to move the swipe screen without swiping.
3	Calculations shortcut 	Select to open the CALCULATION SETTINGS menu.
4	Measure Settings shortcut 	Select to open the MEASURE SETTINGS menu for the selected function.
5	Restore indicator 	Indicates that you can swipe up to display the swipe screen.
6	Graph shortcut 	Select to open the Graph screen.

SOURCE swipe screen

The SOURCE swipe screen shows the present value of the source and the set values for source, source range, and source limit. You can change the set values from the front panel by selecting the buttons on this screen.

Figure 20: SOURCE swipe screen



Source function indicators on the right side of the screen signify settings that affect the displayed source value:

- **MEAS:** Source readback is on and the value shown is the measured value of the source.
- **PROG:** Source readback is off and the value shown is the programmed source value. If the output is off, the displayed source value is replaced with **Output Off**.

When Limit label is shown in yellow, the instrument is limiting the source.

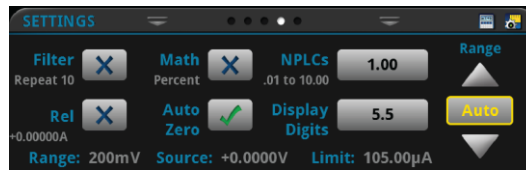
The present value is updated continuously when the measurement method is set to Continuous. When the measurement method is set to Manual Trigger Mode or Initiate Trigger Model, the value is updated when the next measurement occurs.

The icon on the right side of the swipe screen heading bar is a shortcut to the full SOURCE SETTINGS menu.

SETTINGS swipe screen

The SETTINGS swipe screen gives you front-panel access to some instrument settings. It shows you the present settings and allows you to change, enable, or disable them quickly.

Figure 21: SETTINGS swipe screen



To disable or enable a setting, select the box next to the setting so that it shows an X (disabled) or a check mark (enabled).

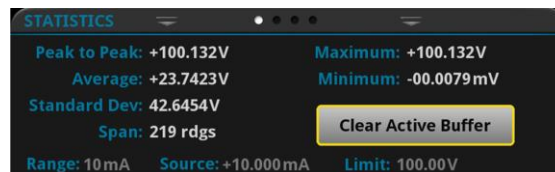
The icons on the right side of the swipe screen heading bar are shortcuts to the CALCULATIONS SETTINGS and MEASURE SETTINGS menus.

For descriptions of the settings, use the navigation control to select the button, then press the HELP key. You can also press and hold the on-screen button while pressing the **HELP** key.

STATISTICS swipe screen

The STATISTICS swipe screen contains information about the readings in the active reading buffer. When the reading buffer is configured to fill continuously and overwrite old data with new data, the buffer statistics include the data that was overwritten. To get statistics that do not include data that has been overwritten, define a large buffer size that will accommodate the number of readings you will make. You can use the **Clear Active Buffer** button on this screen to clear the data from the active reading buffer.

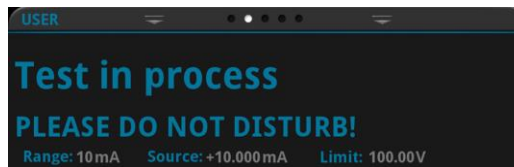
Figure 22: STATISTICS swipe screen



USER swipe screen

You can program custom text and display it on the USER swipe screen. For example, you can program the 2470 to show that a test is in process. This swipe screen is only displayed if custom text has been defined. Refer to “Customizing a message for the USER swipe screen” in the *Model 2470 Reference Manual*.

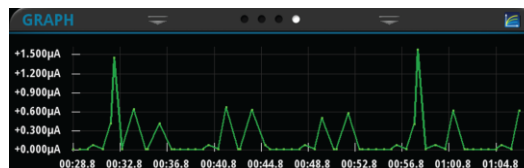
Figure 23: USER swipe screen



GRAPH swipe screen

The GRAPH swipe screen shows a graphical representation of the readings in the presently selected reading buffer.

Figure 24: GRAPH swipe screen



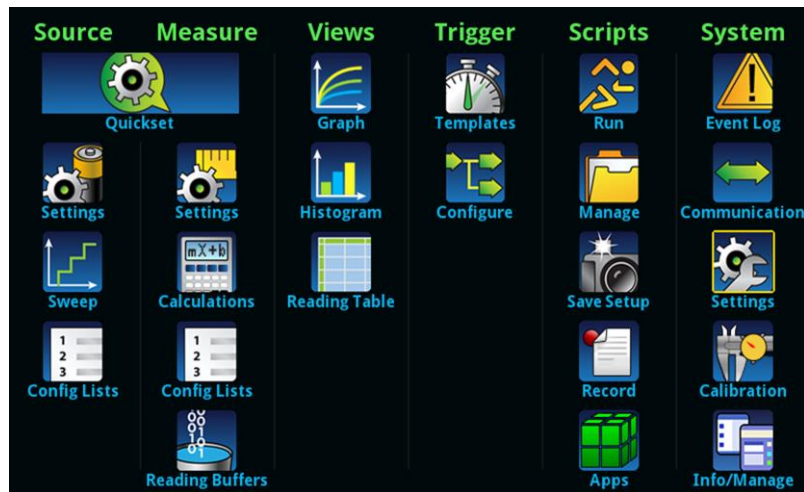
To view the graph on the full screen and to access graph settings, select the graph icon on the right side of the swipe screen header. You can also open the full-function Graph screen by pressing the **MENU** key and selecting **Graph** under Views.

For more information about graphing measurements, see “Graphing” in the *Model 2470 Reference Manual*.

Menu overview

To access the main menu, press the MENU key on the 2470 front panel. The figure below shows the organization of the main menu.

Figure 25: 2470 main menu



The main menu includes submenus that are labeled in green across the top of the display. Selecting an option in a submenu opens an interactive screen.

QuickSet menu



The QuickSet menu, which is centered under Source and Measure on the main menu, allows you to:

- Select predefined setups for the source and measure functions
- Use the Performance slider to adjust for performance (resolution versus speed)
- Select Quick Setups that provide instrument-type emulation

CAUTION




When you select a Quick Setup, the instrument turns the output on. Carefully consider and configure the appropriate output-off state, source, and limits before connecting the 2470 to a device that can deliver energy, such as other voltage sources, batteries, capacitors, or solar cells. Configure the settings that are recommended for the instrument before making connections to the device. Failure to consider the output-off state, source, and limits may result in damage to the instrument or to the device under test (DUT).

When you adjust the Performance slider, the instrument adjusts settings based on where you position the slider. As you increase speed, you lower the amount of resolution. As you increase resolution, you decrease the reading speed. The settings that the instrument adjusts include autozero, autodelay and filter settings, display digits, NPLC, and source readback. These settings take effect the next time the output is turned on and measurements are made.

When you select a Quick Setup, the home screen is displayed so you can see the readings generated by the Quick Setup.


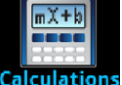

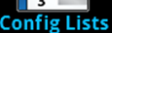
Source menus

The Source menus allow you to select, configure, and perform source and sweep operations from the front panel.

 <p>Settings</p>	<p>The Source Settings menu contains settings for the selected source function. They include the range, output off state, overvoltage protection limit, interlock, high capacitance, source readback, and source delay settings.</p>
 <p>Sweep</p>	<p>The Sweep menu allows you to set up a sweep and generate a source configuration list. It also builds a trigger model for the sweep.</p>
 <p>Config Lists</p>	<p>The Config Lists menu allows you to select an existing source configuration list, create a new list, load configuration settings to and from the instrument, delete a configuration index, and view the settings of a point in a source configuration list.</p>




Measure menus

The Measure menus allow you to select, configure, and perform measure operations from the front panel.

 <p>Settings</p>	<p>The Settings menu contains settings for the presently selected measure function. Settings include autorange, autozero, count, display digits, NPLC, offset compensation, range, and 2-wire or 4-wire sense.</p>
 <p>Calculations</p>	<p>The Calculations menu contains settings that specify the way measurement information is processed and returned. Use this menu to set the relative offset, filter, $mX+b$, percent, reciprocal, and zero reference.</p>
 <p>Config Lists</p>	<p>The Config Lists menu allows you to select an existing measure configuration list, create a new list, load configuration settings to and from the instrument, and view the settings of an index in a configuration list.</p>
 <p>Reading Buffers</p>	<p>The Reading Buffers menu allows you to view the list of existing reading buffers and select one to be the active buffer. You can also create, save, delete, resize, and clear buffers from this screen.</p>



Views menu

The Views menus allow you to select, configure, and view data that was gathered from measure operations.

	<p>The Graph menu opens a screen that displays a graph of the measurements as traces in selected reading buffers. It also contains tabs that you can use to customize the graph display.</p> <p>You can also select the trigger mode and initiate the trigger model from this screen.</p>
	<p>The Histogram menu allows you to graph the distribution of measurement data in the selected reading buffer. It also contains tabs that you can use to customize the histogram.</p>
	<p>The Reading Table menu allows you to view data in the selected reading buffer.</p>






Trigger menu

The Trigger menus allow you to configure the trigger model from the front panel.

	<p>The Templates menu allows you to choose from one of several preprogrammed trigger models. When you select a template, settings you can specify for that template are shown in the lower part of the screen.</p>
	<p>The Configure menu allows you to view and modify the structure and parameters of a trigger model. You can also monitor trigger model operation.</p>






Scripts menu

The Scripts menus allow you to configure, run, and manage scripts from the front panel. Scripts are blocks of commands that the instrument can run as a group.

	<p>The Run menu contains a list of scripts that you can select to run immediately. You can also copy a script to a script that runs each time the instrument power is turned on. You can access scripts that are in the instrument or on a USB flash drive.</p>
	<p>The Manage menu allows you to copy scripts to and from the instrument and the USB flash drive. You can also delete scripts from the instrument or USB flash drive.</p>
	<p>The Save Setup menu allows you to save the present settings and configuration lists of the instrument into a configuration script. You can use this script to recall the settings.</p>
	<p>The options in the Record menu allow you to record your actions and store them in a macro script. The script can be run and managed like any other script using the options in the Scripts menu or remote commands. Note that only settings are stored; no key presses or front-panel only options are stored (including pressing the OUTPUT ON/OFF switch).</p>
	<p>Open the APPS MANAGER, which allows you to manage prebuilt Test Script Processor (TSP™) applications. TSP applications are Keithley-developed programs that enable the 2470 to use specialized functions, test automation, and visualize information on the user interface. TSP applications are available when the instrument is used in the TSP or SCPI command set. Applications may be preinstalled on your 2470.</p>

System menu

The menus under System in the main menu allow you to configure general instrument settings from the 2470 front panel. Among these settings are the event log, communications, backlight, time, and password settings.

 Event Log	<p>The Event Log menu allows you to view and clear event log entries. You can also adjust which events are displayed or logged.</p>
 Communication	<p>The Communication menu opens a set of tabs that contain information about the communications settings. Most of the tabs contain settings that you can change.</p>
 Settings	<p>The Settings menu contains general instrument settings. It includes command set, beeper and key click, backlight brightness and timer, time and date, system access level, password, and reading format settings.</p>
 Calibration	<p>The Calibration menu displays factory calibration information, including the last adjustment date, the last calibration date, and the number of times the instrument has been adjusted.</p>
 Info/Manage	<p>The Info/Manage menu gives you access to version and serial number information and settings for instrument firmware and reset functions.</p>

Store measurements on a USB flash drive

If there is measurement data in the buffer, you can copy it from the 2470 to a USB flash drive. The information is saved in the `.csv` file format.

To store measurement data:

1. Insert a flash drive into the front-panel USB port.
2. Press the **MENU** key.
3. In the Measure column, select **Reading Buffers**.
4. Select the buffer that you want to save.
5. Select **Save to USB**.
6. On the File Content dialog, make selections as needed for your data set. You can press **HELP** to get information about each option.
7. Select **OK**.

Save screen captures to a USB flash drive

You can save a screen capture of the front-panel display to a graphic file on a USB flash drive. The instrument saves the graphic file in `.png` file format.

To save a screen capture:

1. Insert a USB flash drive into the USB port on the front panel of the instrument.
2. Navigate to the screen you want to capture.
3. Press the **HOME** and **ENTER** keys. The instrument displays `Saving screen capture`.
4. Release the keys.

Making basic front-panel measurements

In this section:

Introduction	4-1
Equipment required	4-2
Device connections	4-2
Make front-panel measurements.....	4-3

Introduction

You can use the 2470 to source voltage or current and make measurements from the front panel.

NOTE

Make sure you select functions before you make changes to other instrument settings. The options that you have for settings depend on the functions that are active when you make the changes. If you make a change that is not compatible with the active functions, you may get unexpected results or you may receive an event message. Also note that when you select a different function, the instrument clears the buffer. The applications in this manual illustrate the order in which you should perform operations for best results.

In this section, you make measurements on a 10 k Ω resistor by sourcing voltage and measuring current. You can make similar measurements on any two-terminal device under test (DUT) if appropriate source values are used.

Some of the methods you can use to set up the 2470 to make measurements from the front panel include:

- **Use Quicksets.** Press the **QUICKSET** key to open a menu of preconfigured setups, including voltmeter, ammeter, ohmmeter, and power supply setups. It also allows you to choose test functions and adjust performance for better resolution or speed.
- **Select source and measure functions.** Press the **FUNCTION** key to select from a list of source and measure functions.
- **Use menu options.** Press the **MENU** key to open a menu of options.

After selecting your source and measure functions, select buttons on the 2470 home screen and Settings swipe screens to change the settings.

You will use a combination of these methods to set up the measurement for this application.

Equipment required

Equipment required for this example:

- 2470 High Voltage SourceMeter Instrument
- Two insulated banana cables; you can use the set that is provided with the 2470, the Keithley Model 8608 High-Performance Clip Lead Set (part number 012173001)
- One 10 k Ω resistor to test

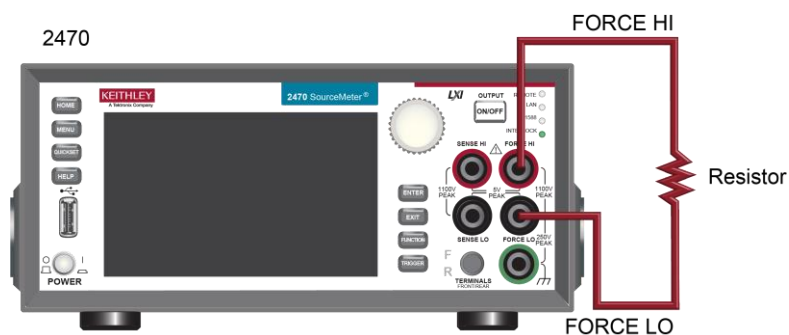
Device connections

NOTE

Turn the power to the instrument off before attaching connections to the 2470.

Connect the 2470 to the resistor in a 2-wire (local sense) configuration. In this configuration, the device is connected between the FORCE HI and FORCE LO terminals.

The physical connections to the front panel are shown in the following figure.



Make front-panel measurements

For this application, you will:

- Select the source and measure functions
- Select the source range
- Set the source value
- Set the source limit
- Select the measurement range
- Turn on the source output
- Observe the readings on the display
- Turn off the source output

How to make front-panel measurements

To make a measurement from the front panel:

1. Press the **POWER** switch on the front panel to turn on the instrument.
2. On the front panel, press the **FUNCTION** key.
3. Under Source Voltage and Measure, select **Current**.
4. Select the source range. On the home screen, under SOURCE V, select **Range**.
5. Select **20 V**.
6. Select **Source**.
7. Enter **10 V** and select **OK**.
8. Select **Limit**.
9. Enter **10 mA** and select **OK**.
10. In the MEASURE area of the home screen, select **Range**.
11. Select **Auto**.
12. Turn on the output by pressing the **OUTPUT ON/OFF** switch. The OUTPUT indicator light turns on.
13. Observe the readings on the display. For the 10 k Ω resistor, typical display values are:
1.00000 mA
+9.99700 V
14. When measurements are complete, turn the output off by pressing the **OUTPUT ON/OFF** switch. The OUTPUT indicator light turns off.

In this section:

Introduction	5-1
Line fuse replacement.....	5-1
Lithium battery.....	5-2
Front-panel display.....	5-3
Upgrading the firmware.....	5-4

Introduction

This section describes routine maintenance of the instrument that an operator can perform.

Line fuse replacement

A fuse on the 2470 rear panel protects the power-line input of the instrument. The following instructions describe how 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.

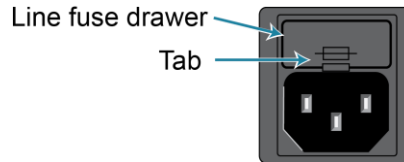
Use only the correct fuse type. Failure to do so could result in injury, death, or instrument damage.

Use a 5 x 20 mm slow-blow fuse rated at 250 V at 2 A.

To replace the fuse, you will need a small, flat-bladed screwdriver.

Complete the following steps to replace the line fuse:

1. Power off the instrument.
2. Remove all test leads connected to the instrument.
3. Remove the line cord.
4. Locate the fuse drawer, which is above the AC receptacle, as shown in the figure below.

Figure 27: 2470 line fuse

5. Use the screwdriver to lift the tab from the fuse drawer.
6. Slide the fuse drawer out. The fuse drawer does not pull completely out of the power module.
7. Snap the fuse out of the drawer.
8. Replace the fuse.
9. 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 for repair.

Lithium battery

The 2470 contains a CR2032 cell (LiMnO₂) battery. Perchlorate material may require special handling. See [Hazardous waste - perchlorate \(dtsc.ca.gov/hazardouswaste/perchlorate\)](https://dtsc.ca.gov/hazardouswaste/perchlorate).

This battery is not replaceable by the user.

Front-panel display

Do not use sharp metal objects, such as tweezers or screwdrivers, or pointed objects, such as pens or pencils, to touch the touchscreen. It is strongly recommended that you use only fingers to operate the instrument. Use of clean-room gloves to operate the touchscreen is supported.

Cleaning the front-panel display

If you need to clean the front-panel LCD touchscreen display, use a soft dry cloth.

CAUTION

Do not use liquids to clean the display.

Abnormal display operation

If the display area is pushed hard during operation, you may see abnormal display operation. To restore normal operation, turn the instrument off and then back on.

Removing ghost images or contrast irregularities

If the display has been operating for a long time with the same display patterns, the display patterns may remain on the screen as ghost images and a slight contrast irregularity may appear. Note that if this occurs, it does not adversely affect the performance reliability of the display.

To regain normal operation, stop using the front-panel display for some time. You can turn off the front-panel display while continuing operation using remote commands and the virtual front panel.

To turn off the front-panel display using a SCPI command:

Send the command:

```
DISPlay:LIgHt:STATe OFF
```

To turn off the front-panel display using a TSP command:

Send the command:

```
display.lightstate = display.STATE_LCD_OFF
```

Upgrading the firmware

To upgrade the 2470 firmware, you load an upgrade file into the instrument. You can load the file from the front-panel USB port using either a remote interface or the front panel of the instrument. If you are using Test Script Builder (TSB), you can upgrade the firmware from TSB using a file saved to the computer on which TSB is running.

During the upgrade process, the instrument verifies that the version you are loading is newer than what is on the instrument. If the version is older or at the same revision level, no changes are made.

If you want to return to a previous version or reload the present version of the firmware, select **Downgrade to Older**. This forces the instrument to load the firmware regardless of the version.

The upgrade process normally takes about five minutes.

Upgrade files are available on tek.com/keithley.

CAUTION

Disconnect the input and output terminals before you upgrade or downgrade.

Do not remove power from the instrument or remove the USB flash drive while an upgrade or downgrade is in progress. Wait until the instrument completes the procedure and shows the opening display. If you are upgrading an instrument with no front panel (NFP), the LAN and 1588 LEDs on the front panel blink in unison during the upgrade and stop when the upgrade is complete.

Do not initialize or reset TSP-Link before starting the upgrade.

Before upgrading, turn the instrument power off, wait a few seconds, then turn the instrument power on.

Front panel firmware upgrade

CAUTION

Do not turn off power or remove the USB flash drive until the upgrade process is complete.

NOTE

The firmware file must be in the root subdirectory of the flash drive and must be the only firmware file in that location. You can upgrade or downgrade the firmware from the front panel or from the virtual front panel.

From the front panel or virtual front panel:

1. Copy the firmware file (.upg file) to a USB flash drive.
2. Verify that the firmware file is in the root subdirectory of the flash drive and that it is the only firmware file in that location.
3. Disconnect any input and output terminals that are attached to the instrument.
4. Turn the instrument power off. Wait a few seconds.
5. Turn the instrument power on.
6. Insert the flash drive into the USB port on the front panel of the instrument.
7. From the instrument front panel, press the **MENU** key.
8. Under System, select **Info/Manage**.
9. Choose an upgrade option:
 - To upgrade to a newer version of firmware, select **Upgrade to New**.
 - To return to a previous version of firmware, select **Downgrade to Older**.
10. If the instrument is controlled remotely, a message is displayed. Select **Yes** to continue.
11. When the upgrade is complete, reboot the instrument.

A message is displayed while the upgrade is in progress.

Troubleshooting FAQs

In this section:

About this section	6-1
Where can I find updated drivers?	6-1
How do I upgrade the firmware?	6-1
Why can't the 2470 read my USB flash drive?	6-2
How do I change the command set?	6-2
Why am I getting a 5074 event code?	6-3
How do I save the present state of the instrument?	6-4
Why did my settings change?	6-5
What are the Quick Setup options?	6-5

About this section

This section helps you find answers to the most common questions encountered with the 2470. For additional FAQs, see “Frequently Asked Questions (FAQs)” in the *Model 2470 Reference Manual*.

Where can I find updated drivers?

For the latest drivers and additional support information, see tek.com/support.

To see what drivers are available for your instrument:

1. Go to tek.com/support.
2. Select Product Support & Downloads.
3. Enter the model number of your instrument.
4. Select **Software** from the filter list.
5. Select **Driver** from the filter list.

NOTE

If you use the native LabVIEW™ or IVI driver, you must configure the 2470 to use the SCPI command set. For information on changing the command set, refer to [How do I change the command set?](#) (on page 6-2).

Why can't the 2470 read my USB flash drive?

Verify that the flash drive is formatted with the FAT32 file system. The 2470 only supports FAT and FAT32 drives using Master Boot Record (MBR).

In Microsoft™ Windows™, you can check the file system by checking the properties of the USB flash drive.

NOTE

Higher capacity USB drives take longer to be read and loaded by the instrument.

How do I change the command set?

You can change the command set that you use with the 2470. The remote command sets that are available include:

- **SCPI:** An instrument-specific language built on the SCPI standard.
- **TSP:** A scripting programming language that contains instrument-specific control commands that can be executed from a stand-alone instrument. You can use TSP to send individual commands or use it to combine commands into scripts.

If you change the command set, reboot the instrument.

You cannot combine the command sets.

NOTE

As delivered from Keithley, the 2470 is set to work with the SCPI command set.

To set the command set from the front panel:

1. Press the **MENU** key.
2. Under System, select **Settings**.
3. Select the appropriate **Command Set**.

You are prompted to confirm the change to the command set and reboot the instrument.

To verify which command set is selected from a remote interface, send the command:

```
*LANG?
```

To change to the SCPI command set from a remote interface, send the command:

```
*LANG SCPI
```

Reboot the instrument.

To change to the TSP command set from a remote interface, send the command:

```
*LANG TSP
```

Reboot the instrument.

Why am I getting a 5074 event code?

The instrument provides an interlock circuit on the rear panel. You must enable this circuit in order for the instrument to set source voltages greater than ± 42 V DC. If you try to assign a high-voltage output and turn the source on when the interlock is not asserted, event code 5074, "Output voltage limited by interlock," is generated.

WARNING

The 2470 is provided with an interlock circuit that must be positively activated for the high voltage output to be enabled. The interlock helps facilitate safe operation of the equipment in a test system. Bypassing the interlock could expose the operator to hazardous voltages that could result in personal injury or death.

The action when the interlock signal is not asserted depends on the Interlock setting. If Interlock is set to Off, if the safety interlock signal is not asserted, the following occurs:

- The nominal output is limited to less than ± 42 V.
- The front-panel INTERLOCK indicator is not illuminated.
- You can output voltages less than ± 42 .

If Interlock is set to On, when the safety interlock signal is not asserted, the following occurs:

- You cannot turn on the source output.
- The front-panel INTERLOCK indicator is not illuminated.

Whenever the interlock changes state (from asserted to not asserted or vice versa), the output is turned off.

To recover from this error, properly engage the interlock using a safe test fixture before turning on the 2470 output.

How do I save the present state of the instrument?

You can save the settings in the instrument as a script using the front-panel menus or from a remote interface. After they are saved, you can recall the script or copy it to a USB flash drive.

From the front panel:

1. Configure the 2470 to the settings that you want to save.
2. Press the **MENU** key.
3. Under Scripts, select **Save Setup**.
4. Select **Create**. A keyboard is displayed.
5. Use the keyboard to enter the name of the script.
6. Select the **OK** button on the displayed keyboard. The script is added to internal memory.

Using SCPI commands:

1. Configure the instrument to the settings that you want to save.
2. Send the command:
`*SAV <n>`
Where <n> is an integer from 0 to 4.

NOTE

In the front-panel script menus, the setups saved with the `*SAV` command have the name `Setup0x`, where `x` is the value you set for <n>.

Using TSP commands:

1. Configure the instrument to the settings that you want to save.
2. Send the command:
`createconfigscript("setupName")`
Where `setupName` is the name of the setup script that is created.

Why did my settings change?

Many of the commands in the 2470 are saved with the source or measure function that was active when you set them. For example, assume you have the measure function set to current and you set a value for display digits. When you change the measure function to voltage, the display digits value changes to the value that was last set for the voltage measure function. When you return to the current measure function, the display digits value returns to the value you set previously.

What are the Quick Setup options?

The **QUICKSET** key opens a screen that provides access to function selection, performance adjustments, and quick setups.

The Function button on the Quickset menu allows you to select a source or measure function. The options are the same as those available when you use the front-panel **FUNCTION** key.

The Performance slider allows you to adjust speed and resolution. As you increase speed, you lower the amount of resolution. As you increase resolution, you decrease the reading speed. These settings take effect the next time the output is turned on and measurements are made.

The Quick Setups allow you to set the instrument to operate as a Voltmeter, Ammeter, Ohmmeter, or Power Supply.

CAUTION

When you select a Quick Setup, the instrument turns the output on. Carefully consider and configure the appropriate output-off state, source, and limits before connecting the 2470 to a device that can deliver energy, such as other voltage sources, batteries, capacitors, or solar cells. Configure the settings that are recommended for the instrument before making connections to the device. Failure to consider the output-off state, source, and limits may result in damage to the instrument or to the device under test (DUT).

Next steps

In this section:

[Additional 2470 information.....](#) 7-1

Additional 2470 information

This manual has prepared you to start using your new 2470 High Voltage SourceMeter Instrument for your application. For detailed information on all features of the 2470, refer to the *Model 2470 Reference Manual*, part number 2470-901-01.

Also see tek.com/keithley for support and additional information about the instrument. From the website, you can access:

- The Knowledge Center, which contains the following handbooks:
 - *The Low Level Measurements Handbook: Precision DC Current, Voltage, and Resistance Measurements*
 - *Switching Handbook: A Guide to Signal Switching in Automated Test Systems*
- Application notes
- Updated drivers
- Information about related products

Your local Field Applications Engineer can help you with product selection, configuration, and usage. Check the website for contact information.

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