

Model 2601B-PULSE System SourceMeter Instrument

User's Manual

2601B-PULSE-900-01 Rev. A August 2021



2601B-PULSE-900-01A

Model 2601B-PULSE
System SourceMeter[®] Instrument
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 2017.

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Introduction

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Welcome

Thank you for choosing a Keithley Instruments product. The 2601B-PULSE System SourceMeter® 10 μ s Pulser/SMU Instrument with PulseMeter™ technology is an industry-leading high current/high speed pulser with measure capabilities and the full functionality of a traditional source-measure instrument (SMU). This instrument offers 10 A current pulse output at 10 V with a minimum pulse width of 10 μ s. Its built-in dual 1 Megasample/second (MS/s), 18-bit digitizers make it possible to acquire both pulse current and voltage waveforms simultaneously without the need to use a separate instrument.

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-us.

Customer documentation

The documentation for the 2601B-PULSE includes a Quick Start Guide, User's Manual (this document), and Reference Manual. The 2601B-PULSE Quick Start Guide is provided as a hard copy with the instrument. You can also access it from tek.com/keithley as an Adobe Acrobat PDF file.

The documents include the following information:

- **Quick Start Guide:** Provides unpacking instructions, describes basic connections, and reviews basic operation information. If you are new to Keithley Instruments equipment, refer to the Quick Start Guide to take the steps needed to unpack, set up, and verify operation.
- **User's Manual:** Includes installation, instrument description, operation, and maintenance information.
- **Reference Manual:** Includes advanced operation information. Programmers looking for a command reference and users looking for an in-depth description of how the instrument works (including troubleshooting and optimization) should refer to the Reference Manual.

Product software and drivers

Go to the [Product Support and Downloads web page \(tek.com/product-support\)](http://tek.com/product-support) to download drivers and software for your instrument.

Available drivers and software include:

- **KickStart Software:** Enables quick test setup and data visualization when using one or more instruments.
- **Test Script Builder (TSB):** This software provides an environment to develop a test program and the ability to load the test program onto the instrument. Running a program loaded on the instrument eliminates the need to send individual commands from the host computer to the instrument when running a test.
- **IVI-COM Driver:** An IVI instrument driver you can use to create your own test applications in C/C++, VB.NET, or C# programming languages. It can also be called from other languages that support calling a DLL or ActiveX (COM) object. Refer to [IVI Foundation \(ivifoundation.org\)](http://ivifoundation.org) for additional information.
- **LabVIEW™ Software drivers:** Drivers to communicate with National Instruments LabVIEW Software.
- **Keithley I/O layer:** Manages the communications between Keithley instrument drivers and software applications and the instrument itself. The I/O Layer handles differences in communications required to support GPIB, serial, ethernet, and other communications buses so that drivers and software applications do not need to handle the differences themselves.

To identify IP addresses of instruments that are connected to the local area network (LAN) and support the VXI-11 discovery protocol, you can also use LXI Discovery Tool, available from the [Resources \(lxistandard.org/Resources/Resources.aspx\)](http://lxistandard.org/Resources/Resources.aspx) page of the [LXI Consortium website \(lxiconsortium.org\)](http://lxiconsortium.org).

Power and environmental ratings

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

Category	Specification
Power supply	100 V ac to 240 V ac, 50 Hz or 60 Hz (autosensing). 240 VA maximum
Input and output connections	See Front panel (on page 3-1) and Rear panel (on page 3-5)
Environmental conditions	For indoor use only. Operating altitude: Maximum 2000 meters (6562 feet) above sea level Operating temperature: 0 °C to 35 °C at up to 70% relative humidity; at 35 °C to 50 °C, derate 3% relative humidity per °C Storage: –25 °C to 65 °C Pollution degree: 1 or 2

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

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

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

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Introduction

This section provides the information you need to install the 2601B-PULSE, make communications connections, and power up the instrument.

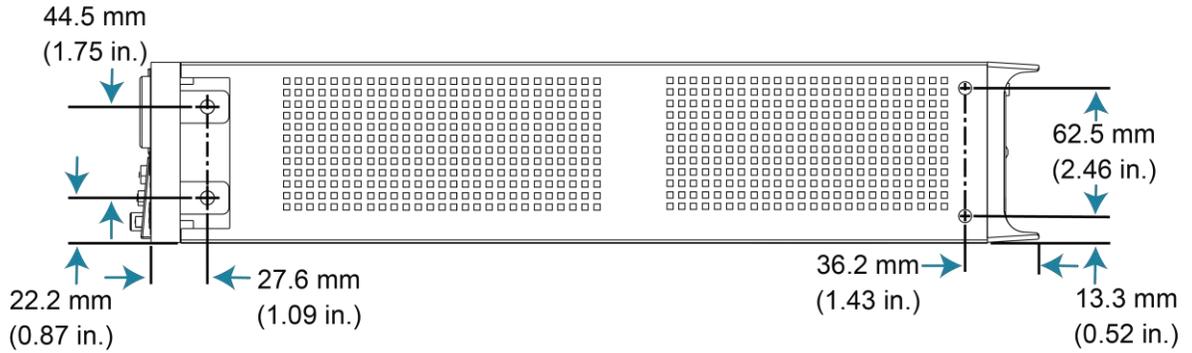
2601B-PULSE weights and dimensions

The instrument weighs 5.9 kg (13 lb) without the 2601B-P-INT attached. With the 2601B-P-INT attached, it weighs 6.4 kg (14 lb).

The following figure shows the mounting screw locations and dimensions. The dimensions shown are typical for both sides of the instrument.

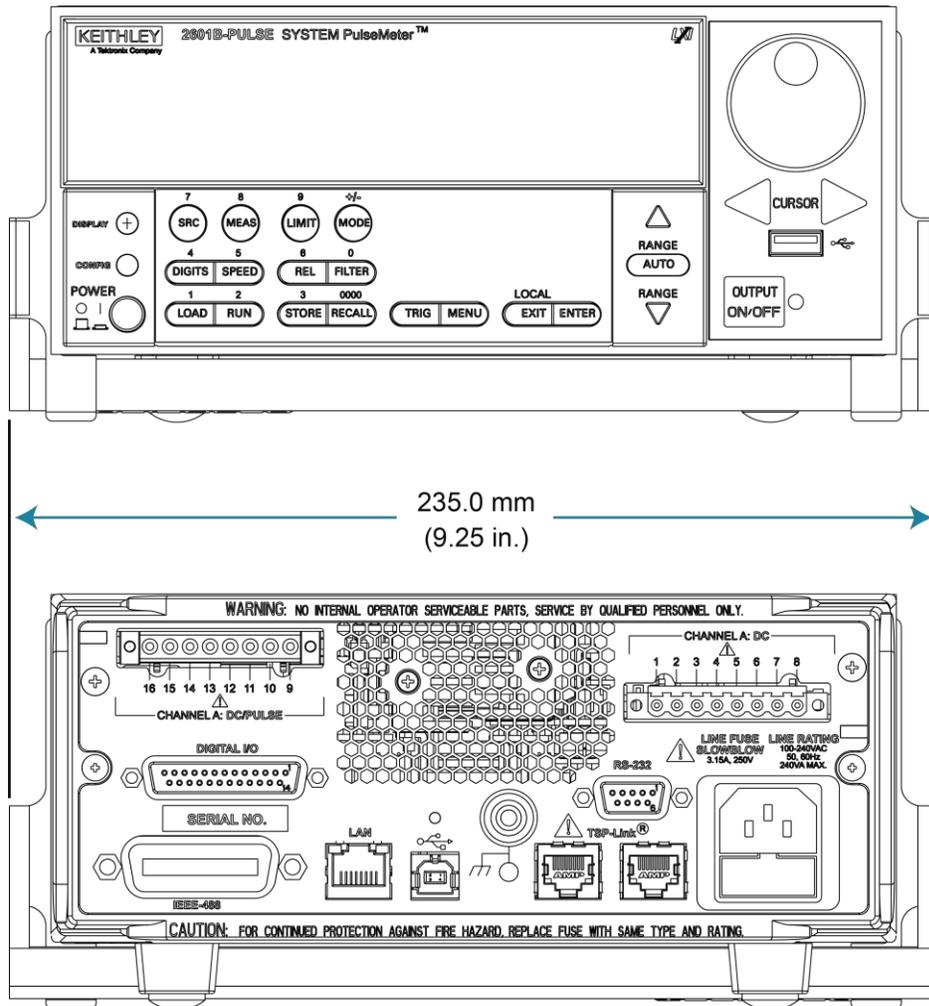
For front mounting, use #8-32 x 3/8 in. Phillips pan-head screws. For rear mounting, use #10-32 x 3/8 in. Phillips pan-head SEMS screws.

Figure 1: Mounting screw locations and dimensions



The following figures show the dimensions when the handle is installed.

Figure 2: 2601B-PULSE dimensions front and rear with handle



The following figures show the dimensions when the handle has been removed.

Figure 3: 2601B-PULSE front and rear panel dimensions with handle removed

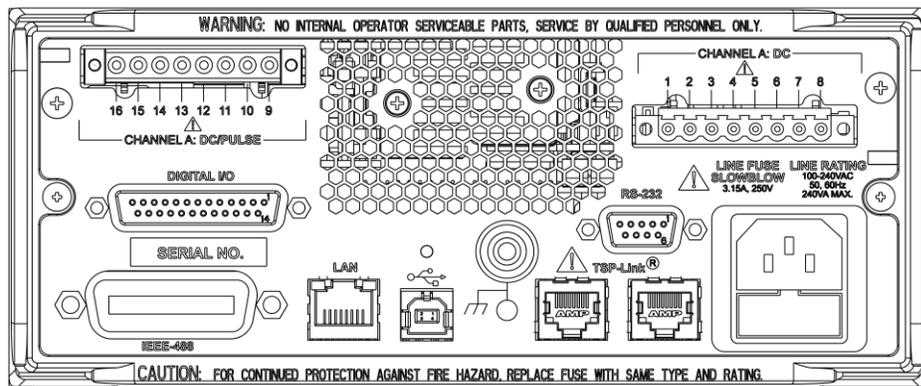
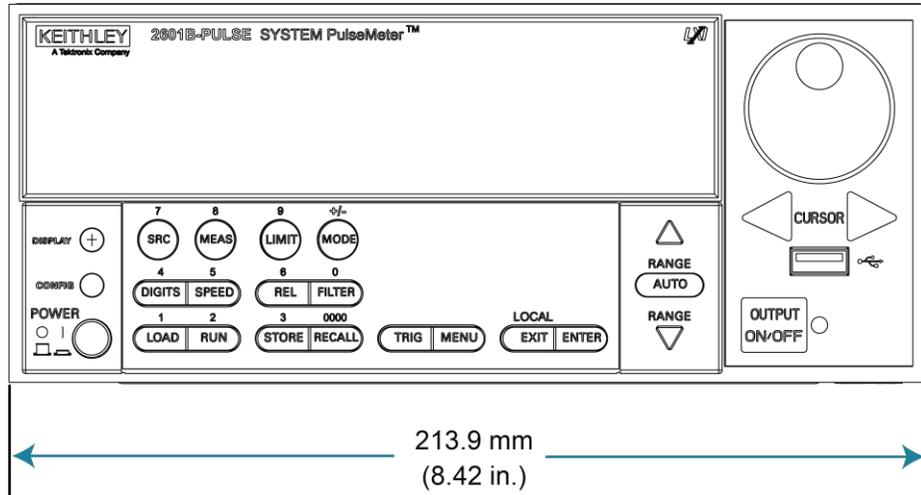


Figure 4: 2601B-PULSE height and length

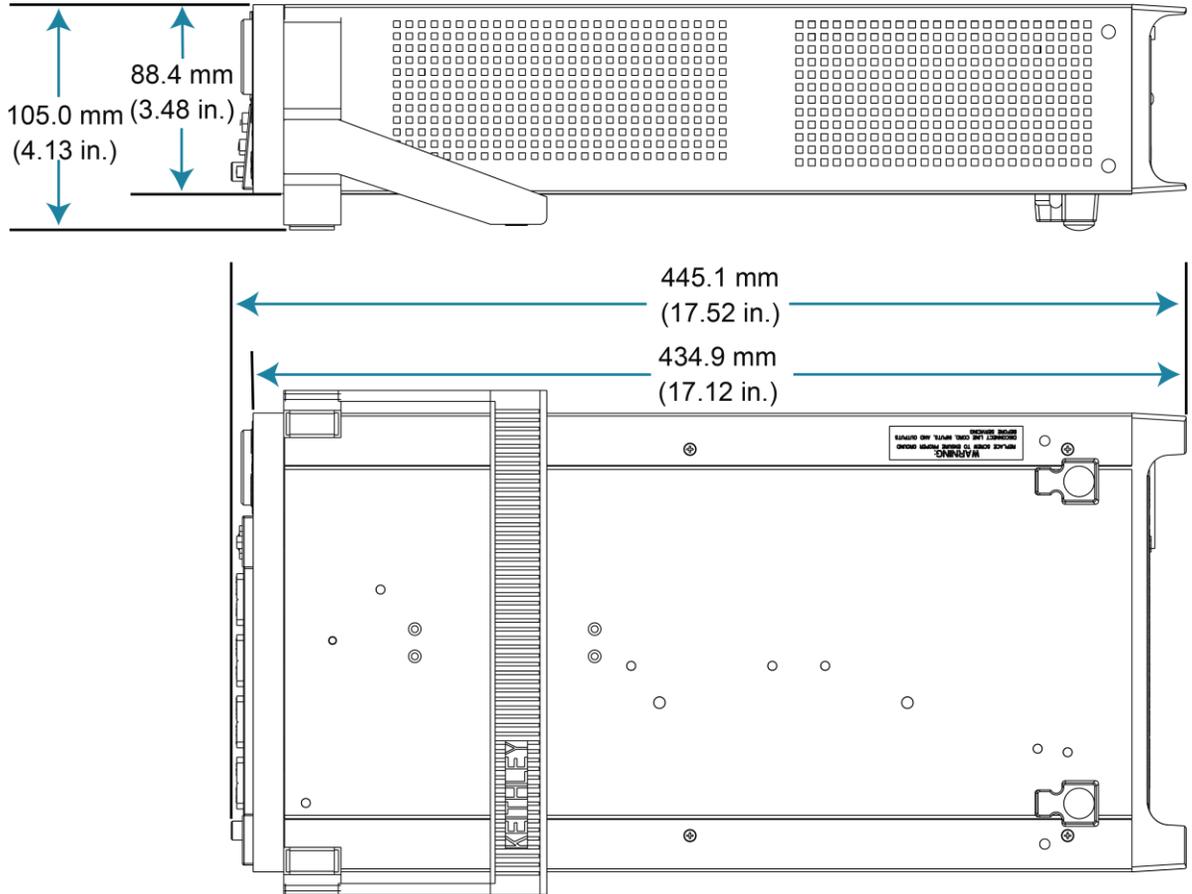
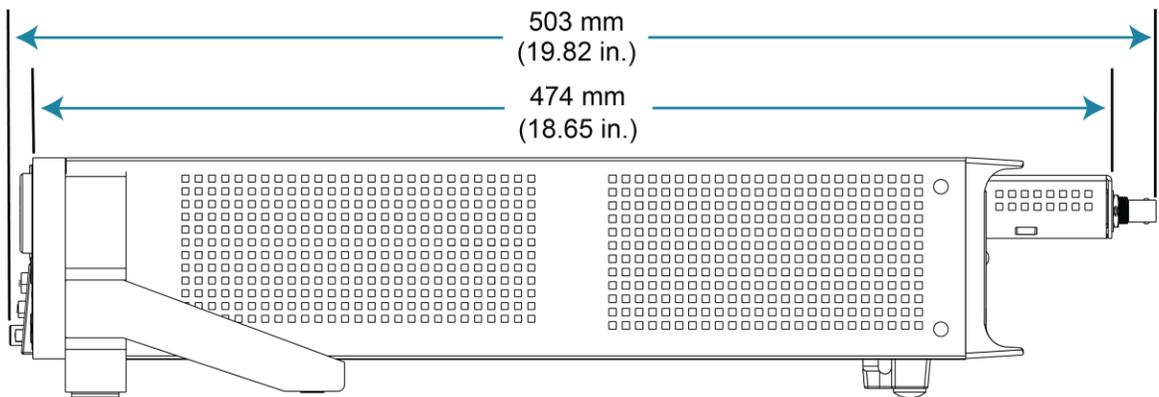


Figure 5: 2601B-PULSE with 2601B-P-INT length

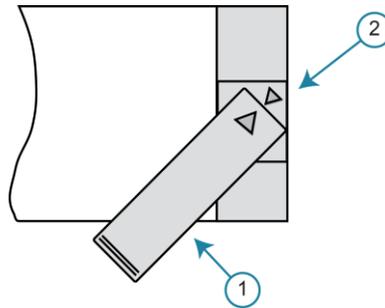


Preparing the instrument for rack mounting

To remove the handle, mounting ears, and rear feet:

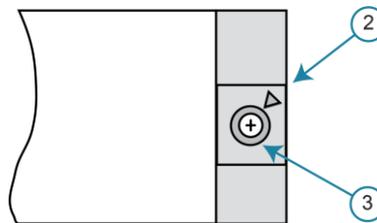
1. Gently pull the handle (1) away from the sides of the instrument case and swing it up or down until the orientation arrows on the handles line up with the orientation arrows on the two mounting ears, as shown in the following figure.

Figure 6: Rack-mount kit handle removal



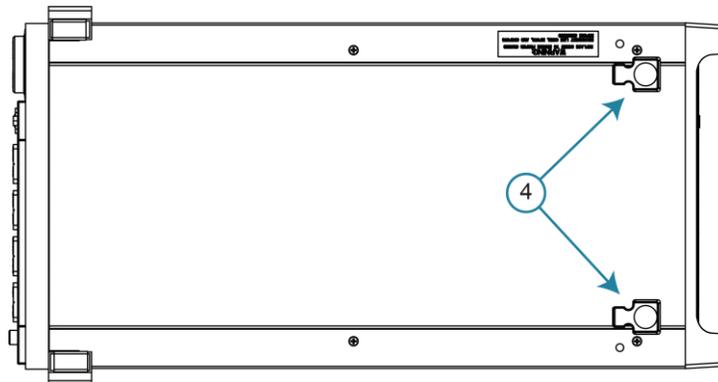
2. After you align the arrows (2), pull the ends of the handle (1) away from the case.
3. Remove the screws that secure the two mounting ears (3).
4. Pull down and out to remove each ear.

Figure 7: Mounting ear removal



5. From the bottom of the instrument, pull out the two rubber feet and remove the two screws (4). For the locations, see the following figure.

Figure 8: Instrument rubber feet removal



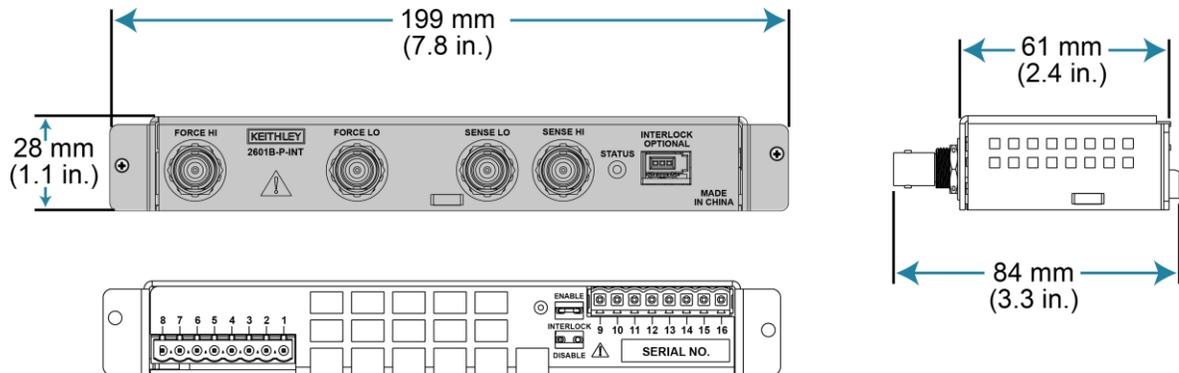
Store the handle, rubber feet, and hardware for future use.

2601B-P-INT dimensions

The following figure show the dimensions of the 2601B-P-INT Interlock and Cable Connector Box.

The 2601B-P-INT weighs 0.5 kg (1 lb).

Figure 9: 2601B-P-INT dimensions



Installing the 2601B-P-INT

The 2601B-PULSE is shipped with the 2601B-P-INT Rear Panel Interlock and Cable Connector Box accessory. The 2601B-P-INT:

- Simplifies test connections to the 2601B-PULSE by converting terminal strip connections to standard BNC connectors
- Makes the connections between the CHANNEL A: DC and CHANNEL A: DC/PULSE terminal strips
- Provides connections for an optional interlock

Refer to [Using the interlock](#) (on page 2-37) for detail on connecting the interlock.

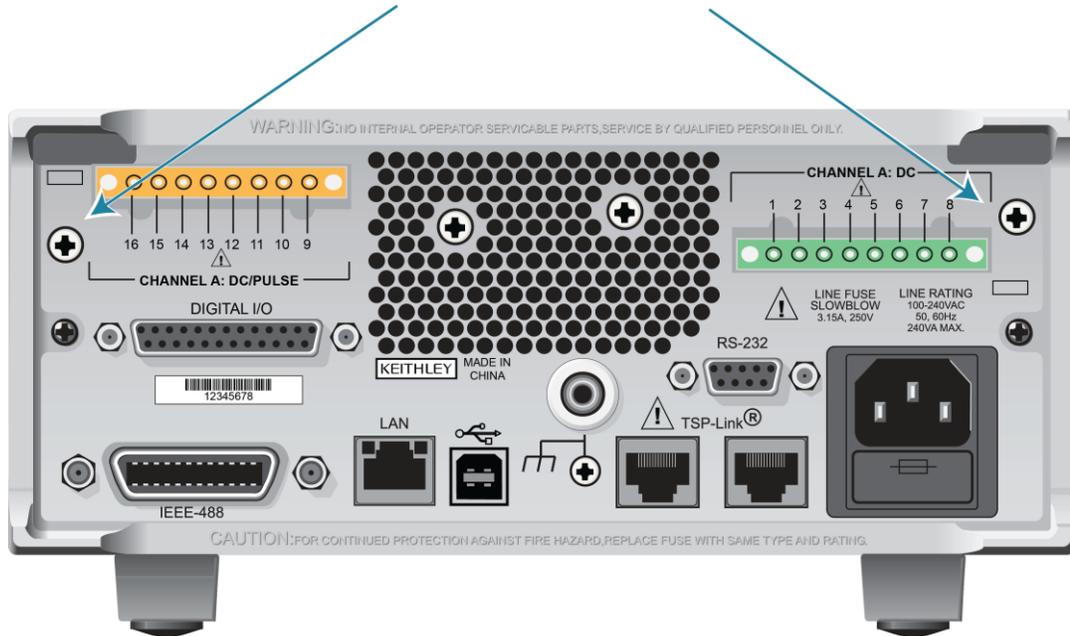
NOTE

You must use the screws that are provided with the 2601B-P-INT to attach it to the instrument. The screws that you remove from the instrument will not provide a secure connection.

To install the 2601B-P-INT:

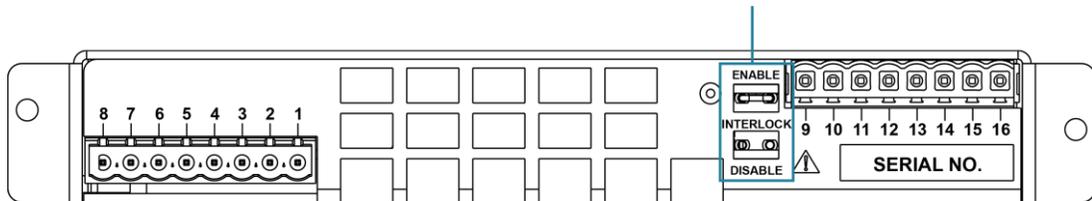
1. Remove power connections from the 2601B-PULSE.
2. On the rear panel of the 2601B-PULSE, remove the screws to the left of the CHANNEL A: DC/PULSE terminal strip and to the right of the CHANNEL A: DC terminal strip. Save the screws for operation with the 2601B-P-INT uninstalled. Screw locations are shown in the following figure.

Figure 10: Remove screws from 2601B-PULSE rear panel



3. On the terminal strip panel of the 2601B-P-INT, position the INTERLOCK jumper. Use needle-nose pliers to position the jumper in the ENABLE slot if you are using an interlock or DISABLE if you are not using the interlock. The INTERLOCK jumper is shown in the following figure.

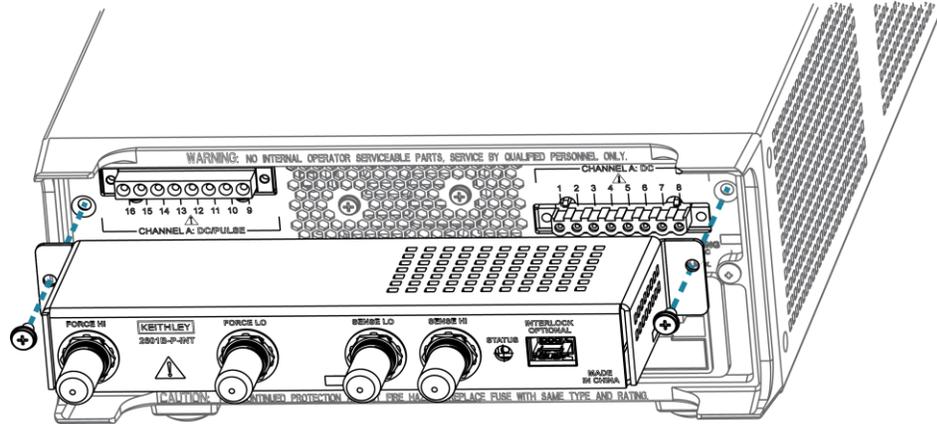
Figure 11: INTERLOCK jumper on the 2601B-P-INT Interlock Box terminal strip panel



4. Align the terminal strip panel of the 2601B-P-INT to the terminal strips on the rear panel of the 2601B-PULSE.
5. Press the 2601B-P-INT connections firmly onto the terminal strips on the rear panel of the 2601B-PULSE.

- Use the screws provided with the 2601B-P-INT to secure it to the rear panel of the 2601B-PULSE.

Figure 12: Installation of the 2601B-P-INT



NOTE

Replacement jumpers are available from Keystone Electronics Corp., part number 1430-1, Uninsulated Shorting Pin.

Cooling vents

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

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

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

CAUTION

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

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

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

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

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

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

Turning the instrument on and off

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

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

CAUTION

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

To turn a 2601B-PULSE on and off:

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

 WARNING

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

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

 WARNING

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

NOTE

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

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

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

Placing a 2601B-PULSE in standby

WARNING

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 2601B-PULSE while the instrument is powered on. Turn off the equipment from the front panel or disconnect the main power cord from the rear of the 2601B-PULSE before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

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

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

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

Warmup period

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

Line frequency configuration

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

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

To configure the line frequency from the front panel:

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

To configure the line frequency from a remote interface:

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

```
localnode.linefreq = 60
```

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

```
localnode.autolinefreq = true
```

Remote communications interfaces

You can choose from one of several communication interfaces to send commands to and receive responses from the 2601B-PULSE.

You can control the 2601B-PULSE from only one communications interface at a time. The first interface on which the instrument receives a message takes control of the instrument. If another interface sends a message, that interface can take control of the instrument. You may need to enter a password to change the interface, depending on the setting of interface access.

The 2601B-PULSE automatically detects the type of communications interface (LAN, USB, GPIB, or RS-232) when you connect to the respective port on the rear panel of the instrument. In most cases, you do not need to configure anything on the instrument. In addition, you do not need to reboot if you change the type of interface that is connected.

Remote interface connections

The 2601B-PULSE supports the following remote interfaces:

- **USB:** Communicate with the instrument over a USB connection.
- **LAN:** Local area network (LAN) communications provide the flexibility to build scalable and functional test or data acquisition systems with a large degree of flexibility.
- **GPIB:** General purpose interface bus is an IEEE-488 instrumentation data bus.
- **RS-232:** Communicate with the instrument over the serial port or with another instrument using its serial port.

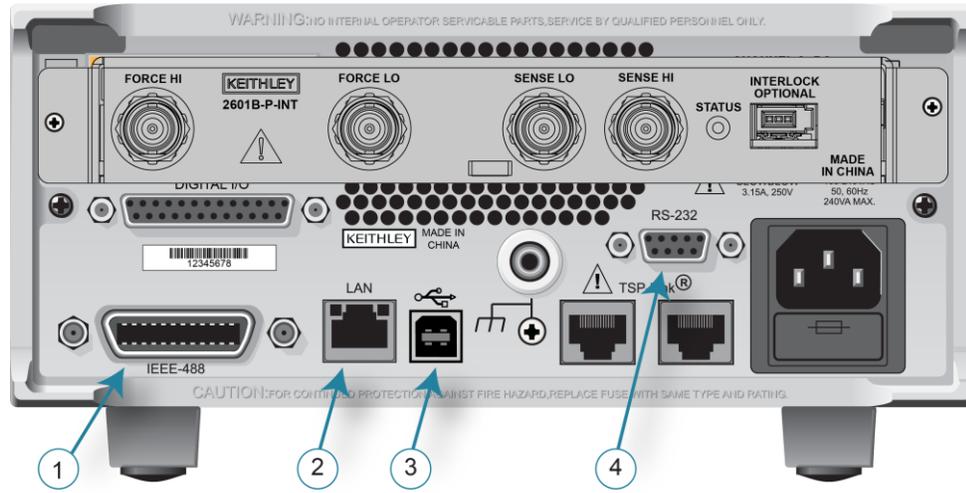
NOTE

The 2601B-PULSE can be controlled from only one communication interface at a time. The first interface from which it receives a message takes control of the instrument. It ignores the other interfaces until the instrument is returned to local operation.

For more information about the remote interfaces, see:

- [USB communications](#) (on page 2-13)
- [LAN communications](#) (on page 2-15)
- [GPIB operation](#) (on page 2-27)
- [RS-232 interface operation](#) (on page 2-31)

Figure 13: 2601B-PULSE IEEE-488, LAN, USB, and RS-232 connections



1 IEEE-488 connection
2 LAN connection
3 USB connection
4 RS-232 connection

Output queue

Response messages, such as those generated from print commands, are placed in the output queue. All remote command interfaces share the same output queue.

The output queue sets the message available (MAV) bit in the status model.

The data in the output queue is cleared by the *CLS command.

USB communications

To use the rear-panel USB port, you need a driver that communicates using the USBTMC protocol, such as NI-VISA, on the host computer.

When installed, the USBTMC protocol allows the Microsoft® Windows® operating system to recognize the instrument.

When you connect a USB device that implements the USBTMC or USBTMC-USB488 protocol to the computer, the driver automatically detects the device. Note that the driver does not recognize other USB devices, such as printers, scanners, and storage devices.

In this section, "USB instruments" refers to devices that implement the USBTMC or USBTMC-USB488 protocol.

See [Software components for applications and instrument drivers](#) (on page 2-34) for more information on drivers.

Communicate with the instrument

When using Virtual Instrument Software Architecture (VISA) to communicate with the USB device, you need to use a VISA communication driver. VISA requires a resource string in the following format to connect to the correct USB instrument:

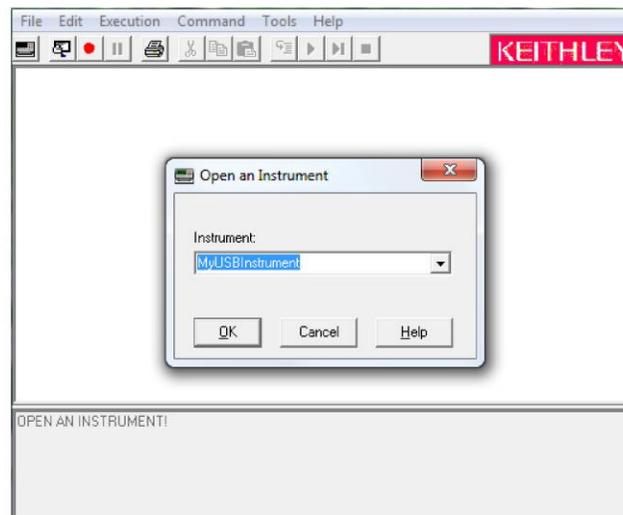
```
USB[board]::manufacturer ID::model code::serial number[::USB interface
number] [::INSTR]
```

This requires that you determine the parameters. You can gather this information by running a utility that automatically detects all instruments connected to the computer. If you installed the Keithley I/O Layer, the Keithley Configuration Panel is available from the Microsoft® Windows® Start menu in the Keithley Instruments menu.

To use the Keithley Configuration Panel to determine the VISA resource string:

1. Start the Keithley Configuration Panel. The Keithley Configuration Wizard opens to the Select Operation dialog box.
2. Complete the wizard.
3. Save the configuration. From the Configuration Utility, select **File > Save**.
4. Open the Keithley Communicator.
5. Select **File > Open Instrument** to open the instrument you named in the wizard.

Figure 14: Keithley Communicator Open an Instrument



6. Select **OK**.
7. Send a command to the instrument and see if it responds.

NOTE

If you have a full version of NI-VISA on your system, you can run NI-MAX or the VISA Interactive Utility. See their documentation for information.

If you have the Keysight IO Libraries on your system, you can run Keysight Connection Expert to review your USB instruments. See their documentation for information.

Connecting multiple USB instruments to the computer

The most convenient way to connect USB instrumentation to the computer is to plug a USB cable directly from the instrument to the computer. If you have more than one USB instrument or have other USB devices, such as printers, keyboards, and mice, you might not have enough USB connectors on the computer.

To gain more ports, you can use a USB hub or add more USB controller cards if you have available PCI or PCI Express slots.

LAN communications

You can communicate with the instrument using a local area network (LAN). The 2601B-PULSE can connect directly to a host computer or interact with a DHCP or DNS server and other LXI-compliant instruments on a local area network (LAN). The LAN interface can be used to build flexible test systems that include web access. This section provides an overview of LAN communications for the 2601B-PULSE.

When you connect using a LAN, you can use a web browser to access the internal web interface of the instrument and change some of the instrument settings.

There is one LAN port, which is on the rear panel of the instrument, that supports full connectivity on a 10 Mbps or 100 Mbps network. The 2601B-PULSE automatically detects the speed.

The 2601B-PULSE also supports Multicast DNS (mDNS) and DNS Service Discovery (DNS-SD), which are useful on a LAN with no central administration.

NOTE

Contact your network administrator to confirm your specific network requirements before setting up a LAN connection.

If you have problems setting up the LAN, refer to [LAN troubleshooting suggestions](#) (on page 2-25).

The 2601B-PULSE is a Version 1.5 LXI Device Specification 2016 compliant instrument that supports TCP/IP and complies with IEEE Std 802.3 (ethernet).

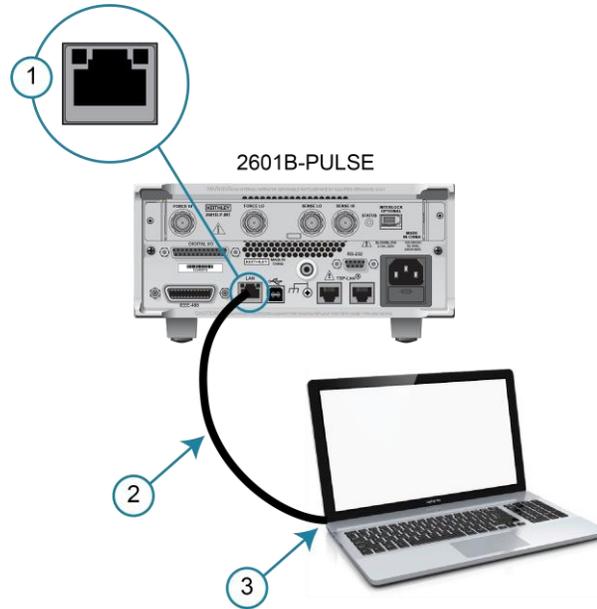
LAN cable connection

The 2601B-PULSE includes two LAN crossover cables. One cable is intended for use with the TSP-Link® network and the other cable is intended for use with the LAN.

However, you can use any standard LAN crossover cable (category 5e, RJ-45, male-to-male) or straight-through cable to connect your equipment. The instrument automatically senses which cable you have connected.

The following figure shows the location of the LAN port on the rear panel of the instrument. Connect the LAN cable between this connection and the LAN port on the computer.

Figure 15: 2601B-PULSE ethernet connection



1 2601B-PULSE ethernet port (LAN)
2 Straight-through LAN cable or crossover LAN cable
3 Ethernet port (on the host computer)

You can connect the instrument to the LAN in a one-to-one, one-to-many, two network card, or enterprise configuration, as described in the following topics.

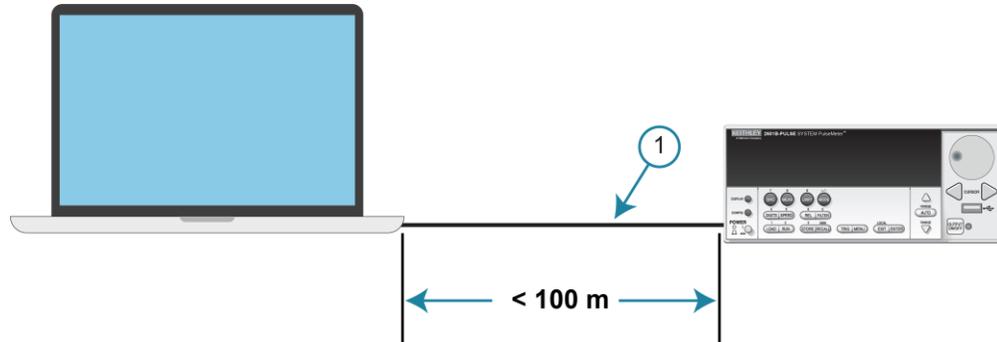
One-to-one connection

With most instruments, a one-to-one connection is done only when you are connecting a single instrument to a single network interface card.

A one-to-one connection using a network crossover cable connection is similar to a typical RS-232 system using a null modem cable. The crossover cable has its receive (RX) and transmit (TX) lines crossed to allow the receive line input to be connected to the transmit line output on the network interfaces.

The figure below shows a category 5e RJ-35 crossover cable (1) between the instrument and the computer.

Figure 16: One-to-one connection with a crossover cable



NOTE

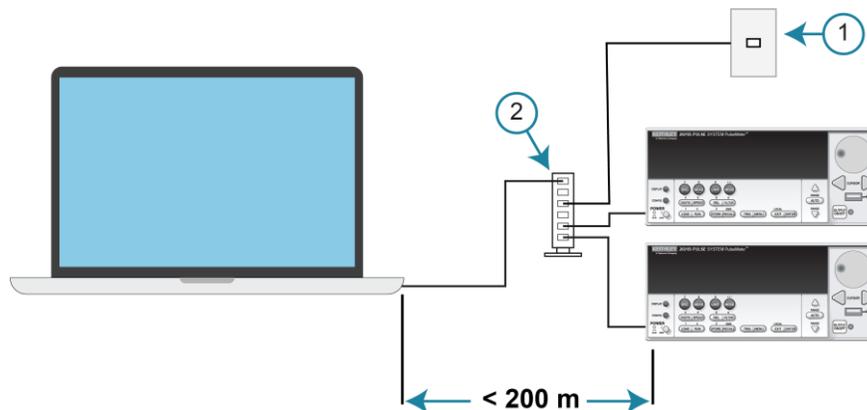
The 2601B-PULSE supports Auto-MDIX and can use either normal LAN CAT-5 cables (patch) or crossover cables. The instrument automatically adjusts to support either cable.

One-to-many connection

With a LAN hub, a single network interface card can be connected to as many instruments as the hub can support. This requires straight-through network (not crossover) cables for hub connections.

The advantage of this method is easy expansion of measurement channels when the test requirements exceed the capacity of a single instrument. With only the instruments connected to the hub, this is an isolated instrumentation network. However, with a corporate network attached to the hub, the instruments become part of the larger network.

Figure 17: One-to-many connection using a network hub or switch



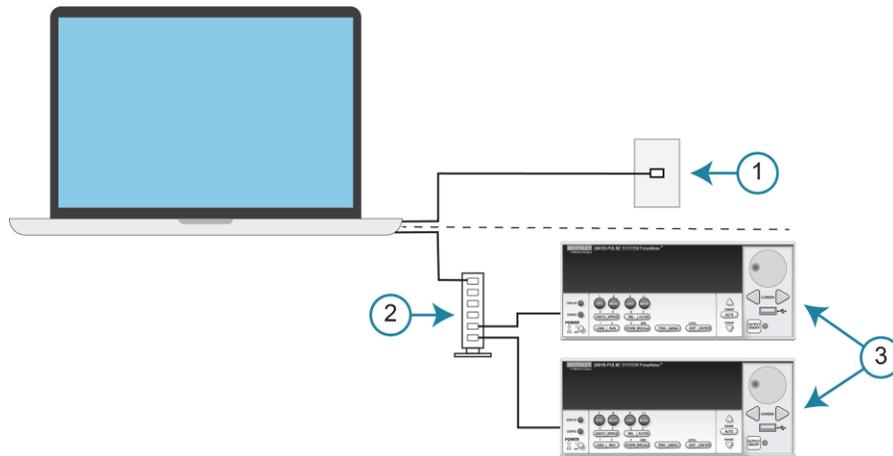
- | |
|---------------------|
| 1 Corporate network |
| 2 Hub |

Two network card connection

If you need to connect independent corporate and instrumentation networks, two network interface cards are required in the computer controller. Though the two networks are independent, stations on the corporate network can access the instruments and the instruments can access the corporate network using the same computer.

This configuration resembles a GPIB setup in which the computer is connected to a corporate network, but also has a GPIB card in the computer to communicate with instruments.

Figure 18: Two network card connection

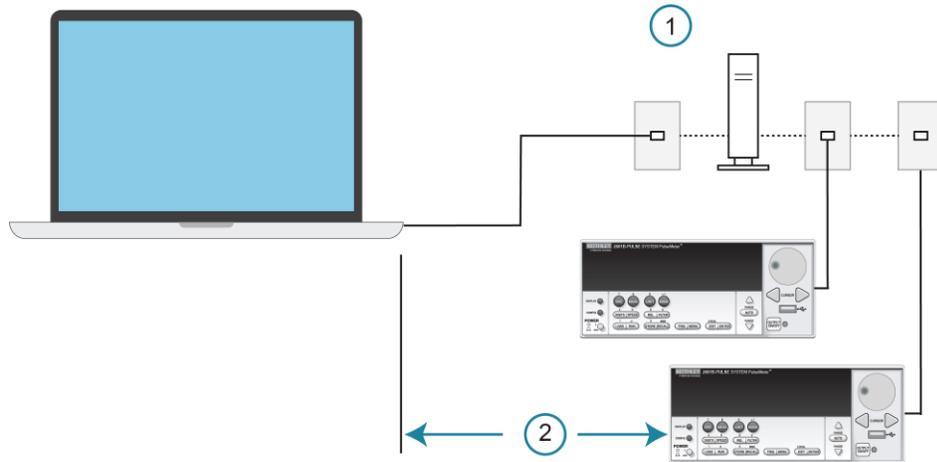


1 Corporate network
2 Hub
3 Instrumentation network

Instrumentation connection to enterprise routers or servers

This connection uses an existing network infrastructure to connect instruments to the computer controller. In this case, you must get the network resources from the network administrator.

Usually, the instruments are kept inside the corporate firewall, but the network administrator can assign resources that allow them to be outside the firewall. This allows instruments to be connected to the internet using appropriate security methods. Data collection and distribution can be controlled from virtually any location.

Figure 19: Instrumentation connection to enterprise routers or servers

1 Enterprise-wide or internet (routers or servers)
--

2 Limited by network size

Set up LAN communications on the instrument

The following topics describe how to check the existing LAN communications settings and set up manual or automatic LAN communications.

Check communications settings

Before configuring the LAN, you can check the communications settings on the instrument without making any changes.

To view the active network settings:

1. From the front panel, press the **MENU** key, and then select **LAN > STATUS**.
2. Use the navigation wheel to select one of the following network settings:
 - **IP-ADDRESS**
 - **GATEWAY**
 - **SUBNET-MASK**
 - **METHOD**
 - **DNS**
 - **MAC-ADDRESS**
3. Press the **ENTER** key to view the active setting.
4. Press the **EXIT (LOCAL)** key once to return to the STATUS menu.

Set up automatic LAN configuration

If you are connecting to a LAN that has a DHCP server or if you have a direct connection between the instrument and a host computer, you can use automatic IP address selection.

If you select Auto, the instrument attempts to get an IP address from a DHCP server. If this fails, it reverts to an IP address in the range of 169.254.1.0 through 169.254.254.255.

NOTE

Both the host computer and the instrument should be set to use automatic LAN configuration. Though it is possible to have one set to manual configuration, it is more complicated to set up.

To set up automatic IP address selection using the front panel:

1. From the front panel, press the **MENU** key, and then select **LAN > CONFIG > METHOD**.
2. Select **AUTO**.
3. Press the **ENTER** key.
4. Press the **EXIT (LOCAL)** key until you return to the LAN CONFIG menu.
5. Select **APPLY_SETTINGS > YES**, and then press the **ENTER** key.

Set up manual LAN configuration

NOTE

These steps assume that you are making all the settings in the order shown here. If you only change one or a few settings, you need to apply the settings before they take effect. To apply the settings, from the **LAN CONFIG** menu, select **APPLY_SETTINGS > YES**, and then press the **ENTER** key.

NOTE

Contact your corporate information technology (IT) department to secure a valid IP address for the instrument when placing the instrument on a corporate network.

To set up the LAN configuration manually using the front panel:

1. Press the **MENU** key to display the MAIN MENU.
2. Use the navigation wheel to select **LAN**. The LAN CONFIG menu is displayed.
3. Select **CONFIG > METHOD > MANUAL** and then press the **ENTER** key.
4. Press the **EXIT (LOCAL)** key once to return to the LAN CONFIG menu.
5. Select **CONFIG > IP-ADDRESS**.
6. Turn the navigation wheel to select and enter a valid IP address for the instrument.

NOTE

The IP address of the instrument can have leading zeros, but the IP address of the computer cannot.

7. Press the **ENTER** key to confirm the changes.
8. Press the **EXIT (LOCAL)** key twice to return to the LAN CONFIG menu.
9. Select **CONFIG > GATEWAY**.
10. Turn the navigation wheel to select and enter a valid gateway address for the instrument.
11. Press the **ENTER** key to confirm the changes.
12. Press the **EXIT (LOCAL)** key twice to return to the LAN CONFIG menu.
13. Select **CONFIG > SUBNETMASK**.
14. Turn the navigation wheel to select and enter a valid subnet mask for the instrument.
15. Press the **ENTER** key to confirm the changes.
16. Press the **EXIT (LOCAL)** key twice to return to the LAN CONFIG menu.
17. Select **APPLY_SETTINGS > YES**, and then press the **ENTER** key.

LAN speeds

Another characteristic of the LAN is speed. The 2601B-PULSE negotiates with the host computer and other LXI-compliant devices on the LAN to transmit data at the highest speed possible. LAN speeds must be configured to match the speed of the other instruments on the network.

To set the LAN speed:

1. From the front panel, press the **MENU** key and select **LAN > CONFIG > SPEED**.
2. Turn the navigation wheel to select either **10 Mbps** or **100 Mbps**.
3. Press the **ENTER** key.
4. Press the **EXIT (LOCAL)** key once to return to the previous menu.
5. Select **APPLY_SETTINGS > YES**, and then press the **ENTER** key.

Configuring the domain name system (DNS)

The Domain Name System (DNS) lets you type a domain name in the address bar to connect to the instrument. If you use DNS, you can use a name instead of an IP address.

Example:

Model2601B-PULSE.XYZcompany.com

NOTE

Contact your corporate information technology (IT) department for information about DNS. If a DNS server is not part of the LAN infrastructure, do not use this setting.

To enable or disable DNS host name verification:

1. From the front panel, press the **MENU** key, and then select **LAN > CONFIG > DNS > VERIFY**.
2. Turn the navigation wheel to select either **ENABLE** or **DISABLE**. When enabled, the instrument performs a DNS lookup to verify the DNS host name matches the value specified in the `lan.config.dns.hostname` attribute.
3. Press the **ENTER** key.
4. Press the **EXIT (LOCAL)** key twice to return to the LAN CONFIG menu.

To enable or disable DNS registration:

1. From the front panel, press the **MENU** key and select **LAN > CONFIG > DNS > DYNAMIC**.
2. Turn the navigation wheel to select either **ENABLE** or **DISABLE**. DNS registration works with the DHCP to register the host name specified in the `lan.config.dns.hostname` attribute with the DNS server.
3. Press the **ENTER** key.
4. Press the **EXIT (LOCAL)** key twice to return to the LAN CONFIG menu.
5. Select **APPLY_SETTINGS > YES**, and then press the **ENTER** key.

To set the DNS server IP addresses:

1. From the front panel, press the **MENU** key and select **LAN > CONFIG > DNS**.
2. Turn the navigation wheel to select either **DNS-ADDRESS1** or **DNS-ADDRESS2**.
3. Press the **ENTER** key.
4. Turn the navigation wheel to select and enter a valid IP address for the DNS server.
5. Press the **ENTER** key.
6. Press the **EXIT (LOCAL)** key twice to return to the LAN CONFIG menu.
7. Select **APPLY_SETTINGS > YES**, and then press the **ENTER** key.

Confirming the active speed and duplex negotiation

The 2601B-PULSE automatically detects the speed and duplex negotiation active on the LAN. Once the speed and duplex negotiation is detected, the instrument automatically adjusts its own settings to match the LAN settings.

To confirm the active LAN speed and duplex mode:

1. From the front panel, press the **MENU** key.
2. Select **LAN > STATUS**.
3. Use the navigation wheel to select one of the following:
 - **SPEED**
 - **DUPLEX**
4. Press the **ENTER** key to view the active setting.
5. Press the **EXIT (LOCAL)** key once to return to the STATUS menu.

To set the duplex mode:

1. From the front panel, press the **MENU** key and select **LAN > CONFIG > DUPLEX**.
2. Turn the navigation wheel to select either **HALF** or **FULL**.
3. Press the **ENTER** key.
4. Press the **EXIT (LOCAL)** key once to return to the LAN CONFIG menu.
5. Select **APPLY_SETTINGS > YES**, and then press the **ENTER** key.

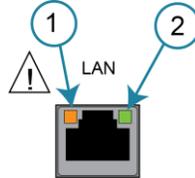
Use the LXI Discovery Tool

To find the IP address of the 2601B-PULSE from a computer, use the LXI Discovery Tool, a utility that is available from the Resources tab of the [LXI Consortium website \(lxistandard.org\)](http://lxistandard.org).

LAN status LEDs

The figure below illustrates the two status light-emitting diodes (LEDs) that are on the LAN port of the instrument. The table below the figure provides explanations of the LED states. The LED labeled 1 indicates the LAN port is connected to a 100 Mbps network. The LED labeled 2 indicates the LAN port is connected to a 10 Mbps network.

Figure 20: LAN status



When an LED is:	The network:
Off	is not connected
On	is connected
Blinking	is sending or receiving data

Selecting a LAN interface protocol

You can use a remote interface protocol to connect to the 2601B-PULSE. The 2601B-PULSE provides Telnet, VXI-11, and raw socket LAN interfaces, with associated LAN protocols (each interface uses a different protocol). Select the interface based on the protocol needed.

You can also use a dead socket termination interface (DST) to troubleshoot connection problems.

NOTE

You can only use one remote interface at a time. Although multiple ethernet connections to the instrument can be opened, only one can be used to control the instrument at a time.

Telnet connection

The Telnet protocol is similar to raw socket and can be used when you need to interact directly with the instrument. Telnet is often used for debugging and troubleshooting. You need a separate Telnet program to use this protocol.

The 2601B-PULSE supports the Telnet protocol, which you can use over a TCP/IP connection to send commands to the instrument. You can use a Telnet connection to interact with scripts or send real-time commands.

VXI-11 connection

This remote interface is similar to GPIB and supports message boundaries, serial poll, and service requests (SRQs). A VXI-11 driver or NI-VISA software is required. Test Script Builder (TSB) uses NI-VISA and can be used with the VXI-11 interface. You can expect a slower connection with this protocol.

Raw socket connection

All Keithley instruments that have LAN connections support raw socket communication. This means that you can connect to the TCP/IP port on the instrument and send and receive commands. A programmer can easily communicate with the instrument using the Winsock API on computers with the Microsoft® Windows® operating system or using the Berkeley Sockets API on Linux® or Apple® computers.

Raw socket is a basic ethernet connection that communicates in a manner similar to RS-232 without explicit message boundaries. The instrument always terminates messages with a line feed, but because binary data may include bytes that resemble line-feed characters, it may be difficult to distinguish between data and line-feed characters.

Use raw socket as an alternative to VXI-11. Raw socket offers a faster connection than VXI-11. However, raw socket does not support explicit message boundaries, serial poll, and service requests.

Dead socket connection

The dead socket termination (DST) port is used to terminate all existing ethernet connections. A dead socket is a socket that is held open by the instrument because it has not been properly closed. This most often happens when the host computer is turned off or restarted without first closing the socket. This port cannot be used for command and control functions.

Use the dead socket termination port to manually disconnect a dead session on any open socket. All existing ethernet connections are terminated and closed when the connection to the dead socket termination port is closed.

Confirming port numbers

To view the port number assigned to each remote interface protocol:

1. From the front panel, press the **MENU** key, and then select **LAN > STATUS > PORT**.
2. Use the navigation wheel to select one of the following:
 - **RAW-SOCKET**
 - **TELNET**
 - **VXI-11**
 - **DST**
3. Press the **ENTER** key to view the port number.
4. Press the **EXIT (LOCAL)** key once to return to the PORT menu.

The following table displays the remote interface protocols supported by the 2601B-PULSE and their assigned port numbers.

Port number

Command interface	Port number
Raw socket	5025
Telnet	23
VXI-11	1024
DST (dead socket termination)	5030

Reset LAN settings

To reset the LAN settings to the factory defaults from the front panel, select **MENU > LAN > RESET**.

LAN troubleshooting suggestions

If you are unable to connect to the web interface of the instrument, check the following items:

- The network cable is in the LAN port on the rear panel of the instrument, not one of the TSP-Link® ports.
- The network cable is in the correct port on the computer. The LAN port of a laptop may be disabled when the laptop is in a docking station.
- The setup procedure used the configuration information for the correct ethernet card.
- The network card of the computer is enabled.
- The IP address of the instrument is compatible with the IP address on the computer.
- The subnet mask address of the instrument is the same as the subnet mask address of the computer.

You can also try restarting the computer and the instrument.

To restart the instrument:

1. Turn the power to the instrument off, and then on.
2. Wait at least 60 seconds for the network configuration to be completed.

Access the instrument web interface

To access the instrument web interface:

1. Open a web browser on the host computer.
2. Enter the IP address of the instrument in the web browser address box. For example, if the instrument IP address is 192.168.1.101, enter 192.168.1.101 in the browser address box.
3. Press **Enter** on the computer keyboard to open the instrument web interface.

NOTE

If the web interface does not open in the browser, see [LAN troubleshooting suggestions](#) (on page 2-25).

Viewing LAN status messages

To view the LAN status messages:

1. From the front panel, press the **MENU** key and select **LAN > STATUS > CONFIG/FAULT**.
2. Press the **ENTER** key.

Figure 21: LAN CONFIG/FAULT



There are two types of LAN status messages:

- **LAN fault messages:** Communicate issues related to physical connectivity.
- **LAN configuration messages:** Communicate issues or events related to configuration.

The following table displays possible fault and configuration messages.

LAN CONFIG/FAULT messages

LAN message type	Possible messages
LAN fault	Could not acquire IP address
	Duplicate IP address detected
	DHCP lease lost
	Lan Cable Disconnected
LAN configuration	Starting DHCP Configuration
	DHCP Server Not Found
	DHCP configuration started on xxx.xxx.xxx.xxx
	Searching for DNS server(s)
	Starting DLLA Configuration
	DLLA Failed
	DLLA configuration started on xxx.xxx.xxx.xxx
	Starting Manual Configuration
	Manual configuration started on xxx.xxx.xxx.xxx
Closed	

Monitoring the LAN

The `lan.autoconnect` command configures the instrument to monitor the LAN for lost connections. All ethernet connections are disconnected if the LAN link is disconnected for longer than the time-out value specified in the `lan.linktimeout` attribute.

GPIB operation

The following topics contain information about GPIB standards, bus connections, and primary address selection.

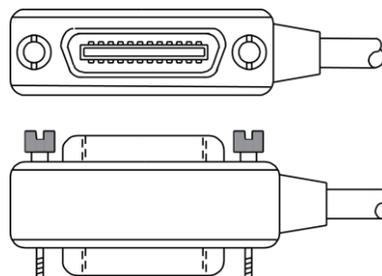
GPIB standards

The GPIB is the IEEE-488 instrumentation data bus, which uses hardware and programming standards originally adopted by the Institute of Electrical and Electronic Engineers (IEEE) in 1975. The instrument is IEEE Std 488.1 compliant and supports IEEE Std 488.2 common commands and status model topology.

Connect the GPIB cable

To connect an instrument to the GPIB bus, use a cable equipped with standard IEEE-488 connectors, as shown below.

Figure 22: GPIB connector

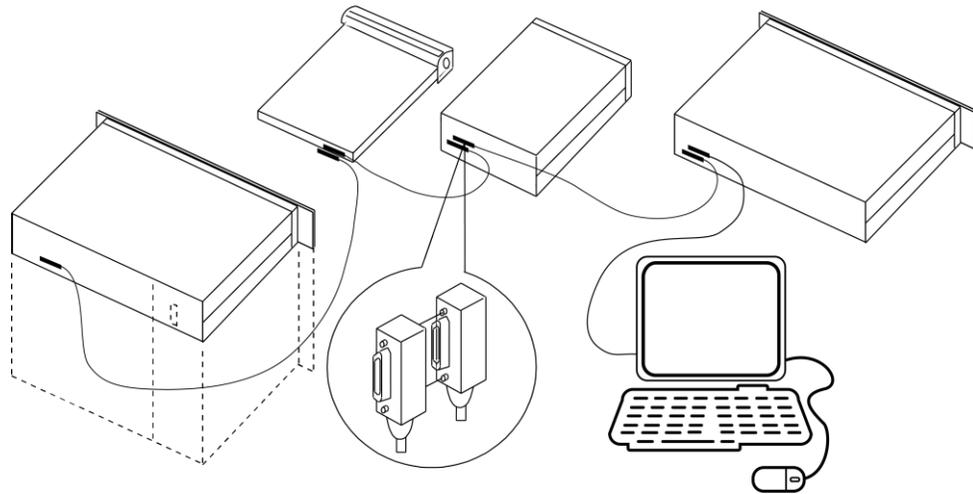


To allow many parallel connections to one instrument, stack the connectors. Each connector has two screws on it to ensure that connections remain secure. The figure below shows a typical connection diagram for a test system with multiple instruments.

CAUTION

To avoid possible mechanical damage, stack no more than three connectors on any one instrument. To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. Contact Keithley Instruments for shielded cables.

Figure 23: IEEE-488 connections



To connect the instrument to the IEEE-488 bus, line up the cable connector with the connector on the rear panel. Install and tighten the screws securely, making sure not to overtighten them. Refer to [Remote interface connections](#) (on page 2-12) for the location of the connector.

Connect any additional connectors from other instruments as required for your application. Make sure the other end of the cable is properly connected to the controller. You can have up to 15 devices connected to a GPIB interface, including the controller. The maximum cable length is the lesser of either:

- The number of devices multiplied by 2 m (6.5 ft)
- 20 m (65.6 ft)

You may see erratic bus operation if you ignore these limits.

Primary address

The 2601B-PULSE ships from the factory with a GPIB primary address of 26. If the GPIB interface is enabled, it momentarily displays the primary address on power-up. You can set the address to a value from 0 to 30, but do not assign the same address to another device or to a controller that is on the same GPIB bus (controller addresses are usually 0 or 21).

To set or check the primary address from the front panel:

1. Press the **MENU** key, select **GPIB**, and then press the **ENTER** key or the navigation wheel.
2. Select **ADDRESS**, then press the **ENTER** key or the navigation wheel.
3. Use the navigation wheel to set the primary address to the appropriate value, then press the **ENTER** key or the navigation wheel.
4. Press the **EXIT (LOCAL)** key twice to return to the normal display.

To set the primary address remotely:

```
gpib.address = address
```

To set the primary address remotely to 20:

```
gpib.address = 20
```

Note that changing the GPIB address takes effect when the command is processed. Any response messages generated after processing this command are sent with the new settings. If command messages are being queued (sent before this command has executed), the new settings may take effect in the middle of a subsequent command message, so be careful when setting this attribute from the GPIB interface.

GPIB terminator

When receiving data over the GPIB, the instrument terminates messages on any line feed character or any data byte with EOI asserted (line feed with EOI asserted is also valid). When sending data, it appends a line feed character to all outgoing messages. The EOI line is asserted with the terminating line feed character.

Front-panel GPIB operation

This section describes aspects of the front panel that are part of GPIB operation, including messages, status indicators, and the LOCAL key.

Error and status messages

The front-panel display may show error and status messages (see [Displayed error and status messages](#) (on page 3-14)). The instrument can be programmed to generate a service request (SRQ), and command queries can be performed to check for specific error conditions.

Communication status indicators

The remote (REM), talk (TALK), listen (LSTN), and service request (SRQ) indicators show the communication bus status. Each of these indicators is described in the following table.

Status indicator	Applies to
REM	GPIB, VXI-11, USB, RS-232
TALK	GPIB only
LSTN	GPIB only
SRQ	GPIB, VXI-11, USB

REM

This indicator is illuminated when the instrument is in the remote-control state. When the instrument is in the remote-control state, all front-panel keys, except for the EXIT (LOCAL) key and OUTPUT ON/OFF control, are locked out. When REM is off, the instrument is in the local-control state and front-panel operation is restored.

TALK

This indicator is on when the instrument is in the talker active state. Place the instrument in the talk state by addressing it to talk with the correct talk command. TALK is off when the instrument is in the talker idle state. Place the instrument in the talker idle state by sending a UNT (untalk) command, addressing it to listen, or by sending the IFC (interface clear) command.

LSTN

This indicator is on when the instrument is in the listener active state, which is activated by addressing the instrument to listen with the correct listen command. LSTN is off when the instrument is in the listener idle state. Place the instrument in the listener idle state by sending UNL (unlisten), addressing it to talk, or by sending the IFC (interface clear) command over the bus.

SRQ

You can program the instrument to generate a service request (SRQ) when one or more errors or conditions occur. When this indicator is on, a service request was generated. This indicator stays on until all conditions that caused the SRQ are cleared.

Note that while the SRQ indicator turns on when a service request is generated, it reflects the state of the master summary status (MSS) bit and not the request for service (RQS) bit. Therefore, performing a serial poll does not turn off the indicator. To turn off the indicator, you must use `*CLS` or `status.reset()` to clear all the conditions that caused the MSS bit to be set.

NOTE

The SRQ applies to all available communication buses. However, actual service requests only apply to GPIB, USB, and VXI-11.

For additional information on using the SRQ, refer to “Status byte and service request (SRQ)” in the *Model 2601B-PULSE Reference Manual*.

LOCAL key

The EXIT (LOCAL) key cancels the remote state and restores local operation of the instrument. Pressing the EXIT (LOCAL) key turns off the REM indicator and returns the display to normal if a user-defined message was displayed. Pressing the EXIT (LOCAL) key or the OUTPUT ON/OFF control also aborts any commands or scripts that are being processed.

If the LLO (local lockout setting) command is in effect, the EXIT (LOCAL) key is inoperative. For safety reasons, you can use the OUTPUT ON/OFF control to turn the output off while in LLO.

RS-232 interface operation

The following topics contain information about configuring RS-232 communication parameters, sending or receiving command messages, and requesting or retrieving data. To control the 2601B-PULSE, connect a controller or personal computer to the 2601B-PULSE RS-232 interface. Alternatively, you can use the 2601B-PULSE to control another device over RS-232.

Setting RS-232 interface parameters

To set interface parameters from the front panel:

1. Press the **MENU** key, select **RS232**, and then press the **ENTER** key or the navigation wheel.
2. Select and enter the following interface parameters:
 - **BAUD:** Set baud rate (see [Baud rate](#) (on page 2-32))
 - **BITS:** Set number of bits (see [Data bits and parity](#) (on page 2-32))
 - **PARITY:** Set parity
 - **FLOW-CTRL:** Set [Flow control and signal handshaking](#) (on page 2-32)
 - **ENABLE:** Enable or disable the RS-232 interface
3. Press the **EXIT (LOCAL)** key twice to return to the normal display.

Remote RS-232 parameters

Commands to set RS-232 parameters are listed in the following table.

RS-232 interface commands

Command	Description
<code>serial.baud = baud</code>	Set baud rate (300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200)
<code>serial.databits = bits</code>	Set number of bits (7 or 8)
<code>serial.flowcontrol = flow</code>	Set flow control: <code>serial.FLOW_NONE</code> (no flow control) <code>serial.FLOW_HARDWARE</code> (hardware flow control)
<code>serial.parity = parity</code>	Set parity: <code>serial.PARITY_NONE</code> (no parity) <code>serial.PARITY_EVEN</code> (even parity) <code>serial.PARITY_ODD</code> (odd parity)

Changes to a serial port setting take effect when the command is processed. Any response messages generated after the commands are processed are sent with the new settings. If command messages are being queued (sent before the commands have executed), the new settings may take effect in the middle of a subsequent command message, so be careful when setting these attributes from the RS-232 interface.

RS-232 programming example

The programming example below illustrates how to set the baud rate to 9600 with no flow control:

```
serial.baud = 9600
serial.flowcontrol = serial.FLOW_NONE
```

Sending and receiving data

The RS-232 interface transfers data using 7 or 8 data bits; 1 stop bit; and no, even, or odd parity. Make sure the device you connect to the 2601B-PULSE also uses the same settings.

RS-232 terminator

When receiving data over the RS-232 interface, the command interface terminates on line feeds. A line feed is appended to all output messages when the RS-232 interface is used as a command interface.

Sending data using the `serial.write()` function does not append a terminator. Be sure to append the appropriate terminator to the message before sending it.

Baud rate

The baud rate is the rate at which the 2601B-PULSE and the programming terminal communicate. Select one of the following available rates:

- 115200
- 57600
- 38400
- 19200
- 9600
- 4800
- 2400
- 1200
- 600
- 300

The factory-selected baud rate is 9600.

Both the 2601B-PULSE and the programming terminal must be configured for the same baud rate. Make sure the device connected to the 2601B-PULSE RS-232 port can support the selected baud rate.

Data bits and parity

The RS-232 interface can be configured to send/receive data that is 7 or 8 bits long using even, odd, or no parity.

Flow control and signal handshaking

Signal handshaking between the controller and the instrument allows the two devices to communicate to each other to determine if they are ready to receive data.

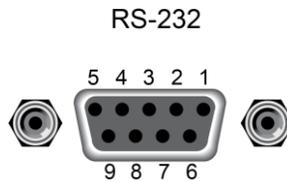
The RS-232 interface provides two control lines (request to send and clear to send) for this purpose. The instrument asserts the RTS signal when it is admissible for the computer to transmit to the instrument. It sends information to the computer when the CTS signal is asserted by the computer.

RS-232 connections

Connect the RS-232 serial port of the 2601B-PULSE to the serial port of a computer using a straight-through RS-232 cable terminated with DB-9 connectors. Do not use a null modem cable. The serial port uses the transmit (TXD), receive (RXD), CTS and RTS (if flow control is enabled), and signal ground (GND) lines of the RS-232 standard. The connector location is shown in [Remote communications interfaces](#) (on page 2-12).

If your computer uses a DB-25 connector for the RS-232 interface, you need a standard cable or adapter with a DB-25 connector on one end and a DB-9 connector on the other.

Figure 24: RS-232 interface connector



RS-232 connector pinout

Pin number	Description
1	Not used
2	TXD, transmit data
3	RXD, receive data
4	Not used
5	GND, signal ground
6	Not used
7	RTS, ready to send
8	CTS, clear to send
9	Not used

The following table provides pinout identification for the 9-pin (DB-9) or 25-pin (DB-25) serial port connector on the computer.

Computer serial port pinout

Signal*	DB-9 pin number	DB-25 pin number
DCD, data carrier detect	1	8
RXD, receive data	2	3
TXD, transmit data	3	2
DTR, data terminal ready	4	20
GND, signal ground	5	7
DSR, data set ready	6	6
RTS, request to send	7	4
CTS, clear to send	8	5
RI, ring indicator	9	22

* The 2601B-PULSE does not use all RS-232 signals. See [Flow control and signal handshaking](#) (on page 2-32).

Software components for applications and instrument drivers

The majority of software applications and all instrument drivers from Keithley Instruments depend on the following software components:

- NI-VISA
- VISA shared components
- IVI shared components
- NI CVI runtime engine
- NI IVI compliance package
- Keithley instrument driver

These software components are available for download from the [Product Support and Downloads web page](https://www.tek.com/product-support) ([tek.com/product-support](https://www.tek.com/product-support)).

Instrument driver types

There are several different styles of instrument drivers. Keithley Instruments provides the following instrument drivers for the 2601B-PULSE:

- A native LabVIEW driver
- An IVI-C driver
- An IVI-COM driver

You need to pick the style that best suits the application development environment (ADE) that you are using. For example, if you are using LabVIEW, pick a native LabVIEW driver. If a native LabVIEW driver is not available, you can use an IVI-C driver because LabVIEW has the option of creating a wrapper for the IVI-C driver.

LabVIEW supports IVI-COM drivers, but they are not preferred. However, if they are the only driver types available for the instrument, they can be used.

If LabWindows/CVI or C/C++ is your programming language, an IVI-C driver is the best option. For Microsoft® Visual Basic® 6.0 and any .NET language (C#, VB.NET, and so on), an IVI-COM driver is the best option.

Sometimes instrument vendors do not provide all three driver types. Most languages can accommodate other driver types, but this is not optimal.

The following sections describe the different driver types in more detail.

VXIPnP drivers

VXI*plug&play* (VXIPnP) style drivers are Win32 DLLs that have some standard functions defined by the [IVI Foundation \(ivifoundation.org\)](http://ivifoundation.org), such as:

- init
- close
- error_message
- reset
- self_test
- read
- initiate
- fetch
- abort

The application programming interface (API) was defined so that users of instruments have a familiar API from instrument to instrument. There are some basic guidelines when creating APIs for your instrument, such as using VISA data types and how to construct the CVI hierarchy.

LabVIEW drivers

Native LabVIEW drivers

A native LabVIEW™ driver is a LabVIEW driver that is created using entirely built-in LabVIEW VIs. It does not make any calls to external DLLs or Library files. This makes the driver portable to all the platforms and operating systems that LabVIEW and VISA supports (such as Linux® on x86, Mac OS® X, and Microsoft® Windows®).

LabVIEW driver wrappers

All IVI-C drivers have a function panel file (file name extension .fp) that shows a hierarchy of the function calls into a DLL. It is a tool that guides a user to select the correct function call in the driver, because a DLL only has a flat API entry point scheme (unlike COM or .NET).

Any CVI-generated .fp files can be imported into LabVIEW and LabVIEW generates a wrapper for the DLL. The drawback here is that the driver is dependent on the DLL, which is not portable and is therefore specific to the Windows operating system.

Getting instrument drivers

To see what drivers are available for your instrument:

1. Go to the [Product Support and Downloads web page \(tek.com/product-support\)](http://tek.com/product-support).
2. Enter the model number of your instrument.
3. Select **Software** from the list.
4. Select and download the file.

For LabVIEW™, you can also go to the National Instruments website and search their instrument driver database.

Instrument driver examples

All Keithley drivers come with examples written in several programming languages that show you how to do common tasks with the instruments. The examples are available in the drivers and through Test Script Builder.

IVI shared components

The IVI shared components are similar in concept to the VISA shared components. The IVI Foundation provides class drivers for:

- All the supported instruments (DMM, Scope, Fgen, and so on)
- The configuration store

The IVI shared components also create the installation folders and registry keys that all IVI drivers and support files use for installation.

Interchangeable Virtual Instruments (IVI) style drivers

The [IVI Foundation](http://ivifoundation.org) (ivifoundation.org) defined a set of application programming interfaces (APIs) for instruments, including digital multimeters, arbitrary waveform/function generators, dc power supplies, ac power supplies, oscilloscopes, switches, spectrum analyzers, RF signal generators, and power meters.

There are two types of IVI drivers, IVI-COM and IVI-C. IVI-COM drivers use Microsoft® COM technology to expose driver functionality. IVI-C drivers use conventional Microsoft® Windows® DLLs to export simple C-based functions.

For more information about IVI drivers and the differences between the COM, C, and .NET interfaces, see [Understanding the Benefits of IVI](http://ivifoundation.org/docs/Understanding%20the%20Benefits%20of%20IVI[3].pdf) ([ivifoundation.org/docs/Understanding%20the%20Benefits%20of%20IVI\[3\].pdf](http://ivifoundation.org/docs/Understanding%20the%20Benefits%20of%20IVI[3].pdf)).

NI CVI runtime engine

IVI-C drivers that are created using the National Instruments (NI™) LabWindows/CVI environment depend on either the CVI runtime DLL (`cvirte.dll`) or the instrument support runtime DLL (`instrsup.dll`). These DLLs must be present on the system for them to run.

NI IVI Compliance Package

The National Instruments (NI™) IVI Compliance Package (ICP) is a software package that contains IVI class drivers and support libraries that are needed for the development and use of applications that leverage IVI instrument interchangeability. The IVI Compliance Package also is based on and is compliant with the latest version of the instrument programming specifications defined by the IVI Foundation.

The NI ICP installer installs the IVI shared components, CVI runtime engine, and the instrument support runtime engine.

Keithley I/O layer

The Keithley I/O Layer (KIOL) is a software package that contains several utilities and drivers. It is mainly used as a supplement to IVI drivers or application software like Test Script Builder (TSB).

For additional detail on the Keithley I/O layer, including computer requirements and installation instructions, see the tek.com/keithley website.

Keithley Configuration Panel

The Keithley Configuration Panel is a configuration utility for IVI drivers, similar to NI-MAX. It can also autodetect USBTMC instruments and LAN instruments that support the VXI-11 protocol.

Keithley Communicator

The Keithley Communicator is a dumb terminal program that uses VISA to communicate with the instrument.

How to install the Keithley I/O Layer

NOTE

Before installing, it is a good practice to check the [Product Support and Downloads web page \(tek.com/product-support\)](http://tek.com/product-support) to verify that you have the latest version of the Keithley I/O Layer.

You can download the Keithley I/O Layer from the Keithley website.

To install the Keithley I/O Layer from the Keithley website:

1. Download the Keithley I/O Layer Software from the Product Support and Downloads web page. The software is a single compressed file.
2. Run the downloaded file from the temporary directory.
3. Follow the instructions on the screen to install the software.
4. Reboot your computer to complete the installation.

Using the interlock

You can set up an interlock for the 2601B-PULSE through the 2601B-P-INT Interlock and Cable Connector Box. When properly used, the output of the instrument turns OFF when the safety fixture switch opens.

The interlock requires a separate safety fixture switch that is wired to the interlock input on the 2601B-P-INT. For the interlock voltage, you can use the +5 V source pins of the 2601B-PULSE digital I/O port or an external +5 V source.

It also requires use of the Keithley Model CS-1616-3 Safety Interlock Mating Connector, which is supplied with the instrument. This part is also available from 3M, part number 37103-A165-00E.

See [DUT Test Connections](#) (on page 4-7) for important safety information when using a test fixture.

⚠ WARNING

When an interlock is required for safety, a separate circuit should be provided that meets the requirements of the application to reliably protect the operator from hazardous conditions. The digital I/O port is a suitable source for the 5 V required to power the physical interlock provided by the 2601B-P-INT. Failure to adhere to these guidelines could result in personal injury or death.

⚠ WARNING

The 2601B-PULSE with the 2601B-P-INT installed provides an optional interlock circuit. Once engaged, the interlock helps facilitate the safe operation of the instrument in a test system by prohibiting the output voltage and current when the interlock circuit is opened. Not using the interlock could expose the operator to hazardous conditions within the test circuit that could result in personal injury or death.

Interlock operation

You can set up the interlock using the +5 V supply pins on the digital I/O port on the rear panel of the instrument or by using an external 5 V source. Both methods use the Model 2601B-P-INT Interlock and Cable Connector Box to make connections.

With either method, relays in the 2601B-P-INT are in a de-energized state until a remote switch is closed. The de-energized state prevents current from passing to the device under test (DUT) by keeping the FORCE HI terminal shorted to the FORCE LO terminal. When the external safety switch closes, current is sourced from a +5 V pin on the digital I/O port or the external power supply, which energizes the relay and opens the shorting contacts. When the contacts are open, the 2601B-PULSE can source power to the DUT.

If the remote switch is part of a test fixture, if the lid of the test fixture opens, the relay is closed and the output of the 2601B-PULSE instrument turns off. When the lid is closed, the relay contacts open and the output can be turned on.

To use the interlock, you must set the jumper on the rear panel of the 2601B-P-INT to ENABLE. Refer to [Installing the 2601B-P-INT](#) (on page 2-6) for information on setting the jumper.

When the jumper is set to ENABLE, the safety interlock relay immediately requires 5 V to open. Depending on the availability of the 5 V signal, the short is applied to or removed from the Force HI and LO terminals on the 2601B-P-INT, regardless of the interlock setting made through the front panel or by using the remote commands.

To synchronize the operation of the 2601B-PULSE output with the jumper setting of the 2601B-P-INT, you must also enable the interlock through the front panel or by using the remote commands.

To enable the interlock through the front panel:

1. Press the **CONFIG** key.
2. Select the **OUTPUT** menu item.
3. Select **INTERLOCK**.
4. Select **DISABLE** to disable the interlock or **ENABLE** to enable it.

To enable the interlock using a remote command, send:

```
smua.interlock.enable = smua.ENABLE
```

To disable the interlock using a remote command, send:

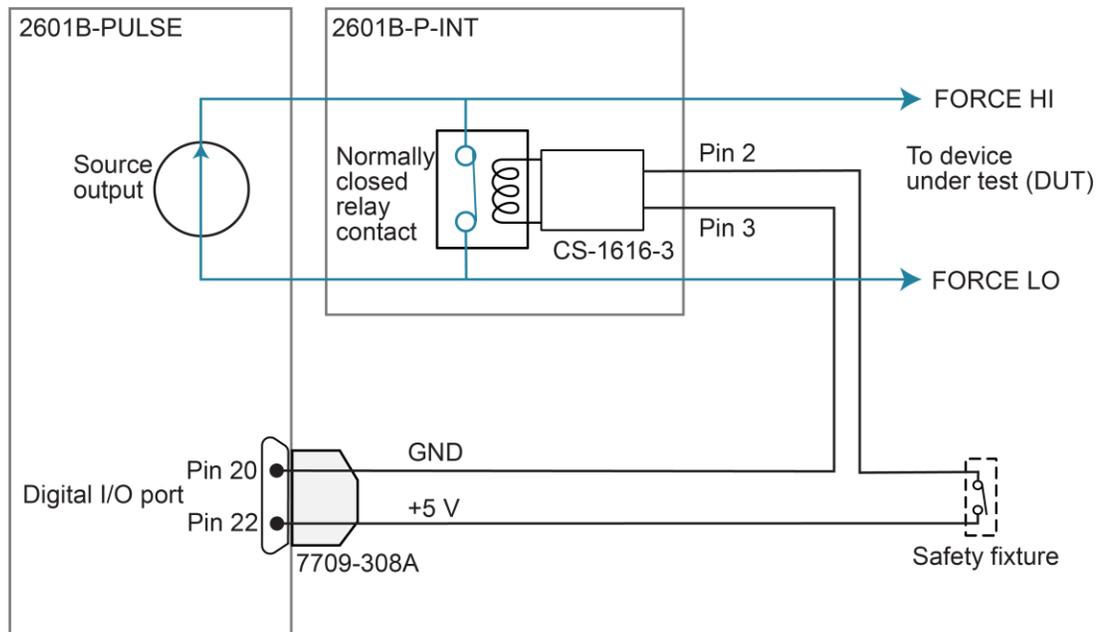
```
smua.interlock.enable = smua.DISABLE
```

Interlock connections through digital I/O port

The following figure shows digital I/O port pin 20 as ground. You can also use pin 15, 16, 17, 18, 19, or 21 as ground.

The +5 V source is shown as digital I/O port pin 22. You can also use pin 23 or 25 as the +5 V source. Use a two-conductor low-voltage cable to connect the +5 V source to the low-voltage remote switch. The recommended cable is 22 AWG (20 AWG maximum) with 1.2 mm to 1.6 mm outer diameter.

Figure 25: Digital I/O port interlock connections

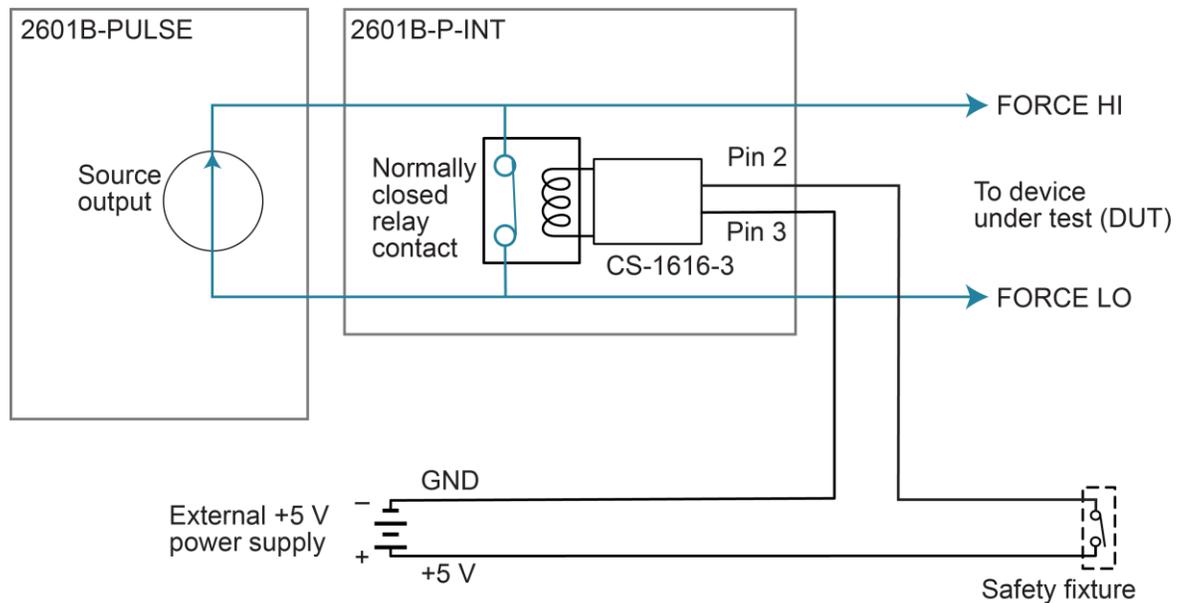


Interlock connections using external source

Use a +5 V external power supply with a $\pm 5\%$ tolerance. The 2601B-P-INT interlock requires approximately 125 mA to operate.

Use a two-conductor low-voltage cable to connect the +5 V source to the low-voltage remote switch. The recommended cable is 22 AWG (20 AWG maximum) with 1.2 mm to 1.6 mm outer diameter.

Figure 26: External source interlock connections



Wiring the interlock mating connector

Use the Keithley Instruments CS-1616-3 Safety Interlock Mating Connector supplied with the 2601B-PULSE to make the interlock connection to the 2601B-P-INT. You must supply connection wire. When using the CS-1616-3 interlock mating connector with a Keithley instrument, use the following recommendations for choosing a connection wire:

- Copper alloy
- 7 to 19 bare and tinned strands
- 0.25 mm² to 0.50 mm², 20 AWG to 24 AWG
- Flexible vinyl, semi-flexible vinyl, polyethylene, cross-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.

To assemble the interlock:

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

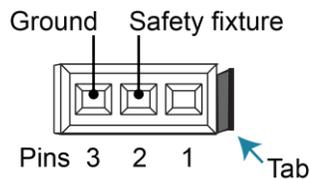
NOTE

You cannot disassemble and reuse the CS-1616-3.

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 27: Interlock mating connector pins



System information

You can retrieve serial number, firmware revision, calibration dates, and memory usage from the instrument.

To view the system information from the front panel:

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

To retrieve system information from a remote interface:

To retrieve the firmware revision and serial number, send the `*IDN?` query.

For more information on retrieving system information, see the *Model 2601B-PULSE Reference Manual*. In particular:

- To determine memory usage, see the `meminfo()` function.
- To determine when calibration was last run, see `smua.cal.date`.
- To determine when calibration is due, see `smua.cal.due`.

Instrument description

In this section:

Controls, indicators, and connectors	3-1
Menu overview	3-7
Beeper	3-14
Displayed error and status messages	3-14
Display operations.....	3-15
Connecting the USB flash drive	3-27
Restoring the factory default setups using remote commands.....	3-28
Using the web interface.....	3-28

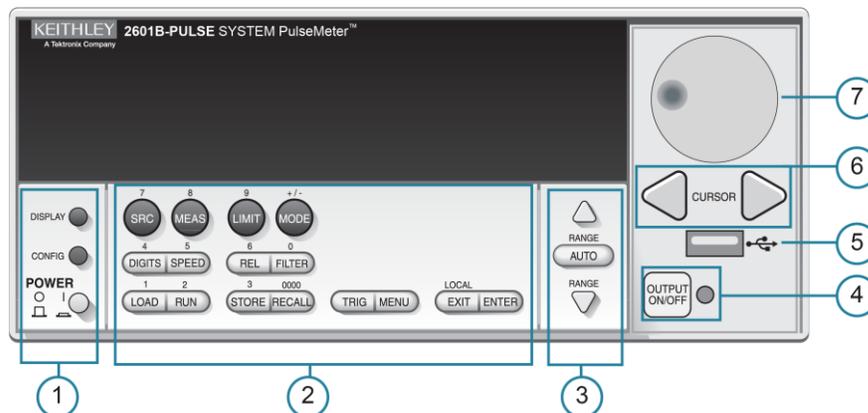
Controls, indicators, and connectors

2601B-PULSE controls, indicators, and the USB port are on the [front panel](#) (on page 3-1). Make connections to the 2601B-PULSE through connectors on the [rear panel](#) (on page 3-5).

Front panel

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

Figure 28: 2601B-PULSE front-panel controls



1. Power switch, display, and configuration keys

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

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

SMU (source-measure unit) setup



SRC	When the pulser is disabled, selects the source function (voltage or current) and places the cursor in the source field for editing. When the pulser is enabled, this key has no action.
MEAS	Cycles through measure functions (voltage, current, resistance, or power).
LIMIT	When the pulser is disabled, places the cursor in the compliance limit field for editing. Also selects the limit value to edit (voltage, current, or power). When the pulser is enabled, switches the display between the source and sense protection levels.
MODE	Selects a meter mode (I-METER, V-METER, OHM-METER, or WATT-METER).

Performance control



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

Special operation

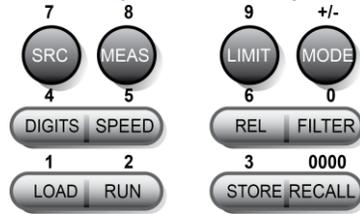


LOAD	Loads a test for execution (FACTORY, USER, or SCRIPTS).
RUN	Runs the last selected factory or user-defined test.
STORE	Accesses reading buffers and makes readings: <ul style="list-style-type: none"> ▪ TAKE_READINGS: Use to make readings and store them in a reading buffer. ▪ SAVE: Use to save a reading buffer to nonvolatile memory or to a user-installed flash drive (USB1) in CSV or XML format. Readings can include measurements, source values, and timestamp values.
RECALL	Recalls information (DATA or STATISTICS) stored in a reading buffer: <ul style="list-style-type: none"> ▪ DATA: Includes stored readings, and if configured, source values and timestamp values. ▪ STATISTICS: Includes MEAN, STD DEV, SAMPLE SIZE, MINIMUM, MAXIMUM, PK-PK.
TRIG	Triggers readings.
MENU	Accesses the main menu (on page 3-8). You can use the main menu to configure many functions and features.
EXIT	Cancels the selection and returns to the previous menu or display. Also used as a LOCAL key to take the instrument out of remote operation.
ENTER	Accepts the selection and moves to the next choice or exits the menu.

Numbers

Number keys

When enabled and in EDIT mode, the number keys (0 to 9, +/-, 0000) allow direct numeric entry. Press the navigation wheel to enter EDIT mode. For more information, see [Setting a value](#) (on page 3-12).



3. Range keys



The RANGE and AUTO keys are only active when the pulser is disabled. Selects the next higher source or measure range.



Enables or disables source or measure autorange.



Selects the next lower source or measure range.

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

4. Output control



Turn the source output on or off.

5. USB port



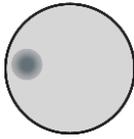
Use the USB port to connect a USB flash drive to the instrument. You can use the USB flash drive to store reading buffer data, scripts, and user setups. You can also use it to upgrade the firmware.

6. Cursor keys



Use the CURSOR keys to move the cursor left or right. When the cursor is on the source or compliance value digit, press the navigation wheel to enter edit mode, and turn the navigation wheel to edit the value. Press the navigation wheel again when you finish editing. Use the CURSOR keys or the navigation wheel to move through menu items. To view a menu value, use the CURSOR keys for cursor control, and then press the navigation wheel to view the value or submenu item.

7. Navigation wheel



Turn the navigation wheel to:

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

Push the navigation wheel to:

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

8. Display indicators (not shown)

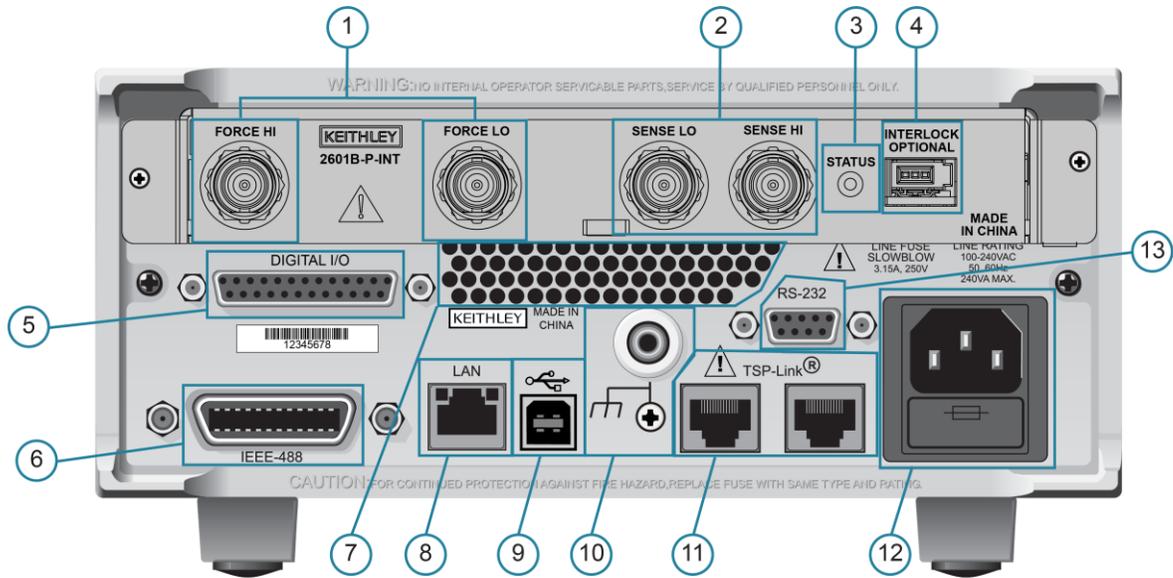
The items listed below represent the possible display indicators and their meanings.

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

Rear panel

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

Figure 29: Rear panel

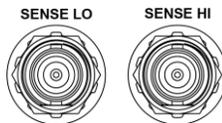


1. FORCE HI and FORCE LO connectors



These connectors provide connections for FORCE HI and FORCE LO. Refer to [FORCE and SENSE connectors](#) (on page 4-8) for additional information.

2. SENSE LO and SENSE HI connectors



These connectors provide connections for SENSE LO and SENSE HI. Refer to [FORCE and SENSE connectors](#) (on page 4-8) for additional information.

3. STATUS indicator



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

4. INTERLOCK connector



This connector provides a connection for the optional interlock. Refer to [Using the interlock](#) (on page 2-37) for information on setting up and connecting the interlock.

5. Digital I/O

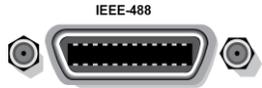


Female DB-25 connector. Use a cable equipped with a male DB-25 connector (L-com part number CSMN25MF-5).

Pins provided:

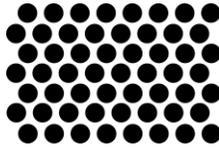
- Fourteen digital input or output pins
- Seven GND pins
- Three +5 V pins

6. IEEE-488



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

7. Cooling exhaust vents



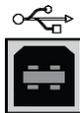
Exhaust vent for the internal cooling fan. Keep the vent free of obstructions to prevent overheating. Also see [Cooling vents](#) (on page 2-8).

8. LAN



RJ-45 connector for a local area network (LAN). The LAN interface supports Auto-MDIX, so you can use either a CAT-5e crossover cable or a normal CAT-5e straight-through cable.

9. USB port



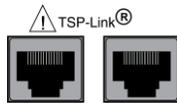
Use the USB-2.0 receptacle (Type B) on the rear panel to connect the instrument to a computer. You can use this connection to send commands to the instrument.

10. Ground



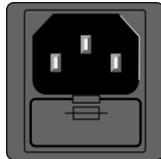
Ground terminal for connecting output HI or LO to chassis ground.
Ground screw for connecting to chassis ground.

11. TSP-Link



Expansion interface that allows a 2601B-PULSE and other TSP-enabled instruments to trigger and communicate with each other.

12. Power module



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

13. RS-232



Female DB-9 connector. For RS-232 operation, use a straight-through (not null modem) DB-9 shielded cable to connect to the computer.

Menu overview

The following topics describe how to work with the front-panel menus.

Menu navigation

To navigate through the menus and submenus, the 2601B-PULSE must not be in edit mode (the EDIT indicator is not illuminated).

Selecting menu items

To navigate the Main and Configuration menus, use the front-panel keys as follows:

- Press either **CURSOR** arrow key to highlight an option.
- Rotate the navigation wheel (clockwise or counterclockwise) to highlight an option.
- Press the **ENTER** key (or the navigation wheel) to select an option.
- Use the **EXIT (LOCAL)** key to cancel changes or to return to the previous menu or display.

NOTE

For quick menu navigation, turn the navigation wheel to highlight an option and then press the navigation wheel to select the highlighted option.

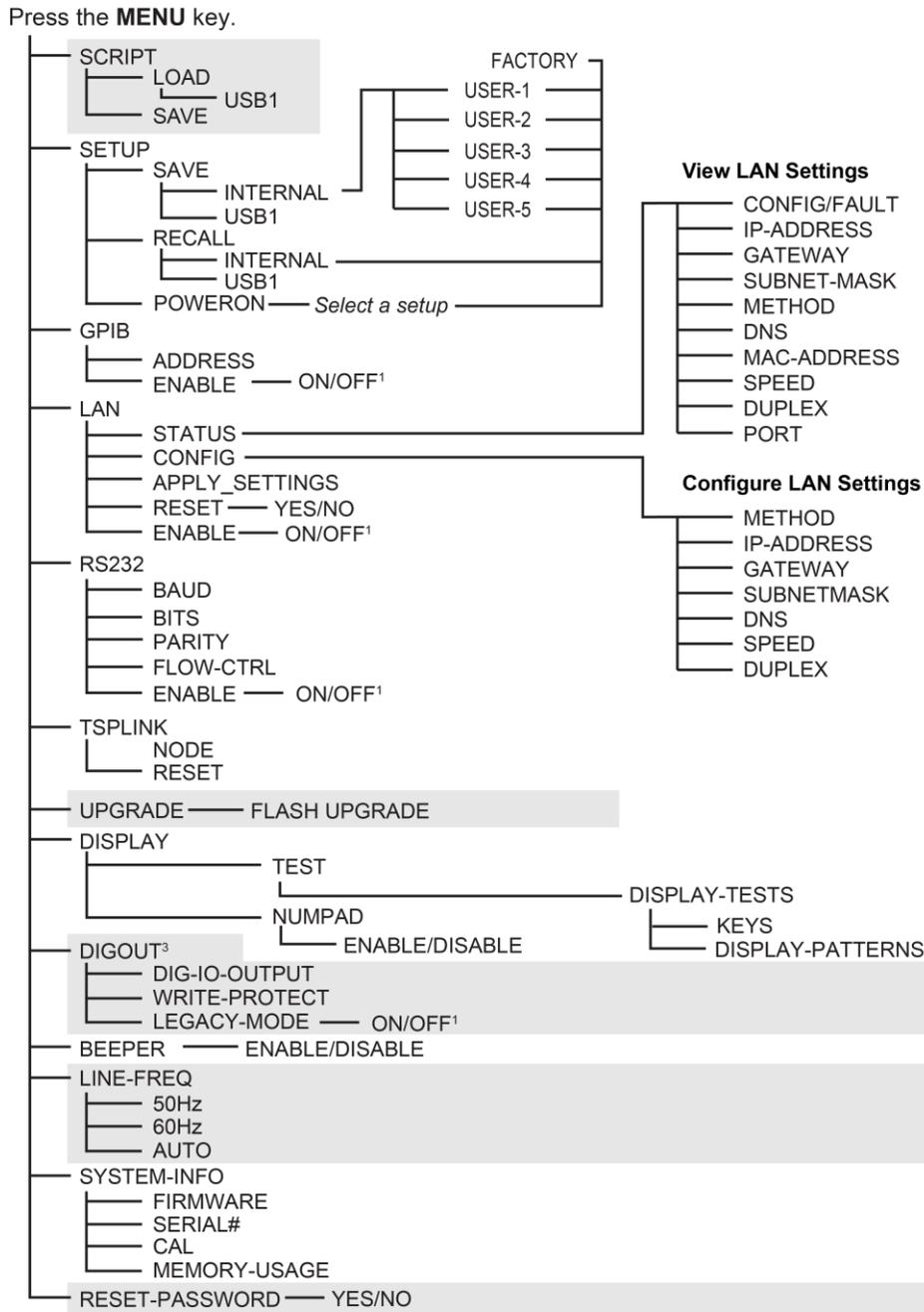
Menu trees

You can configure instrument operation through the menus that are accessed from the front panel.

Main menu

The main menu structure is summarized in the following figure and table. For other menu items, see [Configuration menus](#) (on page 3-10).

Figure 30: Main menu tree



1. Mutually exclusive

The following table contains descriptions of the main menu options and cross-references to related information.

To access a menu option, press the **MENU** key, turn the navigation wheel to move the cursor to select an item, and press the navigation wheel.

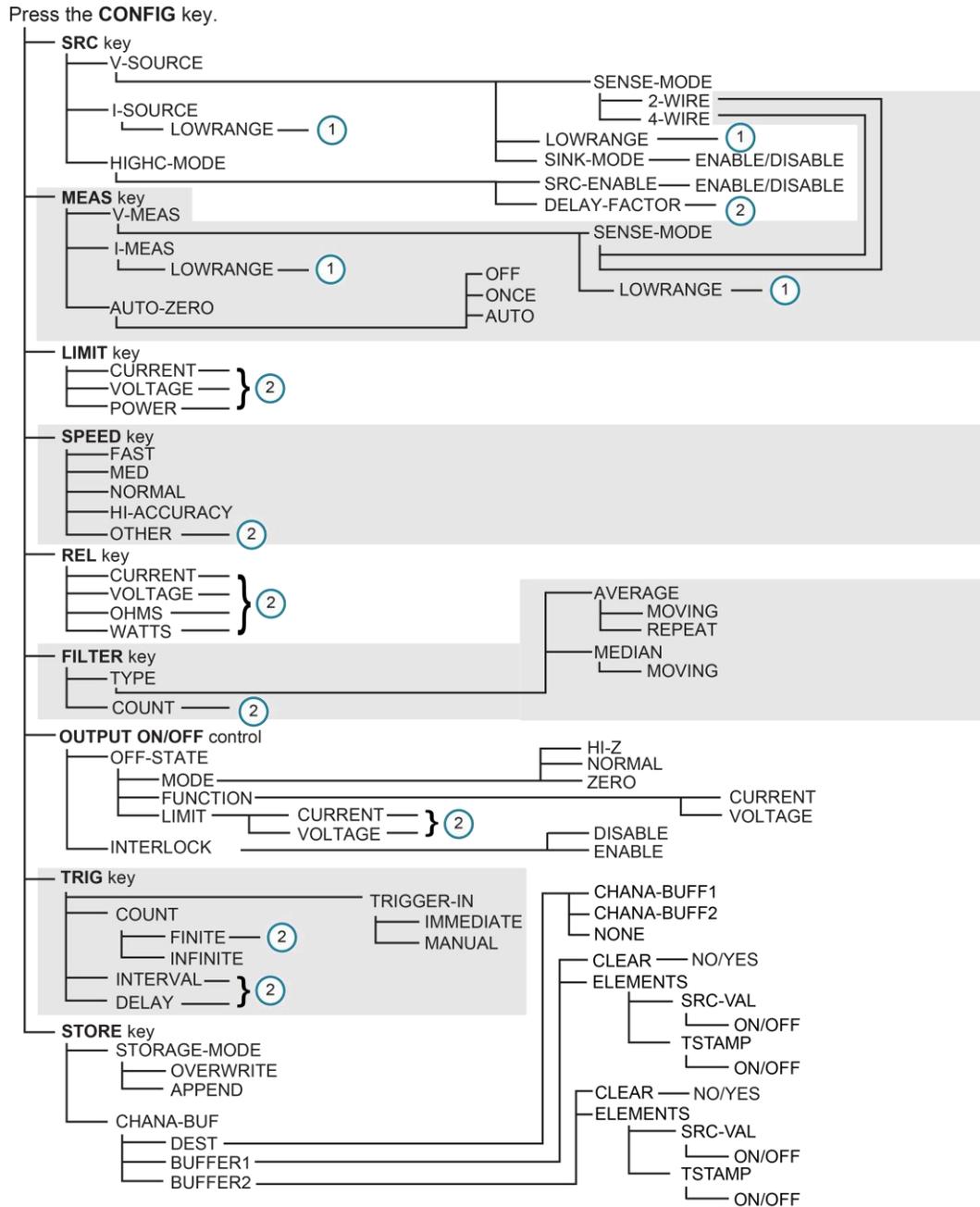
Menu selection	Description	For more information, see:
SCRIPT - LOAD - SAVE	Saves and recalls user scripts Loads scripts into nonvolatile memory Saves scripts	<i>Model 2601B-PULSE Reference Manual</i> , "Manage scripts"
SETUP - SAVE - RECALL - POWERON	Saves and recalls user and factory setup options Saves user setup options Recalls user setup options Sets the configuration used during startup	<i>Model 2601B-PULSE Reference Manual</i> , "Saved setups"
GPIB - ADDRESS - ENABLE	Configures the GPIB interface options Configures the address for the GPIB interface Enables and disables the GPIB interface	Remote communications interfaces (on page 2-12)
LAN - STATUS - CONFIG - APPLY_SETTINGS - RESET - ENABLE	Configures the local area network (LAN) Displays LAN connection status Configures the LAN IP address and gateway Applies changes made using the CONFIG menu Restores the default settings Enables and disables the LAN interface	LAN communications (on page 2-15)
RS232 - BAUD - BITS - PARITY - FLOW-CTRL - ENABLE	Controls the options for the RS-232 interface Sets the baud rate Configures the number of bits Sets the parity Configures the flow control Enables and disables the RS-232 interface	Remote communications interfaces (on page 2-12)
TSPLINK - NODE - RESET	Configure the instrument in a TSP-Link® network Selects the instrument node identifier Resets the TSP-Link network	<i>Model 2601B-PULSE Reference Manual</i> , "TSP-Link system expansion interface"
UPGRADE	Upgrades the firmware from a USB flash drive	Upgrading the firmware (on page 5-4)
DISPLAY - TEST - NUMPAD	Accesses display functions Runs the display test Enables and disables the numeric keypad	Front-panel tests (on page 5-3) See Numeric entry method in Setting a value (on page 3-12)
DIGOUT - DIG-IO-OUTPUT - WRITE-PROTECT - LEGACY-MODE	Controls digital outputs Selects the digital I/O values Write-protects specific digital I/O lines Sets digital I/O to work like an older SourceMeter instrument	<i>Model 2601B-PULSE Reference Manual</i> , "Digital I/O"

Menu selection	Description	For more information, see:
BEEPER - ENABLE - DISABLE	Controls the key beeps Enables the key beeps Disables the key beeps	Beeper (on page 3-14)
LINE-FREQ - 50Hz - 60Hz - AUTO	Configures the line frequency Set the line frequency to 50 Hz Set the line frequency to 60 Hz Enables automatic line-frequency detection during start up	Line frequency configuration (on page 2-11)
SYSTEM-INFO - FIRMWARE - SERIAL# - CAL - MEMORY-USAGE	Displays the system information Displays the version of firmware installed Displays the serial number of the unit Displays the last calibration date Displays memory usage in percentage	System information (on page 2-41)
RESET-PASSWORD	Resets the system password	<i>Model 2601B-PULSE Reference Manual, "Password management"</i>

Configuration menus

The configuration menu structure is summarized in the following figure and table. For directions on navigating the menu, see [Menu navigation](#) (on page 3-7). For other menu items, see [Main menu](#) (on page 3-8).

Figure 31: CONFIG menu tree



- ① Select a value
- ② Enter a value

NOTE

Press the **EXIT** key to return to a previous menu.

Descriptions of the configuration menus

The following table contains descriptions of the configuration menus and cross-references to related information.

To access, press the CONFIG key and then:	Options	For more information, see:
SRC	V-source sense and low range; I-source low range; and high capacitance mode	<i>Model 2601B-PULSE Reference Manual</i> , "Range" Basic source-measure procedure
MEAS	V and I-measure range, V-measure sense, low range, and autozero	<i>Model 2601B-PULSE Reference Manual</i> , "Range" Basic source-measure procedure
LIMIT	V-source and I-source compliance limits	Limits (on page 4-2)
SPEED	Measurement speed (NPLC)	<i>Model 2601B-PULSE Reference Manual</i> , "Speed"
REL	Set relative values	<i>Model 2601B-PULSE Reference Manual</i> , "Relative offset"
FILTER	Control digital filter	<i>Model 2601B-PULSE Reference Manual</i> , "Filters"
OUTPUT ON/OFF	Set off-state, interlock	Output-off states (on page 4-21) Using the interlock (on page 2-37)
STORE	Set buffer count and destination	<i>Model 2601B-PULSE Reference Manual</i> , "Source-measure concepts"
TRIG	Set trigger in, count, interval, and delay	<i>Model 2601B-PULSE Reference Manual</i> , "Triggering"

Setting values

Through the front panel, you can adjust a value using either the **Navigation wheel method** or **Numeric entry method** (using the keypad).

NOTE

When the pulser is enabled, you cannot adjust values through the front panel.

Setting a value

Navigation wheel method:

1. Use the **CURSOR** arrow keys (or turn the navigation wheel) to move the cursor to the digit that needs to be changed.
2. Press the navigation wheel or the **ENTER** key to enter edit mode. The EDIT indicator is illuminated.
3. Rotate the navigation wheel to set the appropriate value.
4. Press the **ENTER** key to select the value or press the **EXIT (LOCAL)** key to cancel the change.
5. To return to the main menu, press the **EXIT (LOCAL)** key.

Numeric entry method:

1. If the keypad is disabled, press the **MENU** key, then select **DISPLAY > NUMPAD > ENABLE**.
2. Use the **CURSOR** arrow keys (or turn the navigation wheel) to move the cursor to the value that needs to be changed.
3. Press the navigation wheel or the **ENTER** key to enter edit mode. The EDIT indicator is illuminated.
4. Press any of the number keys (0-9, +/-, 0000) (see [2. SMU setup, performance control, special operation, and numbers](#) (on page 3-3)). The cursor moves to the next digit on the right.
5. Repeat the above steps as required to set the values.
6. Press the **ENTER** key to select the value or press the **EXIT (LOCAL)** key to cancel the change.
7. To return to the main menu, press the **EXIT (LOCAL)** key.

NOTE

To set a value to zero, press the **0000** numeric entry key. To toggle the polarity of a value, press the **+/-** numeric entry key.

Setting source and compliance values

When the 2601B-PULSE is in the edit mode (EDIT indicator is on), the editing controls are used to set source and compliance values. Note that when you edit the source value, source autoranging is turned off and remains off until you turn it on again.

NOTE

To cancel source editing, press the **EXIT (LOCAL)** key.

To edit the source value:

1. Press the **SRC** key. The cursor flashes in the source value field.
2. Use the **CURSOR** keys (or turn the navigation wheel) to move the cursor to the digit that needs to be changed.
3. Press the navigation wheel or the **ENTER** key to edit the source value. The EDIT indicator is illuminated.
4. Change the source value (see [Setting a value](#) (on page 3-12)).

NOTE

The **+/-** key toggles the polarity. The **0000** key sets the value to 0.

5. When finished, press the **ENTER** key (the EDIT indicator is not illuminated).

To edit compliance limit values:

1. Press the **LIMIT** key.
2. Select the type of compliance (CURRENT, VOLTAGE, or POWER).
3. Press the navigation wheel or the **ENTER** key to enter edit mode. The EDIT indicator is illuminated.
4. Change the compliance value (see [Setting a value](#) (on page 3-12)).
5. When finished, press the **ENTER** key (the EDIT indicator is not illuminated).

NOTE

The up and down range keys change the format of the limit value.

Beeper

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

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

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

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

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

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

```
beeper.enable = 1
```

Displayed error and status messages

During operation and programming, front-panel messages may be briefly displayed. Typical messages are either status or error notifications. Status and error messages are held in a queue.

Refer to the following topics in the *Model 2601B-PULSE Reference Manual*:

- For a list of status and error messages and their meanings: “Error summary list.”
- For information about retrieving messages from queues: “Queues.”
- General information about error messages: “Troubleshooting guide.”

Display operations

This section describes methods for using the display and determining what is displayed.

Display mode

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

Figure 32: Display modes when the pulser is disabled

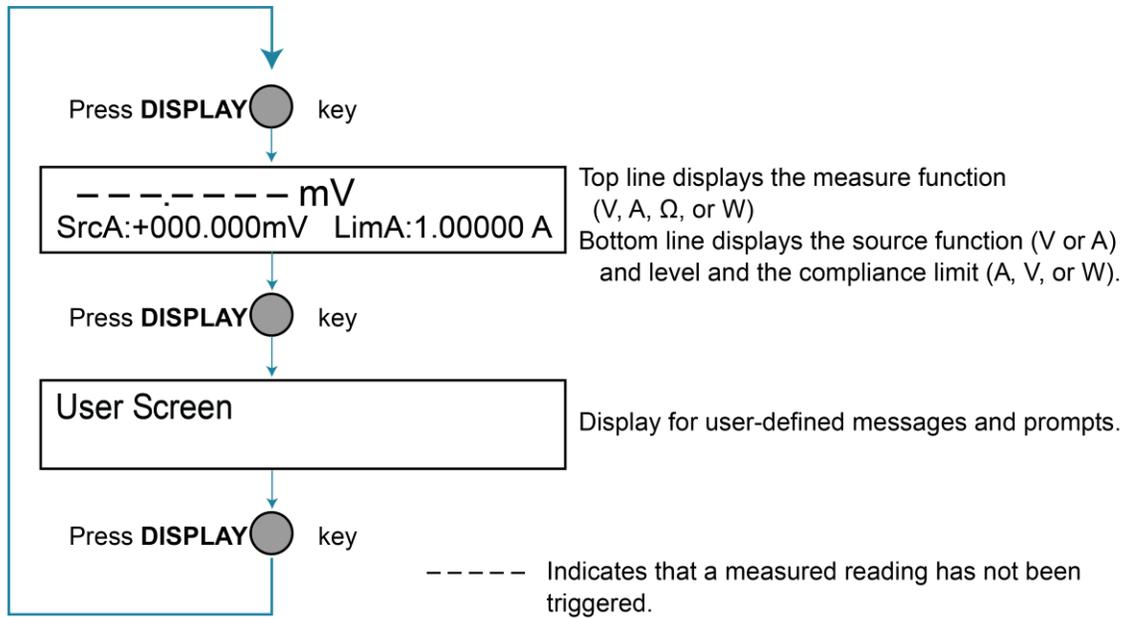
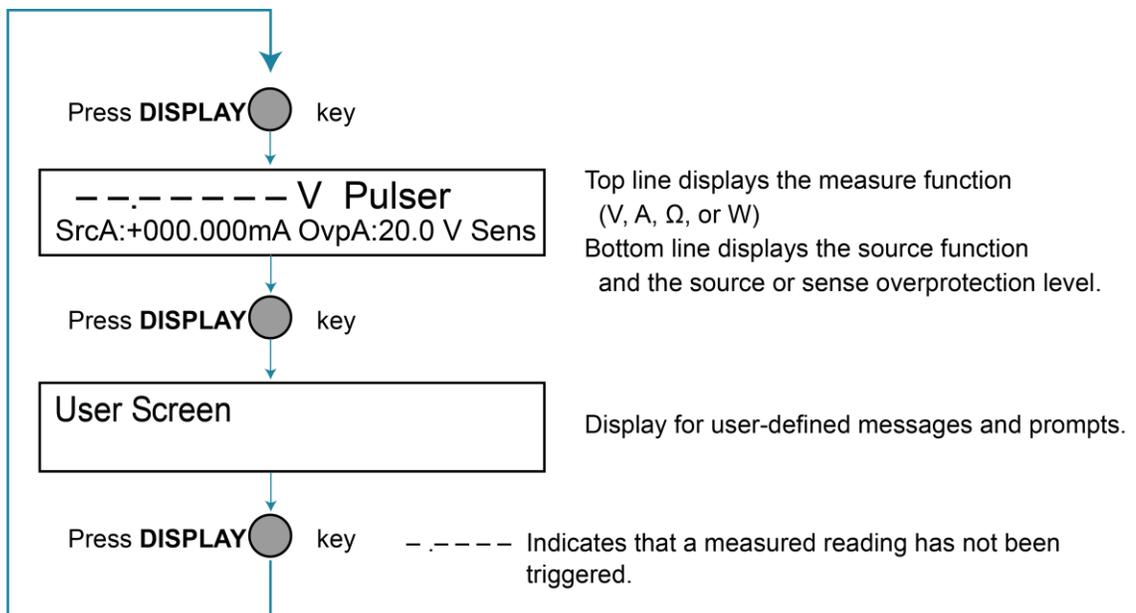


Figure 33: Display modes when the pulser is enabled



Display functions and attributes

The display functions and attributes for the front panel are described in this section. The following table lists each display function and attribute in alphabetical order and cross references it to the topic where the function or attribute is explained.

The “TSP command reference” section of the *Model 2601B-PULSE Reference Manual* provides additional information about the display functions and attributes.

Cross-referencing functions and attributes to section topics

Function or attribute	Section topic
<code>display.clear()</code>	Clearing the display (on page 3-18)
<code>display.getannunciators()</code>	Indicators (on page 3-24)
<code>display.getcursor()</code>	Cursor position (on page 3-19)
<code>display.getlastkey()</code>	<i>Model 2601B-PULSE Reference Manual</i> , “Capturing key-press codes”
<code>display.gettext()</code>	Displaying text messages (on page 3-20)
<code>display.inputvalue()</code>	Parameter value prompting (on page 3-23)
<code>display.loadmenu.add()</code> <code>display.loadmenu.catalog()</code> <code>display.loadmenu.delete()</code>	Load test menu (on page 3-25)
<code>display.locallockout</code>	LOCAL lockout (on page 3-25)
<code>display.menu()</code>	Menu (on page 3-22)
<code>display.numpad</code>	Setting a value (on page 3-12)
<code>display.prompt()</code>	Parameter value prompting (on page 3-23)
<code>display.screen</code>	Display screen (on page 3-17)
<code>display.sendkey()</code>	<i>Model 2601B-PULSE Reference Manual</i> , “Sending key codes”
<code>display.setcursor()</code>	Cursor position (on page 3-19)
<code>display.settext()</code>	Displaying text messages (on page 3-20)
<code>display.smua.digits</code>	Display resolution (on page 3-17)
<code>display.smua.limit.func</code>	Limit functions (on page 3-17)
<code>display.smua.measure.func</code>	Measurement functions (on page 3-17)
<code>display.trigger.clear()</code> <code>display.trigger.wait()</code>	Display trigger wait and clear (on page 3-18)
<code>display.waitkey()</code>	<i>Model 2601B-PULSE Reference Manual</i> , “Capturing key-press codes”

Display features

You can set the front-panel display to display the units of measure, number of digits, and customized text messages for your applications.

Display screen

The front panel displays source-measure values and readings or user-defined messages. The display screen options include:

- **Source-measure, compliance screens:** Display SMU source-measure readings and compliance values.
- **User screen:** Displays user-defined messages and prompts.

Configure the type of source-measure and compliance displayed by setting the `display.screen` attribute. The following programming example illustrates how to display source-measure and compliance values, and measure readings for SMU A:

```
display.screen = display.SMUA
```

Measurement functions

With a source-measure screen selected, the measured reading can be displayed as volts, amperes, ohms, or watts. Configure the type of measured reading displayed by setting the `display.smua.measure.func` attribute. The following programming example illustrates how to display ohms measurements:

```
display.smua.measure.func = display.MEASURE_OHMS
```

Limit functions

When the pulser is disabled, the displayed limit value is either the primary limit value (current or voltage) or the power limit value. Configure the type of limit function that is displayed by setting the `display.smua.limit.func` attribute. The following programming example illustrates how to display the power limit setting:

```
display.smua.limit.func = display.LIMIT_P
```

When the pulser is enabled, the sense and source protection levels are displayed. Use the LIMIT key to switch between the sense and source protection level.

Display resolution

Display resolution for measured readings can be set to 4½, 5½, or 6½. Configure the type of resolution displayed by setting the `display.smua.digits` attribute. The following programming example illustrates how to set 5½ digit resolution for measured readings:

```
display.smua.digits = display.DIGITS_5_5
```

Display trigger wait and clear

To set the instrument to wait for the front-panel TRIG key to be pressed, send the `display.trigger.wait()` function. To clear the trigger event detector, send the `display.trigger.clear()` function.

Display messages

You can define text messages that can be displayed on the front panel of the instrument. Most of the display functions and attributes that are associated with display messaging automatically select the user screen. The attribute for the display screen is explained in [Display screen](#) (on page 3-17).

For example, while a test is running, the following message can be displayed on the 2601B-PULSE front panel:

```
Test in Process
Do Not Disturb
```

The top line of the display can accommodate up to 20 characters (including spaces). The bottom line can display up to 32 characters (including spaces) at a time.

NOTE

The display functions `display.clear()`, `display.setcursor()`, and `display.settext()` are overlapped, nonblocking commands. The script does not wait for one of these commands to complete.

These nonblocking functions do not immediately update the display. For performance considerations, they write to a background file and update the display as soon as processing time becomes available.

The reset functions `reset()` and `smua.reset()` do not change the defined display message or its configuration. The reset functions set the display mode to the previous source-measure display mode. To show the user-defined message again, press DISPLAY until the User screen is displayed.

Clearing the display

When sending a command to display a message, a previously defined user message is not cleared. The new message starts at the end of the old message on that line. It is good practice to routinely clear the display before defining a new message.

After displaying an input prompt, the message is displayed even after the operator performs the prescribed action. The `clear()` function must be sent to clear the display. To clear both lines of the display, but not affect any of the indicators, send the following function:

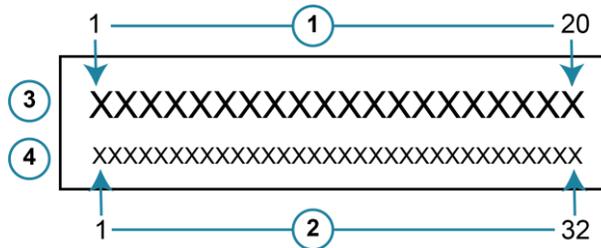
```
display.clear()
```

Cursor position

When displaying a message, the cursor position determines where the message starts. On power-up, the cursor is positioned at row 1, column 1 (see the following figure). At this cursor position, a user-defined message is displayed on the top row (row 1).

Top line text does not wrap to the bottom line of the display automatically. Any text that does not fit on the current line is truncated. If the text is truncated, the cursor is left at the end of the line.

Figure 34: Row and column format for display messaging



1	Columns for Row 1
2	Columns for Row 2
3	Row 1
4	Row 2
X	Display character

The function to set cursor position has the following options:

```
display.setcursor(row, column)
display.setcursor(row, column, style)
```

Where:

- row* 1 or 2
- column* 1 to 20 (row 1)
 1 to 32 (row 2)
- style* 0 (invisible)
 1 (blink)

When set to 0, the cursor is not visible. When set to 1, a display character blinks to indicate the cursor position.

The `display.getcursor()` function returns the present cursor position. You can use it in these ways:

```
row, column, style = display.getcursor()
row, column = display.getcursor()
row = display.getcursor()
```

The following programming example illustrates how to position the cursor on row 2, column 1, and then read the cursor position:

```
display.setCursor(2, 1)
row, column = display.getcursor()
print(row, column)
```

Output:

```
2.00000e+00 1.00000e+00
```

Displaying text messages

To define and display a message, use the `display.setText(text)` function, where `text` is the text string to be displayed. The message starts at the present cursor position. The following programming example illustrates how to display `Test in Process` on the top line, and `Do Not Disturb` on the bottom line:

```
display.clear()
display.setCursor(1, 1, 0)
display.setText("Test in Process")
display.setCursor(2, 6, 0)
display.setText("Do Not Disturb")
```

Character codes

The following special codes can be embedded in the `text` string to configure and customize the message:

- `§N` Starts text on the next line (newline). If the cursor is already on line 2, text is ignored after the '`§N`' is received.
- `§R` Sets text to Normal.
- `§B` Sets text to Blink.
- `§D` Sets text to Dim intensity.
- `§F` Set text to background blink.
- `§§` Escape sequence to display a single "`§`".

In addition to displaying alphanumeric characters, you can display other special characters. Refer to the *Model 2601B-PULSE Reference Manual*, "Display character codes," for a list of special characters and their corresponding codes.

The following programming example illustrates how to display the Greek symbol omega (Ω):

```
display.clear()
c = string.char(18)
display.setText(c)
```

The following programming example illustrates how to use the `$N` and `$B` character codes to display the message `Test in Process` on the top line and the blinking message `Do Not Disturb` on the bottom line:

```
display.clear()
display.setText("Test in Process $N$BDo Not Disturb")
```

The following programming example illustrates how to use the `$$` character code to display the message `You owe me $8` on the top line:

```
display.clear()
display.setCursor(1, 1)
display.setText("You owe me $$8")
```

If the extra `$` character is not included, the `$8` is interpreted as an undefined character code and is ignored. The message `You owe me` is displayed.

NOTE

Be careful when embedding character codes in the text string. It is easy to forget that the character following the `$` is part of the code. For example, if you want to display `Hello` on the top line and `Nate` on the bottom line, send the following command:

```
display.setText("Hello$Nate")
```

The above command displays `Hello` on the top line and `ate` on the bottom line. The correct syntax for the command is as follows:

```
display.setText("Hello$NNate")
```

Returning a text message

The `display.getText()` function returns the displayed message (*text*) and has the following options:

```
text = display.getText()
text = display.getText(embellished)
text = display.getText(embellished, row)
text = display.getText(embellished, row, columnStart)
text = display.getText(embellished, row, columnStart, columnEnd)
```

Where:

<i>embellished</i>	Returns text as a simple character string (<i>false</i>) or includes character codes (<i>true</i>)
<i>row</i>	The row to read text from (1 or 2); if not included, text from both rows is read
<i>columnStart</i>	Starting column for reading text
<i>columnEnd</i>	Ending column for reading text

Sending the command without the *row* parameter returns both lines of the display. The $\$N$ character code is included to show where the top line ends and the bottom line begins. The $\$N$ character code is returned even if *embellished* is set to *false*.

With *embellished* set to *true*, all other character codes that were used in the creation of each message line are returned with the message. With *embellished* set to *false*, only the message is returned.

Sending the command without the *columnStart* parameter defaults to column 1. Sending the command without the *columnEnd* argument defaults to the last column (column 20 for row 1, column 32 for row 2).

Input prompting

You can use display messaging with front panel controls to make a user script interactive. In an interactive script, input prompts are displayed so that the operator can perform a prescribed action using the front panel controls. While displaying an input prompt, the test pauses and waits for the operator to perform the prescribed action.

Menu

You can present a user-defined menu on the display. The menu consists of the menu name on the top line and a selectable list of menu items on the bottom line. To define a menu, use the `display.menu(menu, items)` function, where:

menu The name of the menu; use a string of up to 20 characters (including spaces)
items A string is made up of one or more menu items; each item must be separated by white space

When the `display.menu()` function is sent, script execution waits for the operator to select one of the menu items. Rotate the navigation wheel to place the blinking cursor on a menu item. Items that do not fit in the display area are displayed by rotating the navigation wheel to the right. With the cursor on the menu item, press the navigation wheel (or the **ENTER** key) to select it.

Pressing the EXIT (LOCAL) key does not abort the script while the menu is displayed, but it returns `nil`. The script can be aborted by calling the `exit()` function when `nil` is returned.

The following programming example illustrates how to present the operator with the choice of two menu items: `Test1` or `Test2`. If `Test1` is selected, the message `Running Test1` is displayed. If `Test2` is selected, the message `Running Test2` is displayed.

```
display.clear()
menu = display.menu("Sample Menu", "Test1 Test2")
if menu == "Test1" then
  display.settext("Running Test1")
else
  display.settext("Running Test2")
end
```

Parameter value prompting

You can use the `display.inputvalue()` and `display.prompt()` functions to create an editable input field on the user screen at the present cursor position.

The `display.inputvalue()` function uses the user screen at the present cursor position. Once the command is finished, it returns the user screen to its previous state. The `display.prompt()` function creates a new edit screen and does not use the user screen.

Each of these functions can be used in the following ways:

```
display.inputvalue(format)
display.inputvalue(format, default)
display.inputvalue(format, default, min)
display.inputvalue(format, default, min, max)
display.prompt(format, units, help)
display.prompt(format, units, help, default)
display.prompt(format, units, help, default, min)
display.prompt(format, units, help, default, min, max)
```

Where:

<i>format</i>	String that creates an editable input field on the user screen at the present cursor position (examples: +0.00 00, +00, 0.00000E+0) Value field: + = Include for positive/negative value entry; omitting the + prevents negative value entry 0 = Defines the digit positions for the value (up to six zeros (0)) Exponent field (optional): E = include for exponent entry + = Include for positive/negative exponent entry; omitting the + prevents negative value entry 0 = Defines the digit positions for the exponent
<i>default</i>	Option to set a default value for the parameter, which is displayed when the command is sent
<i>min</i>	Option to specify minimum limits for the input field <ul style="list-style-type: none"> ■ When NOT using the “+” sign for the value field, the minimum limit cannot be set to less than zero ■ When using the “+” sign, the minimum limit can be set to less than zero (for example, -2)
<i>max</i>	Option to specify maximum limits for the input field
<i>units</i>	Text string to identify the units for the value (8 characters maximum), for example: Units text is “V” for volts and “A” for amperes
<i>help</i>	Informational text string to display on the bottom line (32 characters maximum)

Both the `display.inputvalue()` and `display.prompt()` functions display the editable input field, but the `display.inputvalue()` function does not include the text strings for *units* and *help*.

After one of the above functions is executed, command execution pauses and waits for the operator to input the source level. The program continues after the operator enters the value by pressing the navigation wheel or the ENTER key.

The following programming example illustrates how to prompt the operator to enter a source voltage value for SMU A:

```
display.clear()
value = display.prompt("0.00", "V", "Enter source voltage")
display.screen = display.SMUA
smua.source.levelv = value
```

The script pauses after displaying the prompt message and waits for the operator to enter the voltage level. The display then toggles to the source-measure display for SMU A and sets the source level to `value`.

NOTE

If the operator presses EXIT(LOCAL) instead of entering a source value, `value` is set to `nil`.

The second line of the above code can be replaced using the other input field function:

```
value = display.inputvalue("0.00")
```

The only difference is that the display prompt does not include the “V” units designator and the `Enter source value message`.

Indicators

To determine which front-panel display indicators are turned on, use the `display.getannunciators()` function. For example, send the following commands.

```
annun = display.getannunciators()
print(annun)
```

The 16-bit binary equivalent of the returned value is a bitmap. Each bit corresponds to an indicator. If the bit is set to 1, the indicator is turned on. If the bit is set to 0, the indicator is turned off.

The following table identifies the bit position for each indicator. The table also includes the weighted value of each bit. The returned value is the sum of all the weighted values for the bits that are set.

Bit identification for indicators

Bit	B16	B15	B14	B13	B12	B11	B10	B9
Annunciator	REL	REAR	SRQ	LSTN	TALK	REM	ERR	EDIT
Weighted value*	32768	16384	8192	4096	2048	1024	512	256
Binary value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1

Bit	B8	B7	B6	B5	B4	B3	B2	B1
Annunciator	SMPL	STAR	TRIG	ARM	AUTO	4W	MATH	FILT
Weighted value*	128	64	32	16	8	4	2	1
Binary value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1

* The weighted values are for bits that are set to 1. Bits set to 0 have no value.

Not all the indicators shown in above table may be used by the 2601B-PULSE.

For example, assume the returned bitmap value is 34061. The binary equivalent of this value is as follows:

```
1000010100001101
```

For the above binary number, the following bits are set to 1: 16, 11, 9, 4, 3, and 1. Using the table, the following indicators are on: REL, REM, EDIT, AUTO, 4W, and FILT.

Local lockout

You can use the front-panel EXIT (LOCAL) key to cancel remote operation and return control to the front panel. However, this key can be locked out to prevent a test from being interrupted. When locked, this key becomes a NO-OP (no operation). Configure the following attribute to lock or unlock the EXIT (LOCAL) key:

```
display.locallockout = lockout
```

Where *lockout* is set to one of the following values:

0 or `display.UNLOCK`

1 or `display.LOCK`

For example, to lock out the EXIT (LOCAL) key:

```
display.locallockout = display.LOCK
```

Load test menu

The LOAD TEST menu lists tests (USER, FACTORY, and SCRIPTS) that can be run from the front panel.

Factory tests are preloaded and saved in nonvolatile memory at the factory. They are available in the FACTORY TESTS submenu.

If you load named scripts into the runtime environment, they can be selected from the front-panel SCRIPTS menu.

User tests

User tests can be added to or deleted from the USER TESTS submenu.

Adding USER TESTS menu entries

You can use the following function in either of two ways to add an entry into the USER TESTS menu:

```
display.loadmenu.add(displayname, code)
display.loadmenu.add(displayname, code, memory)
```

Where:

<i>displayname</i>	The name string that is added to the USER TESTS menu.
<i>code</i>	The code that is run from the USER TESTS menu when the RUN button is pressed. It can include any valid Lua code.
<i>memory</i>	A value that specifies if the <i>code</i> and <i>displayname</i> parameters are saved in nonvolatile memory. Set to one of the following values: 0 or <code>display.DONT_SAVE</code> 1 or <code>display.SAVE</code> (this is the default setting)

Scripts, functions, and variables that are used in the *code* are not saved when `display.SAVE` is used. Functions and variables need to be saved with the script. If the script is not saved in nonvolatile memory, it is lost when the 2601B-PULSE is turned off. See Example 1 below.

Example 1:

Assume a script with a function named `DUT1` has been loaded into the 2601B-PULSE, and the script has not been saved in nonvolatile memory.

Now assume you want to add a test named `Test` to the USER TESTS menu. You want the test to run the function named `DUT1` and sound the beeper. The following programming example illustrates how to add `Test` to the menu, define the *code*, and then save *displayname* and *code* in nonvolatile memory:

```
display.loadmenu.add("Test", "DUT1() beeper.beep(2, 500)", display.SAVE)
```

When `Test` is run from the front-panel USER TESTS menu, the function named `DUT1` executes and the beeper beeps for two seconds.

Now assume you turn the 2601B-PULSE power off and then on again. Because the script was not saved in nonvolatile memory, the function named `DUT1` is lost. When `Test` is again run from the front panel, the beeper beeps, but `DUT1` does not execute because it is no longer in the runtime environment.

Example 2:

The following command adds an entry called `Part1` to the front-panel USER TESTS submenu for the code `testpart([[Part1]], 5.0)` and saves it in nonvolatile memory:

```
display.loadmenu.add("Part1", "testpart([[Part1]], 5.0)", display.SAVE)
```

Deleting USER TESTS menu entries

You can use the following function to delete an entry from the front-panel USER TESTS menu:

```
display.loadmenu.delete(displayname)
```

Where:

displayname Name to delete from the menu.

The following programming example removes the entry named `Part1` from the front-panel USER TESTS menu:

```
display.loadmenu.delete("Part1")
```

Running a test from the front panel

To run a user, factory, or script test from the front panel:

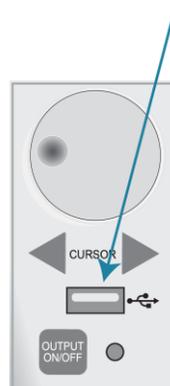
1. Press the **LOAD** key to display the LOAD TEST menu.
2. Select the **USER**, **FACTORY**, or **SCRIPTS** menu item.
3. Position the blinking cursor on the test to be run and press **ENTER** or the navigation wheel.
4. Press the **RUN** key to run the test.

Connecting the USB flash drive

The 2601B-PULSE supports flash drives that comply with USB 2.0 standards and USB 1.0 and 1.1 standards. You can save data to the USB flash drive from the front panel, or you can create a script to save data to the USB flash drive.

To connect the USB flash drive, plug the USB flash drive into the USB port on the front panel of the instrument, shown in the figure below.

Figure 35: USB port



Restoring factory default setups using remote commands

Use one of the reset functions to return the 2601B-PULSE to the original factory defaults. An example of each type of reset is shown in the following program examples.

Restore all factory defaults of all nodes on the TSP-Link® network:

```
reset()
```

Restore all factory defaults (note that you cannot use `*rst` in a script):

```
*rst
```

Restore all factory defaults:

```
setup.recall(0)
```

Restore SMU defaults:

```
smua.reset()
```

Reset only the local TSP-Link node:

```
localnode.reset()
```

Using the web interface

If you are connected to the 2601B-PULSE using LAN communications, you can use an internet browser to connect to the instrument through the 2601B-PULSE web interface.

The LXI web interface allows you to change settings and control your instrument through the web interface. The web interface includes:

- A virtual front panel that you can use to control the instrument.
- TSB Embedded, a script management tool that can also be used to send individual commands to the instrument.
- The instrument status, model, serial number, firmware revision, and the last LXI message.
- An ID button to help you locate the instrument.
- Ability to download data from specific reading buffers into a `.csv` file.
- Administrative options, LAN information, and LXI information.

The web interface resides in the firmware of the instrument. Changes you make through the web interface are immediately made in the instrument.

You can also upgrade the instrument from the web interface. Refer to [Upgrading the firmware](#) (on page 5-4) for instructions.

NOTE

To set up LAN connections, refer to [LAN communications](#) (on page 2-15).

How to access the web interface

You can access the web interface by entering the IP address of the instrument in the address line of an internet browser.

To get the IP address of the instrument:

1. From the front panel, press the **MENU** key.
2. Select **LAN > STATUS**.
3. Use the navigation wheel to select **IP-ADDRESS**.
4. Press the **ENTER** key to view the active setting.
5. Press the **EXIT (LOCAL)** key once to return to the STATUS menu.

NOTE

To find the IP address of the 2601B-PULSE from a computer, use the LXI Discovery Tool, a utility that is available from the Resources tab of the [LXI Consortium website \(lxistandard.org\)](http://lxistandard.org).

To access the web interface:

1. Open a web browser on the host computer.
2. Enter the IP address of the instrument in the web browser address box. For example, if the instrument IP address is 192.168.1.101, enter 192.168.1.101 in the browser address box.
3. Press **Enter** on the computer keyboard to open the web interface of the instrument.

NOTE

If the web interface does not open in the browser, see [LAN troubleshooting suggestions](#) (on page 2-25).

Web interface Welcome page

The Welcome page provides information about the instrument. It includes:

- The instrument model number, manufacturer, firmware revision number, and instrument serial number.
- LXI information.
- LAN connection information.
- The TCP Raw Socket number and Telnet Port number.
- Instrument address strings.
- Calibration dates.
- The ID button, which helps you find the instrument if you have multiple instruments.

Figure 36: Web interface Welcome page

LXI Web Interface - Welcome Page	
Instrument Model:	2601B-PULSE SYSTEM PulseMeter®
Manufacturer:	Keithley Instruments
Firmware Revision:	1.1.0
Serial Number:	
Description:	Keithley Instruments SMU 2601B-PULSE - 4452557
LXI Extended Functions:	VXI-11 Discovery and Identification
LXI Version:	1.5 LXI Device Specification 2016
MAC Address:	
TCP/IP Address:	
Gateway:	
Subnet Mask:	255.255.254.0
LAN Connection:	100Mbps, Full Duplex
Host Name (FQDN):	k-2601b-pulse-4452557.global.tektronix.net, k-2601B-PULSE-4452557.local
DNS Servers:	
Ports:	DST: 5030 Raw Socket: 5025 Telnet: 23 VXI-11 Core: 1024
Instrument Address String:	ASRL[board]: INSTR GPIB[board]: 26: INSTR TCPIP[board]: :inst0: INSTR TCPIP[board]: :5025: SOCKET USB[board]: 0x05e6: 0x28f1: 4452557: INSTR
SMU A Calibration Date:	Tue Jan 14 11:07:44 2020
SMU A Calibration Due:	

Use the ID button to identify the instrument

If you have a bank of instruments, you can select the ID button to determine which instrument you are communicating with.

The ID button is below the menu on every page of the web interface.

To identify the instrument:

1. Select **ID**. The button turns green and the message "LAN Status Indicator" is displayed on the front panel of the instrument.
2. Select **ID** again to return the button to its original color and return the front-panel display to its previous state.

Change the IP configuration through the web interface

You can change the LAN settings through the web interface on the instrument. The LAN settings you can change include the IP address, subnet mask, gateway, and DNS address.

If you change the IP address through the web interface, the web interface tries to redirect to the IP address that is configured in the instrument. In some cases, this may fail. This generally happens if you switch from an IP address assignment that uses a static address to an IP address assignment that uses a DHCP server. If this happens, you need to revert to either using the front panel to set the IP address or use an automatic discovery tool to determine the new IP address.

You can use the host name instead of the IP address to connect to the instrument.

NOTE

You can also change the IP configuration through the front panel or with TSP commands. Refer to [LAN communications](#) (on page 2-15) for information on setting the configuration through the front panel. Refer to the `lan.config.*` command descriptions in the “TSP command reference” section of the *Model 2601B-PULSE Reference Manual* for information on using TSP commands to configure the LAN settings.

To change the IP configuration using the web interface:

1. Access the web interface as described in [How to access the web interface](#) (on page 3-29).
2. Select **IP Configuration**.
3. Select **Modify**. The Modify IP Configuration page is displayed.
4. Change the values.
5. Click **Submit**. The instrument reconfigures its settings, which may take a few moments.

NOTE

You may lose your connection with the web interface after clicking **Submit**. This is normal. If this occurs, find the correct IP address and reopen the web interface of the instrument to continue.

Set the instrument password

You can change the instrument password from the web interface. The instrument password is used for access to the instrument from any remote interface. When password usage is enabled by the `localnode.passwordmode` command, you must supply a password to change the configuration or to control an instrument a remote command interface.

NOTE

When a password is set for the web interface and `localnode.passwordmode` is set to an option that requires a password, you cannot make changes using the web interface options Virtual Front Panel, Flash Upgrade, and TSB Embedded.

The default password is "" (no password).

You cannot retrieve a lost password from any command interface. You can reset the password from the front panel. Select **MENU**, then **RESET-PASSWORD**.

For information on the TSP commands, refer to `localnode.passwordmode` in the *Model 2601B-PULSE Reference Manual*.

To change the password:

1. Select **Set Password**.
2. In the **Current Password** box, enter the presently used password.
3. In the **New Password** and **Confirm New Password** boxes, enter the new password.
4. Select **Submit**.

Using the virtual front panel

The Virtual Front Panel page allows you to control the instrument from a computer as if you were using the front panel of the instrument. You can operate the instrument using a mouse to select options.

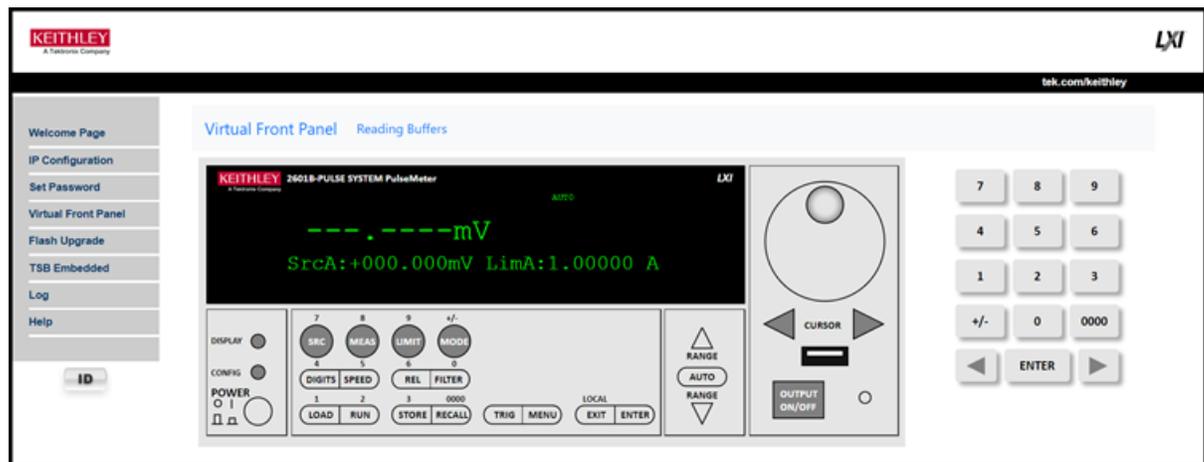
The virtual front panel operates the same way as the actual front panel except that you cannot switch the instrument on or off with the power switch.

For information on the front-panel controls, see [Instrument description](#) (on page 3-1).

To use the virtual front panel, you can use any standard web browsers.

You can access the Virtual Front Panel from multiple interfaces and each interface can make changes. You may need to refresh the browser to see changes made by another interface.

Figure 37: Virtual front panel



View buffer data using the web interface

You can view the data in the reading buffers on the Reading Buffers page of the Virtual Front Panel web page.

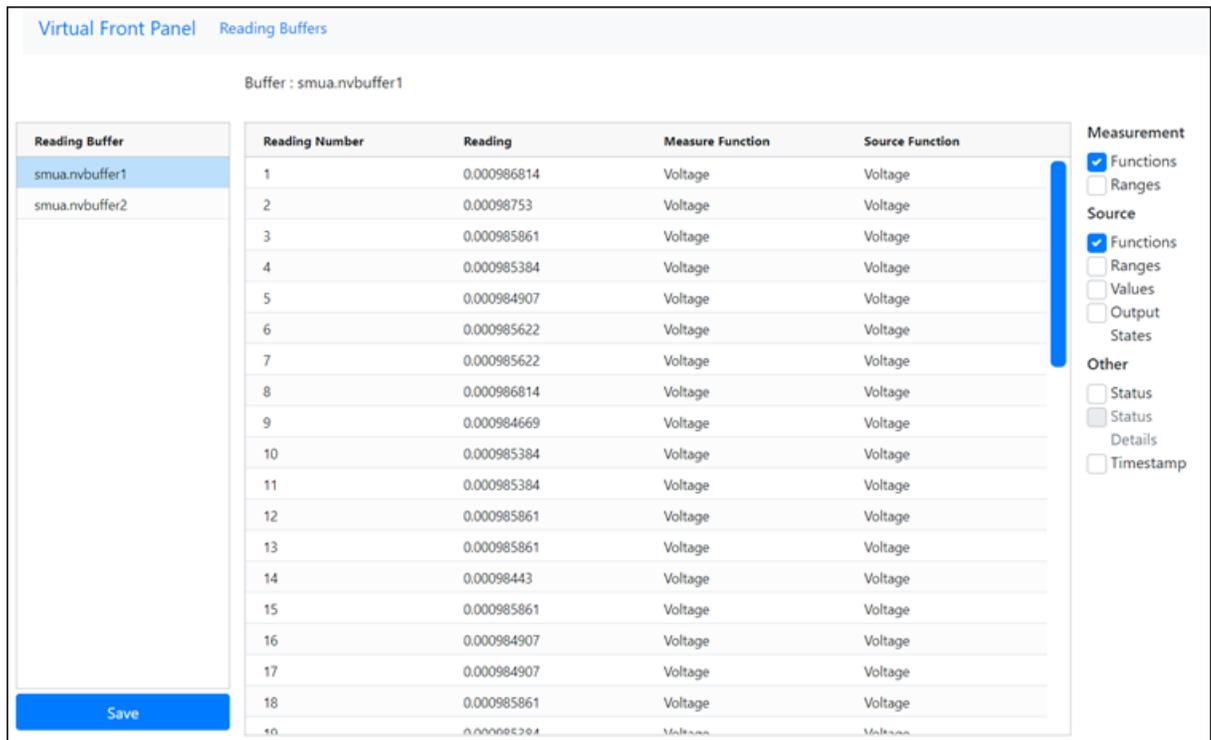
To view the data, at the top of the virtual front panel, select **Reading Buffers**. On the Reading Buffers page, select a reading buffer from the Reading Buffer list. The data is displayed in the table.

Initially, the reading number and reading measurement values are displayed. You can display additional data using the filters to the right of the table. You can choose:

- **Measurement:** Include or exclude measurement information.
- **Source:** Include or exclude source information.
- **Other:** Include or exclude status, status detail, and timestamp information. For detail on the Status value, refer to “Buffer status” in the *Model 2601B-PULSE Reference Manual*.

An example of the Reading Buffers page with the measurement and source functions displayed is shown in the following figure.

Figure 38: Web interface Reading Buffers page



Download reading buffer data using the web interface

You can download reading buffer data to a .csv file from the Reading Buffers page of the web interface.

The data shown in the table on the Reading Buffers page is downloaded.

To download buffer data:

1. From the web interface, select **Virtual Front Panel**.
2. Select **Reading Buffers**.
3. From the Reading Buffer list, select the reading buffer that contains the data you want to download.
4. From the options on the right, filter the reading buffer list to display the data you want to download.
5. Select **Save**. The file is downloaded to your computer.
6. Follow the instructions for your browser to open the file. Typically, the file opens in Microsoft Excel.

Using TSB Embedded

TSB Embedded is a script management tool that is available through the web interface of the instrument. You can use TSB Embedded to create, modify, and save test scripts, and to send individual commands. TSB Embedded provides some of the features of Test Script Builder (TSB). TSB is a software tool that simplifies building test scripts for Keithley Instruments that are enabled to use Test Script Processor (TSP®).

For more information on using TSB Embedded for script management, refer to “Working with TSB Embedded” in the *Model 2601B-PULSE Reference Manual*.

Sending individual commands using the web interface

To send individual commands using the web interface:

1. Select **TSB Embedded**.
2. In the **Console** box, enter the command.
3. Select **Enter** to send the command to the instrument. The command is displayed in the Output box. If there is a response to the command, it is displayed after the command.
4. To clear the Output box, right-click and select **Clear**.

Review events in the LXI Event Log

The Log option opens the LXI Event Log. The event log records all LXI events that the instrument generates and receives. The log includes the following information:

- The EventID column, which shows the identifier of the event that generated the event message.
- The PTP Timestamp column, which displays the seconds and fractional (nano) seconds when the event occurred.
- The Data column, which displays the text of the event message.

To clear the event log and update the information on the screen, select **Refresh**.

Logging LAN trigger events in the event log

You can use the event log to record all LXI triggers generated and received by the 2601B-PULSE. You can view the event log using any command interface or the embedded web interface. The following figure shows the view of the LXI event log from the Log option in the embedded web interface.

Figure 39: LXI Event Log

The screenshot shows the LXI Event Log interface with a table of event data. The table has columns for Receive Time, EventID, From, PTP Timestamp (Seconds and FractionalSeconds), HWDetect, Sequence, Domain, Flags, and Data. The data shows a series of events from 09:51:22.000 to 09:51:41.000 on 25 Apr 2021, all originating from localhost and having a sequence number from 1 to 18.

Receive Time	EventID	From	PTP Timestamp		HWDetect	Sequence	Domain	Flags	Data
			Seconds	FractionalSeconds					
09:51:22.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341530	1	16	0x00
09:51:23.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341531	2	16	0x00
09:51:24.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341532	3	16	0x00
09:51:25.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341533	4	16	0x00
09:51:26.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341534	5	16	0x00
09:51:27.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341535	6	16	0x00
09:51:28.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341536	7	16	0x00
09:51:30.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341537	8	16	0x00
09:51:31.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341538	9	16	0x00
09:51:32.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341539	10	16	0x00
09:51:33.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341540	11	16	0x00
09:51:40.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341546	17	16	0x00
09:51:41.000 25 Apr 2021	LAN0	localhost	0	0.000000000	LXI	1619341547	18	16	0x00

The timestamp, event identifier, IP address, and the domain name identify the incoming and outgoing LXI trigger packets. The following table provides detailed descriptions for the columns in the event log.

Event log descriptions

Column title	Description	Example
Receive Time	Displays the date and time that the LAN trigger occurred in UTC, 24-hour time	11:46:44.000 11 Mar 2020
Event ID	Identifies the <code>lan.trigger[N]</code> that generates an event	LAN0 = <code>lan.trigger[1]</code> LAN1 = <code>lan.trigger[2]</code> LAN2 = <code>lan.trigger[3]</code> LAN3 = <code>lan.trigger[4]</code> LAN4 = <code>lan.trigger[5]</code> LAN5 = <code>lan.trigger[6]</code> LAN6 = <code>lan.trigger[7]</code> LAN7 = <code>lan.trigger[8]</code>
From	Displays the IP address for the device that generates the LAN trigger	localhost 192.168.5.20
Timestamp	A timestamp that identifies the time the event occurred; the timestamp uses the following: <ul style="list-style-type: none"> ▪ PTP timestamp ▪ Seconds ▪ Fractional seconds; the 2601B-PULSE does not support the IEEE Std 1588 standard; the values in this field are always 0 (zero) 	
HWDetect	Identifies a valid LXI trigger packet	LXI
Sequence	Each instrument maintains independent sequence counters: <ul style="list-style-type: none"> ▪ One for each combination of UDP multicast network interface and UDP multicast destination port ▪ One for each TCP connection 	
Domain	Displays the LXI domain number; the default value is 0 (zero)	0
Flags	Contain data about the LXI trigger packet; values are: <ul style="list-style-type: none"> ▪ 1 - Error ▪ 2 - Retransmission ▪ 4 - Hardware ▪ 8 - Acknowledgments ▪ 16 - Stateless bit 	16
Data	The values for this are always 0 (zero)	

Accessing the event log from the command interface

You can access the event log from any remote command interface. The event log must be enabled before LXI trigger events can be viewed. To enable the event log, send:

```
eventlog.enable = 1
```

To view the event log from a remote interface, send:

```
print(eventlog.all())
```

This command outputs one or more strings similar to the following:

```
14:14:02.000 17 Jun 2019, LAN0, 10.80.64.191, LXI, 0, 1560780842, not available, 0,  
0x10,0x00
```

The string displays the same information as the web interface. Commas separate the fields. The fields output in the following order:

- Received time (UTC time)
- Event ID
- From (Sender)
- HWDetect / version
- Domain
- Sequence number
- Timestamp (PTP time)
- Epoch (from 1588)
- Flags
- Data

See the table in [Logging LAN trigger events in the event log](#) (on page 3-35) for detailed descriptions.

To generate log traffic, send the code:

```
local id = 1  
lan.trigger[id].ipaddress = lan.status.ipaddress  
lan.trigger[id].connect()  
for domain = 1, 255 do  
    print(domain)  
    lan.lxidomain = domain  
    lan.trigger[id].assert()  
    delay(1)  
end
```

Help

The help page in the web interface provides basic help for the web interface, a glossary of terms, and a link to licenses for the virtual front panel, firmware upgrade tool, and TSB Embedded.

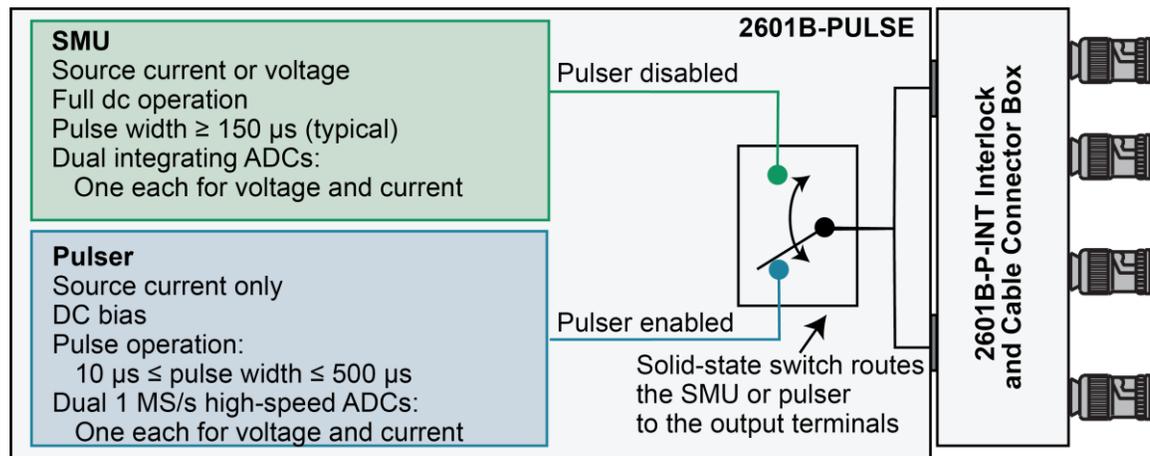
In this section:

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Operation overview

The 2601B-PULSE is a single channel source-measure instrument with the full SMU functionality of a Model 2601B SourceMeter® Instrument plus a high-speed current pulser.

The instrument operates as a SMU or as a current pulser. Internally, a solid-state switch routes the SMU or pulser to the output terminals, as shown in the following figure.

Figure 40: SMU and pulser operation

When the pulser is disabled, the instrument provides the full functionality of a 4-quadrant SMU. You can use the front panel or remote commands to configure the instrument to perform the following source-measure operations:

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

When the pulser is enabled, the instrument generates fast-edge current pulses only. It measures current, voltage, resistance, or power. The pulser sourcing and measuring functionality is only available using remote commands. Pulser protection levels and some measurements are displayed on the front-panel interface.

Limits

Limits are only applied when the pulser is disabled. When the pulser is enabled, protection levels are applied.

When sourcing voltage, you can set the instrument to limit current or power. Conversely, when sourcing current, you can set the instrument to limit voltage or power. In steady-state conditions, the instrument output does not exceed the limit. The maximum limit is the same as the maximum values listed in the following table.

The limit circuit limits in either polarity regardless of the polarity of the source or limit value. The accuracy of the limit opposite in polarity from the source is diminished unless the instrument is in [sink mode](#) (on page 4-5). The maximum limits are based on source range.

The limit operation of the instrument changes dependent on the source mode (current or voltage), load, and the configured limits (current, voltage, and power). It is important to distinguish both the current and voltage limits from the power limit. As the names imply, the current limit restricts the current for sourced voltage, and the voltage limit restricts the voltage for a sourced current. The power limit, however, restricts power by lowering the present limit in effect (voltage or current) as needed to restrict the SMU from exceeding the specified power limit. For additional details on using limits, including load considerations when specifying both a current (or a voltage) limit and a power limit, see “Operating boundaries” in the *Model 2601B-PULSE Reference Manual*.

For additional information on limits, refer to:

- [Pulser operation](#) (on page 4-25)
- “Limit principles” in the *Model 2601B-PULSE Reference Manual*

NOTE

The only exception to the limit not being exceeded is the voltage limit when operating as a current source. To avoid excessive (and potentially destructive) currents from flowing, the voltage limit sources or sinks up to 102 mA for current source ranges on or below 100 mA. For the ranges 1 A and above, the maximum current allowed is the current source setting.

Source range	Maximum limit
100 mV	3 A
1 V	3 A
6 V	3 A
40 V	1 A
100 nA	40 V
1 µA	40 V
10 µA	40 V
100 µA	40 V
1 mA	40 V
10 mA	40 V
100 mA	40 V
1 A	40 V
3 A	6 V

Setting the limit

Set the limit from the front panel as follows:

1. Press the **LIMIT** key to directly access limit editing. Pressing the LIMIT key while in limit edit mode toggles the display between the complementary function limit and the power limit display.
2. Press the navigation wheel and set the limit to the new value.
3. Press the **ENTER** key or the navigation wheel to complete editing.
4. Press the **EXIT (LOCAL)** key to return to the main display.

Set the limit using remote commands as follows:

The table below summarizes basic commands to program a limit. For a more complete description of these commands, refer to the “TSP command reference” section of the *Model 2601B-PULSE Reference Manual*.

Limit commands

Command	Description
<code>smua.source.limiti = limit</code>	Set current limit.
<code>smua.source.limitv = limit</code>	Set voltage limit.
<code>smua.source.limitp = limit</code>	Set power limit.
<code>compliance = smua.source.compliance</code>	Test if in limit (<code>true</code> = in limit; <code>false</code> = not in limit).

To set the limit, send the command with the limit value as the parameter. The following programming example illustrates how to set the current, voltage, and power limit to 50 mA, 4 V, and 1 W respectively:

```
smua.source.limiti = 50e-3
smua.source.limitv = 4
smua.source.limitp = 1
```

The following programming example illustrates how to print the limit state:

```
print(smua.source.compliance)
```

A returned value of `true` indicates one of the following things:

- If the instrument is configured as a current source, the voltage limit has been reached
- If the instrument is configured as a voltage source, the current limit has been reached

Pulser protection circuit

The pulser has two protection circuits, one for the sense terminals and one for the force terminals. Both are set using remote commands. When either of the protection circuits are exceeded, the instrument generates the 5127 "Output protection level exceeded" error and the current pulse terminates within 3 μ s.

The sense terminals are monitored by the voltage protection circuit. If the voltage on the sense terminals goes above the protection level, the output is turned off. If the level was exceeded during a sweep, the output is shorted until all trigger counts are satisfied, then the output is turned off. The voltage protection level can be set from 5 percent to 200 percent of the pulser voltage range.

The force terminals are monitored by the absolute voltage protection circuit. If the voltage on the force terminals goes above the protection level, the 2601B-PULSE automatically turns off the output. The absolute voltage level can be set from 2 V to 40 V, independent of the range. This level ignores normal transients during pulse rise and fall times.

For information on the commands for the pulser protection circuit, refer to the following command descriptions in the *Model 2601B-PULSE Reference Manual*:

- `smua.pulser.protect.sensev`
- `smua.pulser.protect.sourcev`

CAUTION

Setting a protection level does not guarantee that the output will not go above the protection level. The 2601B-PULSE turns off the output as quickly as possible, but the voltage level can briefly exceed this level, potentially causing damage to the device under test (DUT).

Setting and checking the pulser protection levels

To set the voltage protection level using remote commands:

Send the command `smua.pulser.protect.sensev` with the level defined. For example, to set a protection level of 8 V, send:

```
smua.pulser.protect.sensev = 8
```

To set the absolute voltage protection level using remote commands:

Send the command `smua.pulser.protect.sourcev` with the level defined. For example, to set an absolute voltage level of 24 V, send:

```
smua.pulser.protect.sourcev = 24
```

To determine if a pulser level protection was tripped, send:

```
print(smua.pulser.protect.tripped)
```

A returned value of `true` indicates that the protection circuit was tripped. The following events can trip the protection circuit:

- A voltage greater than `smua.pulser.protect.sensev` was detected on the sense terminals.
- A voltage greater than `smua.pulser.protect.sourcev` was detected on the force terminals.
- The maximum pulse width was exceeded during trigger model operation.
- The maximum duty cycle was exceeded during trigger model operation.
- If the SMU cannot keep up with the pulse rate.
- If the SMU cannot keep up with the measurement rate.

The status is reset to `false` when the pulser is disabled or when the output is turned on.

Sink operation

CAUTION

Carefully consider and configure the appropriate output-off state, source function, and compliance limits before connecting the 2601B-PULSE to a device that can deliver energy (for example, other voltage sources, batteries, capacitors, solar cells, or other 2601B-PULSE instruments). Configure recommended instrument settings before making connections to the device. Failure to consider the output-off state, source, and compliance limits may result in damage to the instrument or to the device under test (DUT).

When the instrument is operating as a sink, voltage and current have the opposite polarity. During sink operation, the instrument dissipates power instead of sourcing it. An external source, such as a battery, or an energy storage device, such as a capacitor, can force operation into the sink region.

NOTE

When the pulser is disabled, the accuracy of the limit opposite in polarity from the source is diminished unless the instrument is in sink mode. Enabling sink mode reduces the source limit inaccuracy seen when operating in quadrants II and IV. Quadrants I and III show this source limit inaccuracy.

For example, if a 12 V battery is connected to the voltage source (HI to battery +) that is programmed for +10 V, sink operation occurs in the second quadrant (source +V and measure -I).

CAUTION

When using the SMU current source as a sink, always set the voltage compliance to a level that is higher than the external voltage level. Failure to do so could result in excessive current flow into the instrument and incorrect measurements. See [Limits](#) (on page 4-2) for details about compliance limits.

The sink operating limits are shown in “Continuous power operating boundaries” in the *Model 2601B-PULSE Reference Manual*.

Setting the sink mode using the front panel

To enable or disable the sink mode from the front panel:

1. Press the **CONFIG** key and then the **SRC** key.
2. Select **V-SOURCE**.
3. Select **SINK-MODE**.
4. Select **ENABLE** or **DISABLE**.
5. Press the **ENTER** key. Sink mode is enabled or disabled, as applicable.
6. Press the **EXIT (LOCAL)** key twice to return to the main display.

Setting the sink mode from a remote interface

To enable sink mode from the remote interface, send:

```
smua.source.sink = smua.ENABLE
```

To disable sink mode, send:

```
smua.source.sink = smua.DISABLE
```

DUT test connections

⚠ WARNING

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

⚠ WARNING

SENSE LO and FORCE LO are not internally connected to the chassis. Do not allow them to float above 0 V. Failure to adhere to these guidelines can result in personal injury or death due to electric shock.

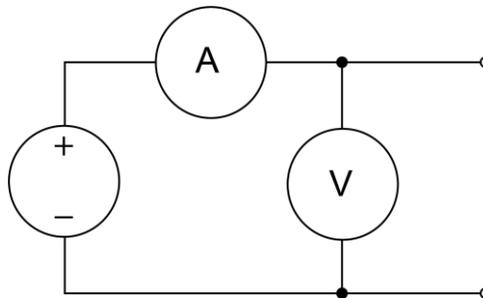
NOTE

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

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

The fundamental source-measure configurations for the 2601B-PULSE are shown in the following figures. When sourcing voltage, you can measure current or voltage, as shown in the following figure.

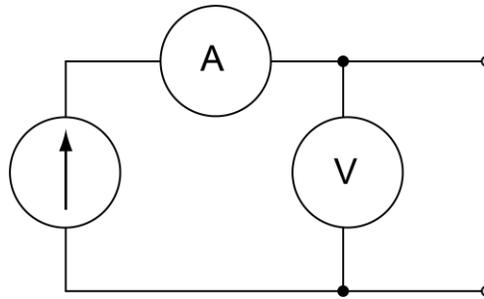
Figure 41: Fundamental source-measure configurations: Source V



A	Current meter
+ -	Voltage source
V	Voltage meter

When the SMU or pulser is sourcing current, you can measure voltage or current, as shown in the following figure.

Figure 42: Fundamental source-measure configuration: Source I



A	Current meter
↑	Current source
V	Voltage meter

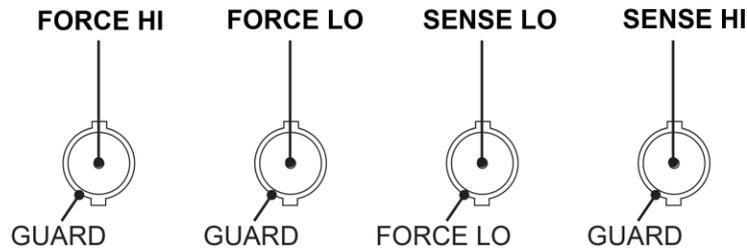
See “Basic circuit configurations” in the *Model 2601B-PULSE Reference Manual* for detailed information.

FORCE and SENSE connectors

You make connections from the instrument to the device under test (DUT) using the BNC connections on the 2601B-P-INT.

The FORCE HI, FORCE LO, and SENSE HI connectors of the 2601B-P-INT have GUARD on the shell. The SENSE LO connector has FORCE LO on the shell.

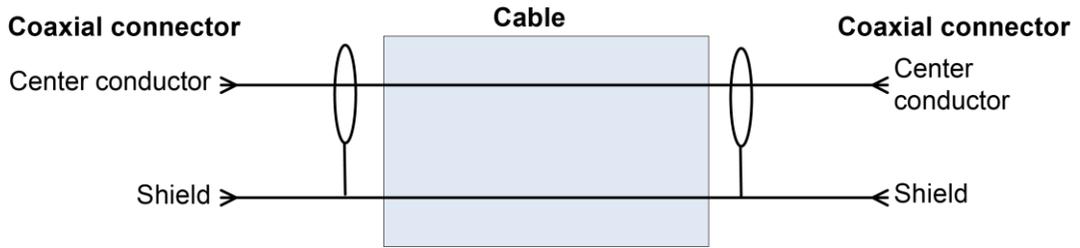
Figure 43: 2601B-P-INT FORCE and SENSE shell connections



NOTE

The FORCE LO shell connection is for shielding only and should not be used to carry signal. Use the center pin of the FORCE LO connector to carry signal.

Figure 44: Coaxial connectors for 2601B-PULSE

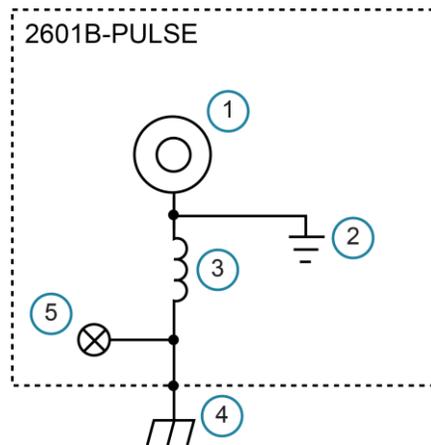


All connections are electrically isolated from chassis ground.

The rear panel of the 2601B-PULSE provides a low-noise chassis ground banana jack that can be used as a common signal ground point for the SENSE and FORCE LOs. This low-noise signal ground banana jack is connected to the chassis through a frequency variable resistor (FVR). The FVR, shown in the figure below, is used to isolate the SMU from high frequencies that may be present on the chassis of the 2601B-PULSE. As frequencies on the chassis increase, the resistance of the FVR increases to dampen their effects. For dc to 60 Hz, the FVR is a virtual short (zero Ω).

The chassis screw terminal is connected to the metal chassis of the 2601B-PULSE.

Figure 45: Chassis ground banana jack



1	Low-noise chassis ground banana jack
2	Signal ground
3	Frequency variable resistor (FVR)
4	Chassis
5	Chassis screw

NOTE

Do not use the chassis as a ground point for signal connections. High frequencies on the chassis of the 2601B-PULSE may result in higher noise. The chassis should only be used as a safety shield. Use the chassis screw for connections to the chassis of the 2601B-PULSE.

⚠ WARNING

The FORCE and SENSE connectors of the 2601B-PULSE are rated for connection to circuits rated Measurement Category I only, with transients rated less than 1500 V_{PEAK}. Do not connect the 2601B-PULSE terminals to CAT II, CAT III, or CAT IV circuits. Connections of the input/output connectors to circuits higher than CAT I can cause damage to the equipment or expose the operator to hazardous voltages.

To prevent electric shock and/or damage to the 2601B-PULSE, when connecting to a source with a greater current capability than the 2601B-PULSE, a user-supplied fuse, rated at no more than 20 A SLO-BLO, should be installed in-line with the 2601B-PULSE input/output connectors.

2-wire local sensing connections

NOTE

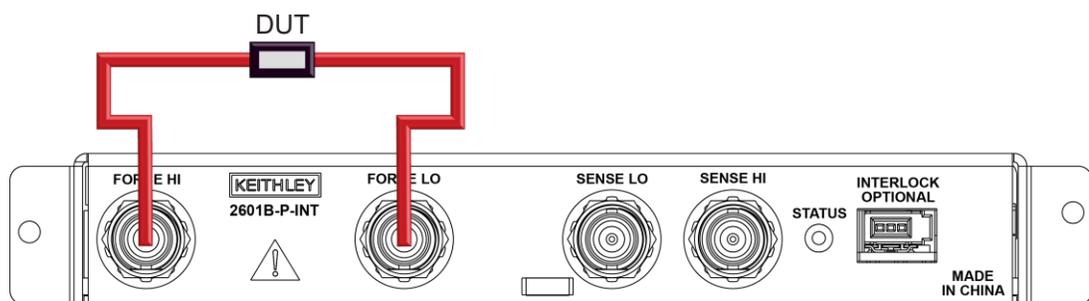
Local voltage sensing is only available when the pulser is disabled.

You can use 2-wire local sensing measurements, shown in the following figure, for the following source-measure conditions:

- Sourcing and measuring current.
- Sourcing and measuring voltage in high impedance (more than 1 kΩ) test circuits.

Make sure to configure the 2601B-PULSE for 2-wire local sensing. Refer to [Sense mode selection](#) (on page 4-20) for information.

Figure 46: Two-wire local sensing 2601B-P-INT connections



4-wire remote sensing connections

When sourcing or measuring voltage in a low-impedance test circuit, there can be errors associated with lead resistance. Voltage source and measure accuracy is optimized by using 4-wire remote sense connections. When sourcing voltage, 4-wire remote sensing ensures that the programmed voltage is delivered to the DUT. When measuring or limiting voltage, only the voltage drop across the DUT is measured.

When the pulser is enabled, you must use 4-wire remote sensing connections. The instrument uses remote sensing regardless of the sense setting.

When the pulser is disabled, the default sense setting is 2-wire local. If you need to use 4-wire remote sensing, you must change the sense. Refer to [Sense mode selection](#) (on page 4-20) for information.

When you are using 4-wire 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. In addition, the voltage across the device may exceed the programmed source limit voltage, possibly causing damage to the device or test fixture.

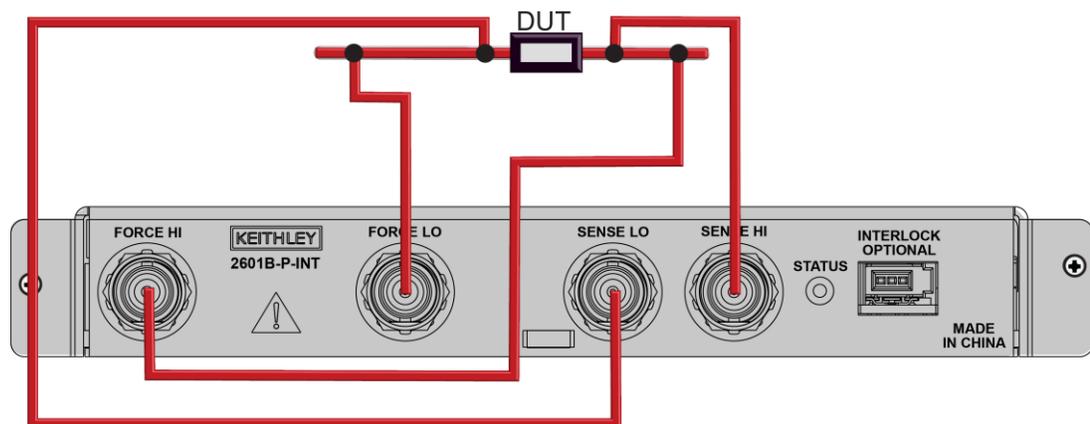
In both cases, the voltage is not measured correctly if a sense lead becomes disconnected from its corresponding force lead.

You can use contact check to verify that the sense leads are connected before enabling remote sensing or before turning on the output. Refer to [Contact check measurements](#) (on page 4-12).

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

- When the pulser is enabled
- Sourcing or measuring voltage in low impedance (<1 k Ω) test circuits
- Enforcing voltage compliance limit directly at the DUT

Figure 47: Four-wire 2601B-P-INT connections (remote sensing)



Connections for pulser operation

Pulser measurements must be made using 4-wire (Kelvin) connections. Refer to [4-wire remote sensing connections](#) (on page 4-10) for connection diagrams.

When making pulser measurements, the allowed maximum total inductance is 3 μH . The open areas between FORCE leads can introduce inductance. To minimize this inductance, jumper the FORCE connection shields at the device under test (DUT). The FORCE connection shields are jumpered inside the 2601B-P-INT, so external jumpers are not needed at the instrument.

NOTE

The signal present at the FORCE terminals is affected by the total inductance in the test circuit. The signal present at the SENSE terminals is only affected by the inductance beyond the Kelvin connection points. Take this into consideration when setting the voltage protection levels.

Keithley Instruments offers several low-inductance cable options that are optimized for pulser applications:

- **2601B-PULSE-CA1 50 Ω BNC-to-BNC cable kit:** A set of two 1.2 m BNC-to-BNC cables and one 1.2 m cable assembly. Use the cables to make the SENSE HI and SENSE LO connections. Use the cable assembly to make the FORCE HI and FORCE LO connections. On the end intended for connection to the device under test (DUT), the shields on the cable kit are jumpered to reduce loop inductance.
- **2601B-PULSE-CA2 50 Ω BNC-to-BNC coaxial cables:** A set of two 3 m cables that are used to make the SENSE HI and SENSE LO connections.
- **2601B-PULSE-CA3 15 Ω BNC-to-BNC cable kit:** A set of two 3 m cables that are used to make the FORCE HI and FORCE LO connections. On the end intended for connection to the DUT, the shields are jumpered to remove loop inductance. The 2601B-PULSE-CA2 must be used for the SENSE connections. This cable kit has lower inductance per meter than the 2601B-PULSE-CA1.

Contact check connections

The contact check function prevents measurement errors due to excessive resistance in the force or sense leads when 4-wire remote sensing is used. Potential sources for this resistance include poor contact at the device under test (DUT), failing relay contacts on a switching card, and wires that are too long or thin. To use contact check, the current limit must be at least 1 mA (this allows enough current to flow when performing the test), and the source-measure unit (SMU) must not be in High-Z output-off mode.

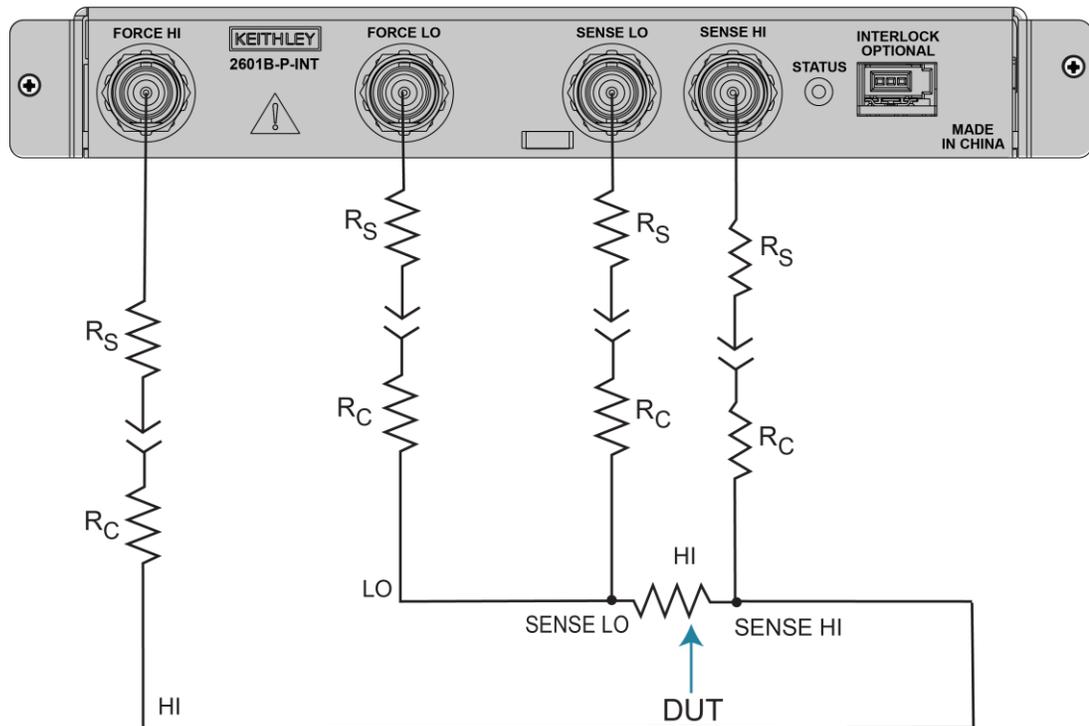
The contact check function also detects open circuits that may occur when a four-point probe is misplaced or misaligned. This relationship is shown schematically in the figure below, where R_C is the resistance of the mechanical contact at the DUT, and R_S is the series resistance of relays and cables.

Contact check requires both force and sense connections. Refer to [4-wire remote sensing connections](#) (on page 4-10) for information.

NOTE

When you are using the 2601B-P-INT, the signals from the SMU are routed through a solid-state multiplexer that adds an additional $25\ \Omega$ to $30\ \Omega$ to each of the SHI and SLO paths. Therefore, the minimum resistance measured for either SHI or SLO when using the 2601B-P-INT is approximately $25\ \Omega$.

Figure 48: Contact check measurement connections to 2601B-P-INT



R_S	Cable and relay resistance
R_C	Contact resistance
DUT	Device under test

NOTE

The contact check function is not available if the pulser is enabled. If you need to use the contact check function in a pulser application, you can disable the pulser, run the contact check measurements, then enable the pulser. See [Example 1: Ten-point pulse sweep](#) (on page 4-28) for an example that shows how to run contact check before running a pulser application.

Contact check commands

The following table summarizes the contact check commands. For a more complete description of these commands, refer to the “TSP command reference” section of the *Model 2601B-PULSE Reference Manual*.

Basic contact check commands

Command	Description
<code>flag = smua.contact.check()</code>	Determine if contact resistance is lower than threshold.
<code>rhi, rlo = smua.contact.r()</code>	Measure the aggregate contact resistance.
<code>smua.contact.speed = speedSetting</code>	Set <i>speedSetting</i> to one of the following: <ul style="list-style-type: none"> ■ 0 or <code>smua.CONTACT_FAST</code> ■ 1 or <code>smua.CONTACT_MEDIUM</code> ■ 2 or <code>smua.CONTACT_SLOW</code>
<code>smua.contact.threshold = rvalue</code>	Set resistance threshold for the contact check function.

Contact check programming example

The following programming example illustrates the setup and command sequence for a typical contact check measurement. These commands set the contact check speed to fast and the threshold to 100 Ω . Then, a contact check measurement against the threshold is made. If it fails, a more accurate contact check measurement is made, and the test is aborted. Otherwise, the output is turned on, and the test continues.

```
-- Restore defaults.
smua.reset()
-- Set contact check speed to fast.
smua.contact.speed = smua.CONTACT_FAST
-- Set the contact check threshold to 100 ohms.
smua.contact.threshold = 100
-- Check contacts against threshold.
if not smua.contact.check() then
  -- Set speed to slow.
  smua.contact.speed = smua.CONTACT_SLOW
  -- Get aggregate resistance readings.
  rhi, rlo = smua.contact.r()
  -- Return contact resistances to the host.
  print(rhi, rlo)
  -- Terminate execution.
  exit()
end
-- Turn output on and continue.
smua.source.output = smua.OUTPUT_ON
```

Guarding and shielding

You can optimize source-measure performance and safety with the effective use of guarding and shielding (noise and safety shields).

Safety shield

You can implement a safety shield to protect the operator from hazards that arise when testing devices under test (DUTs).

Guarding

A driven guard is always enabled and provides a buffered voltage that is at the same level as the input/output HI voltage. The purpose of guarding is to eliminate the effects of leakage current (and capacitance) that can exist between HI and LO. Without guarding, leakage and capacitance in the external high-impedance test circuit could be high enough to adversely affect the performance of the 2601B-PULSE.

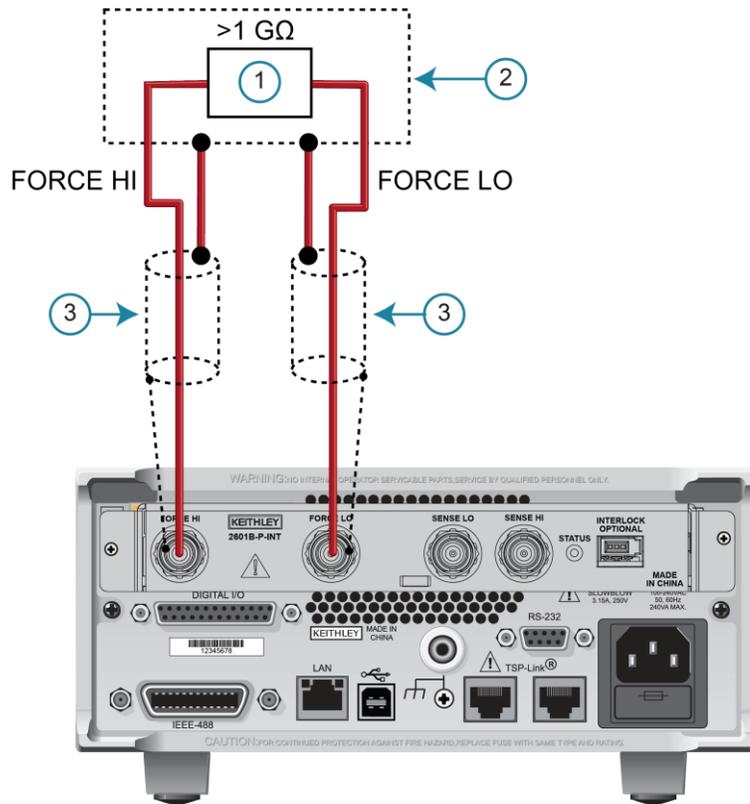
Guarding (shown in the following figure) is recommended when test circuit impedance is $>1 \text{ G}\Omega$.

NOTE

See "Guard" in the *Model 2601B-PULSE Reference Manual* for details on the principles of guarding.

The guard shield can be the shield of a coaxial cable. It can also be an insulated foil that surrounds the conductor. Refer to [FORCE and SENSE connectors](#) (on page 4-8) for detail on the coaxial connections.

Figure 49: Connections for guarding



NOTE

For clarity, sense leads for 4-wire connections are not shown.

1	Test circuit
2	Metal guard shield
3	Coaxial cable shield

Noise shield

Use a noise shield (see following figure) to prevent unwanted signals from being introduced into the test circuit. Low-level signals may benefit from effective shielding. The metal noise shield surrounds the test circuit and should be connected to LO, as shown.

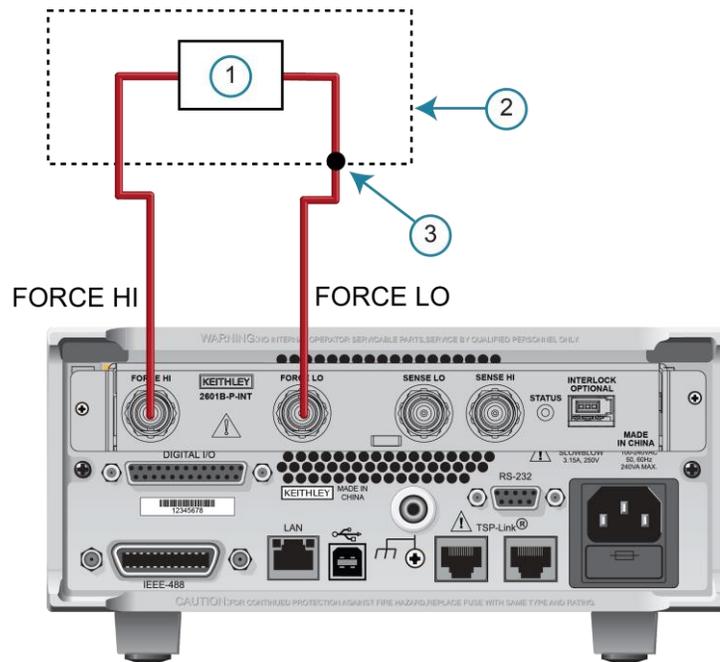
⚠ WARNING

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.

⚠ WARNING

Connections to LO on the 2601B-PULSE are not necessarily at 0 V. Hazardous voltages could exist between LO and chassis ground. Make sure that high-voltage precautions are taken throughout the test system. Alternatively, limit hazardous levels by adding external protection to limit the voltage between LO and chassis. Failure to make sure high-voltage precautions are used throughout the test system or a failure to limit hazardous levels could result in severe personal injury or death from electric shock.

Figure 50: Noise shield



- | |
|--------------------------------|
| 1 Test circuit |
| 2 Metal noise shield |
| 3 LO connected to noise shield |

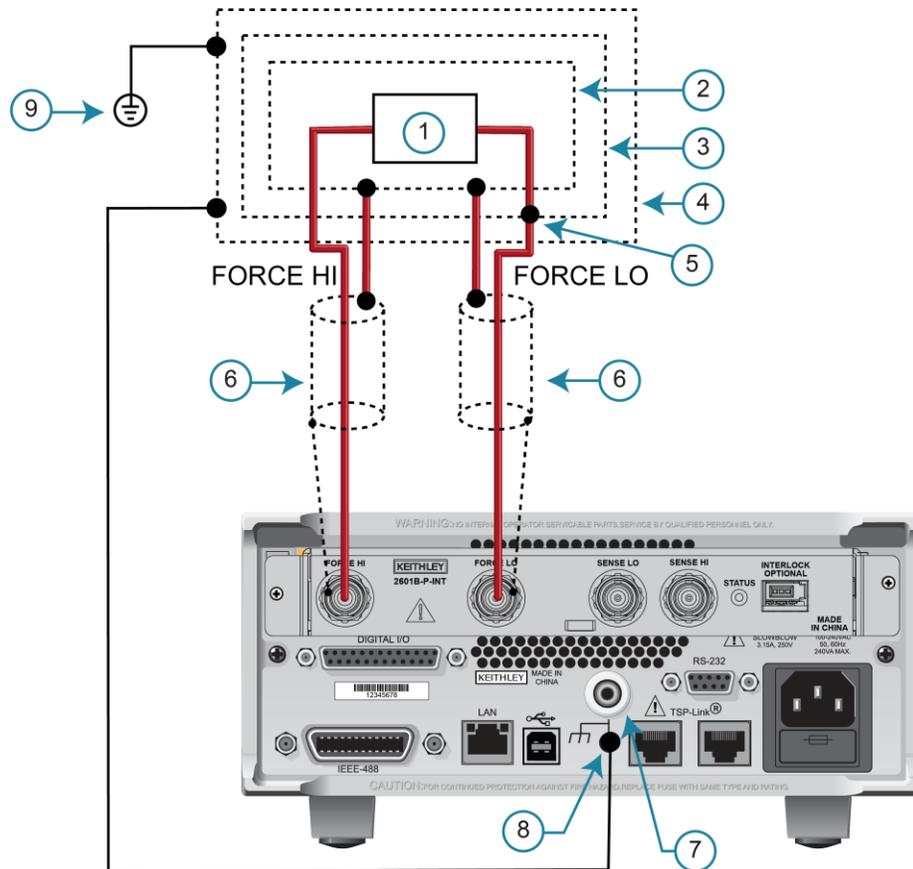
Using shielding and guarding together

The following figures show connections for a test system that uses a noise shield, a safety shield, and guarding. The guard shields are connected to the driven guard of the SMU. The noise shield is connected to LO. The safety shield is connected to the chassis and to protective earth (safety ground).

⚠ WARNING

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.

Figure 51: Using shielding and guarding together



1	Test circuit
2	Metal guard shield
3	Metal noise shield
4	Metal safety shield
5	LO connected to noise shield
6	Coaxial cable shield
7	Low-noise chassis ground banana jack
8	Chassis screw
9	Protective earth (safety ground)

Test fixture

You can use a test fixture to house a device or test circuit. The test fixture can be a metal or nonconductive enclosure and is typically equipped with a lid and an interlock switch. When properly used, the output of the 2601B-PULSE turns off when the lid of the test fixture is opened. The test circuit is mounted inside the test fixture. When hazardous voltages ($>30 V_{RMS}$, $42 V_{PEAK}$) will be present, the test fixture must meet the following safety requirements.

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).

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. Input and output connectors mounted on a metal test fixture 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 opens, and when the lid is closed, the switch closes.

The 2601B-P-INT Interlock and Cable Connector Box provides an interlock option. When properly used with a test fixture, when the lid of the test fixture is opened, the FORCE HI and FORCE LO terminals are shorted and the output of the 2601B-PULSE turns off.

See [Using the interlock](#) (on page 2-37) for information on setting up the interlock.

Sense mode selection

When the pulser is disabled, the voltage sense mode can be set to use [2-wire local sensing connections](#) (on page 4-10) or [4-wire remote sensing connections](#) (on page 4-10). The default sense setting is 2-wire local.

When the pulser is enabled, the sense mode is fixed at 4-wire remote sensing and the sense mode settings are ignored.

Front-panel sense mode selection

To check or change the voltage sense mode from the front panel:

1. Press the **CONFIG** key.
2. Press the **SRC** or **MEAS** key. You can access and set the 2601B-PULSE sense mode from either the V-SOURCE or the V-MEAS menu items.
3. If you pressed the SRC key: Select **V-SOURCE > SENSE-MODE**, and then press the **ENTER** key or the navigation wheel.
If you pressed the MEAS key: Select **V-MEAS > SENSE-MODE**, and then press the **ENTER** key or the navigation wheel.
4. Select **2-WIRE** or **4-WIRE** as needed, and then press the **ENTER** key or the navigation wheel.

Remote interface sense mode selection

To configure the 2601B-PULSE SMU for 4-wire remote sensing, send the command:

```
smua.sense = smua.SENSE_REMOTE
```

The following table summarizes the commands to select the sense mode. See the “TSP command reference” section of the *Model 2601B-PULSE Reference Manual* for details on using these commands.

Commands to select sense mode

Command	Description
<code>smua.source.output = smua.OUTPUT_OFF</code>	Turn off the source-measure unit (SMU) output.
<code>smua.sense = smua.SENSE_LOCAL</code>	Select local (2-wire) sense.
<code>smua.sense = smua.SENSE_REMOTE</code>	Select remote (4-wire) sense.

Output-off modes

CAUTION

Carefully consider and configure the appropriate output-off state, source function, and compliance limits before connecting the 2601B-PULSE to a device that can deliver energy (for example, other voltage sources, batteries, capacitors, solar cells, or other 2601B-PULSE instruments). Configure recommended instrument settings before making connections to the device. Failure to consider the output-off state, source, and compliance limits may result in damage to the instrument or to the device under test (DUT).

Turning off the 2601B-PULSE output may not completely isolate the instrument from the external circuit. You can use the output-off mode to place the 2601B-PULSE in a noninteractive state during idle periods. The available output-off modes are normal, high-impedance, and zero.

Turning off the 2601B-PULSE output may not completely isolate the instrument from the external circuit. You can use the output-off mode to place the 2601B-PULSE in a noninteractive state during idle periods. The available output-off modes are normal, high-impedance, and zero.

Normal output-off mode

The default output-off mode setting is the setting normal. When normal is selected and the pulser is disabled, the source function sources either 0 A or 0 V, as set by the `smua.source.offfunc` attribute. You can limit the output by setting the `smua.source.offlimitY` attribute.

When normal is selected and the pulser is enabled, the output circuit is shorted.

High-impedance output-off mode

For the high-impedance output-off mode (HI-Z), the output relay opens when the output is turned off. This disconnects external circuitry from the input/output of the source-measure unit (SMU). To prevent excessive wear on the output relay, do not use this output-off mode for tests that turn the output off and on frequently.

Zero output-off mode

When the pulser is disabled and the zero output-off mode is selected, the programmed source remains on the display, but internally, the voltage source is selected and is set to 0 V. Measurements are made and displayed.

When the selected source is voltage, the current compliance setting remains the same as the output-on value and compliance detection remains active.

When the selected source is current, the current compliance setting is the programmed current source value or 10 percent full-scale of the present current range, whichever is greater.

You can use the 2601B-PULSE as a current meter when it is in zero output-off mode because it outputs 0 V but measures current.

When the pulser is enabled and the zero output-off mode is selected, the output circuit is shorted and measurements cannot be made.

To configure the output-off mode from the front panel:

1. Press the **CONFIG** key.
2. Press the **OUTPUT ON/OFF** control.
3. Select **OFF-STATE**.
4. Select **MODE**.
5. Select the output-off mode: **HI-Z** (high-impedance), **NORMAL**, or **ZERO**.
6. Press the **EXIT** key to return to the normal display.

To select the normal output-off mode over a remote interface:

```
smua.source.offmode = smua.OUTPUT_NORMAL
```

To select the high-impedance output-off mode over a remote interface:

```
smua.source.offmode = smua.OUTPUT_HIGH_Z
```

To select the zero output-off mode over a remote interface:

```
smua.source.offmode = smua.OUTPUT_ZERO
```

Output-off function

This setting is used only when the output is turned off and the 2601B-PULSE is set to the normal output-off mode (`smua.source.offmode = smua.OUTPUT_NORMAL`).

You can set the output-off function to **CURRENT** or **VOLTAGE** through the **CONFIG** menu on the front panel, or by using the `smua.source.offfunc` attribute from a remote interface. **VOLTAGE** is the default output-off function.

When the output is turned off and the selected output-off function is **VOLTAGE** (`smua.source.offfunc = smua.OUTPUT_DCVOLTS`):

- The source-measure unit (SMU) sources 0 V.
- The current limit is set by the `smua.source.offlimiti` attribute (default 1 mA).

When the output is turned off and the selected output-off function is **CURRENT** (`smua.source.offfunc = smua.OUTPUT_DCAMPS`):

- The SMU sources 0 A.
- The voltage limit is set by the `smua.source.offlimitv` attribute (default 40 V).

When the output-off function is set to either voltage or current, the SMU may source or sink a very small amount of power. In most cases, this source or sink power level is insignificant.

Selecting the output-off function

NOTE

This setting is used only when the output is turned off and the source-measure unit (SMU) is in NORMAL output-off mode.

To configure the output-off function from the front panel:

1. Press the **CONFIG** key.
2. Press the **OUTPUT ON/OFF** control.
3. Select **OFF-STATE** and then select **FUNCTION**.
4. Select **CURRENT** or **VOLTAGE**.
5. Press the **EXIT** key to return to the normal display.

Remote configuration of the output-off function

To configure the output-off function remotely:

To set 0 V output with current limit set by the `smua.source.offlimiti` attribute:

```
smua.source.offfunc = smua.OUTPUT_DCVOLTS
```

To set 0 A output with voltage limit set by the `smua.source.offlimitv` attribute:

```
smua.source.offfunc = smua.OUTPUT_DCAMPS
```

Output-off limits (compliance)

You can set output-off limits (compliance) for the current and voltage output-off functions using the CONFIG menu on the 2601B-PULSE front panel, or by setting the `smua.source.offlimitY` attribute from a remote interface. The output-off limits only apply when the output-off mode is normal.

Setting output-off limits

Setting the output-off limit for CURRENT (`smua.source.offlimiti`) specifies the current limit for the voltage source; setting the output-off limit for VOLTAGE (`smua.source.offlimitv`) specifies the voltage limit for the current source.

To configure the output-off limits from the front panel:

1. Press the **CONFIG** key.
2. Press the **OUTPUT ON/OFF** control.
3. Select **OFF-STATE** and then select **LIMIT**.
4. Select **CURRENT** or **VOLTAGE**.
5. Set the limit value and then press the **ENTER** key or the navigation wheel (for details, see [Setting a value](#) (on page 3-12)).
6. Press the **EXIT** key to return to the normal display.

Setting output-off limits using the remote interface**To set the current limit in NORMAL output-off mode remotely:**

```
smua.source.offlimiti = iValue
```

To set the voltage limit in NORMAL output-off mode remotely:

```
smua.source.offlimitv = vValue
```

Remote programming output-off states quick reference

The content of the following table is a quick reference of commands for programming output-off states from a remote interface.

Output-off state programming quick reference

Command	Description
<code>smua.source.offmode = smua.OUTPUT_NORMAL</code>	Selects normal output-off mode.
<code>smua.source.offmode = smua.OUTPUT_HIGH_Z</code>	Selects high-impedance output-off mode.
<code>smua.source.offmode = smua.OUTPUT_ZERO</code>	Selects zero output-off mode.
<code>smua.source.offfunc = smua.OUTPUT_DCVOLTS</code>	Sets 0 V output with current limit specified by the <code>smua.source.offlimiti</code> attribute.
<code>smua.source.offfunc = smua.OUTPUT_DCAMPS</code>	Sets 0 A output with voltage limit specified by the <code>smua.source.offlimitv</code> attribute.
<code>smua.source.offlimiti = iValue</code>	Sets current limit in normal output-off mode.
<code>smua.source.offlimitv = vValue</code>	Sets voltage limit in normal output-off mode.

Pulser operation

This section contains information specific to using the pulser capabilities of the 2601B-PULSE. The pulser generates fast-edge current pulses and measures current and voltage.

Pulser operation must be set up using TSP commands through a remote communication interface. For information on setting up remote communications, refer to [Remote communication interfaces](#) (on page 2-12).

To use the pulser, you must configure a trigger model. Refer to [Using the trigger model](#) (on page 4-32) for detail.

When the pulser is enabled, there are the following differences in source-measure unit (SMU) functionality:

- You can only source current (not voltage).
- If the output exceeds a maximum pulse width, maximum duty cycle, or the specified protection level during a sweep, the 2601B-PULSE output is shorted, but the sweep continues with no source output until it is finished.
- Some SMU settings are ignored; see [Settings ignored when the pulser is enabled](#) (on page 4-27) for details.
- The `smua.trigger.source.pulsewidth` and `smua.pulser.measure.delay` attributes provide more precise timing than you can achieve using the `smua.trigger.endpulse.stimulus` and `smua.trigger.measure.stimulus` attributes.
- Some of the output-off modes behave differently:
 - **OUTPUT_NORMAL:** The output circuit is shorted when this output-off mode is selected.
 - **OUTPUT_ZERO:** The output circuit is shorted and measurements cannot be made when this output-off mode is selected.
- You cannot use contact check.
- You cannot make measurements when the output is off.
- Compliance limits (`smua.source.limitY`) are not used to control the output. Pulser protection levels are used instead. Refer to [Pulser protection circuit](#) (on page 4-4) for information.

If the output is on and you enable or disable the pulser, the output is automatically turned off.

TSP commands used with the pulser

You must use remote commands and the trigger model to generate fast-edge current pulses and measure current and voltage.

The following table lists attributes that are used to set up the pulser and measure the resulting current and voltage. For complete command descriptions, refer to the *Model 2601B-PULSE Reference Manual*.

TSP attributes for use with the 2601B-PULSE pulser

Command	Description
<code>smua.pulser.enable</code>	Enables or disables the 2601B-PULSE pulser
<code>smua.pulser.measure.aperture</code>	Specifies the pulse measurement aperture when the pulser is enabled
<code>smua.pulser.measure.delay</code>	Sets the measurement delay when the pulser is enabled
<code>smua.pulser.protect.sensev</code>	Sets a voltage protection level used to monitor the sense terminals when the pulser is enabled
<code>smua.pulser.protect.sourcev</code>	Sets an absolute voltage protection level used to monitor the force terminals when the pulser is enabled
<code>smua.pulser.protect.tripped</code>	Indicates if the protection circuit was tripped
<code>smua.pulser.rangeY</code>	Sets the source and measure ranges when the pulser is enabled
<code>smua.trigger.source.pulsewidth</code>	Sets the source pulse width when using a trigger model sweep

Settings ignored when the pulser is enabled

The following source-measure unit (SMU) settings are ignored when the pulser is enabled:

- `display.smua.limit.func`
- `smua.measure.autorangeY`
- `smua.measure.autozero`
- `smua.measure.delay`
- `smua.measure.highcrangedelayfactor`
- `smua.measure.lowrangeY`
- `smua.measure.nplc`
- `smua.measure.rangeY`
- `smua.sense`
- `smua.source.autorangeY`
- `smua.source.delay`
- `smua.source.func`
- `smua.source.highc`
- `smua.source.limitY`
- `smua.source.lowrangeY`
- `smua.source.offflimitY`
- `smua.source.rangeY`
- `smua.source.settling`
- `smua.source.sink`
- `smua.trigger.endpulse.action`
- `smua.trigger.endsweep.action`

Settings ignored when the pulser is disabled

The following pulser settings do not affect source-measure unit (SMU) operation when the pulser is disabled:

- `smua.pulser.measure.aperture`
- `smua.pulser.measure.delay`
- `smua.pulser.protect.sensev`
- `smua.pulser.protect.sourcev`
- `smua.pulser.rangeY`

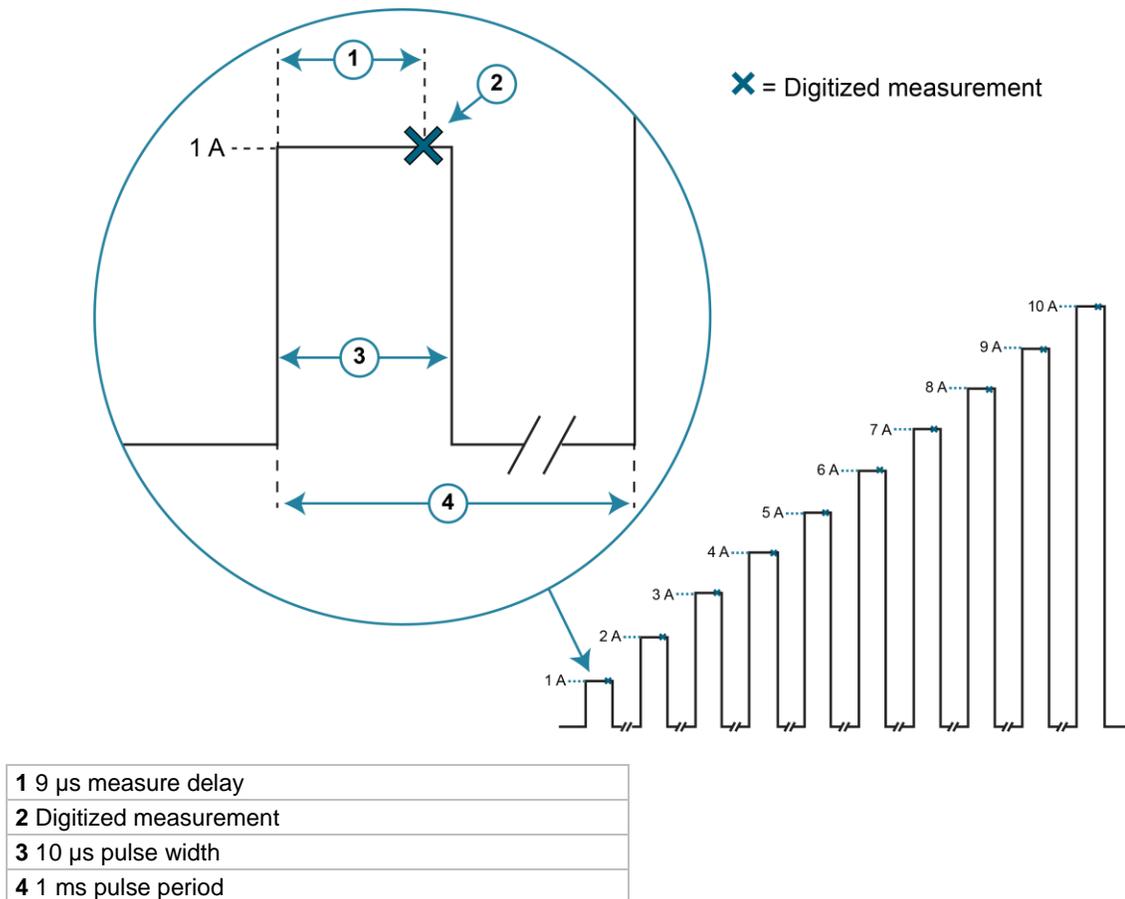
Examples

The following topics contain TSP programming examples for the 2601B-PULSE pulser. You can use these examples as a starting point for your own applications, editing them as needed.

Example 1: Ten-point pulse sweep

The code in this example uses the trigger model to program a 10-point pulse sweep of 10 μs pulses from 1 A to 10 A with a 1 ms pulse period. A 1 Ω resistor is used as the device under test (DUT). The following figure illustrates the pulse action in the example.

Figure 53: 10-point pulse sweep



To program the example pulse sweep, send the following commands:

```
-- Restore instrument defaults and clear the measure buffer.
reset()
smua.nvbuffer1.clear()
-- Disable the pulser.
smua.pulser.enable = smua.DISABLE
-- Set contact check speed to fast.
smua.contact.speed = smua.CONTACT_FAST
-- Set the contact check threshold to 100 ohms.
smua.contact.threshold = 100
-- Check contacts against threshold.
if not smua.contact.check() then
    -- Set speed to slow.
    smua.contact.speed = smua.CONTACT_SLOW
    -- Get aggregate resistance readings.
    rhi, rlo = smua.contact.r()
    -- Return contact resistances to the host.
    print(rhi, rlo)
    -- Terminate execution.
    exit()
end
-- Set the number of pulses to 10.
smua.trigger.count = 10

-- Set trigger timer 1 to generate additional trigger events for the pulse sweep
-- corresponding to the 9 pulses that follow the first one.
trigger.timer[1].count = smua.trigger.count - 1

-- Set trigger timer 1 to delay for 1 ms between events, corresponding to the
-- pulse period.
trigger.timer[1].delay = 1e-3

-- Enable pass-through mode so that the first trigger passes through immediately
-- to generate the first pulse.
trigger.timer[1].passthrough = true

-- Specify which event starts the timer.
trigger.timer[1].stimulus = smua.trigger.ARMED_EVENT_ID

-- Enable source level changes during the sweep.
smua.trigger.source.action = smua.ENABLE

-- Specify a 10-point linear pulse sweep from 1 A to 10 A.
smua.trigger.source.linear(1, 10, smua.trigger.count)

-- Set the source pulse width to 10 microseconds.
smua.trigger.source.pulsewidth = 10e-6

-- Configure the 2601B-PULSE to start the pulse when the trigger
-- timer event occurs.
smua.trigger.source.stimulus = trigger.timer[1].EVENT_ID

-- Enable measurements after a 9 microsecond pulse measure delay and save the result
-- in nvbuffer1. This applies for a 1 microsecond measure aperture.
smua.trigger.measure.action = smua.ENABLE
```

```

smua.pulser.measure.delay = 9e-6
smua.trigger.measure.v(smua.nvbuffer1)
-- Set the pulser ranges.
smua.pulser.rangei = 10
smua.pulser.rangev = 10
-- Enable pulser.
smua.pulser.enable = smua.ENABLE

-- Turn the source output on.
smua.source.output = smua.OUTPUT_ON

-- Initiate the trigger model.
smua.trigger.initiate()

-- Wait for pulse commands to complete.
waitcomplete()

-- Turn the source output off.
smua.source.output = smua.OUTPUT_OFF

-- Output the readings stored in the buffer as a comma-separated string.
printbuffer(1, smua.nvbuffer1.n, smua.nvbuffer1)

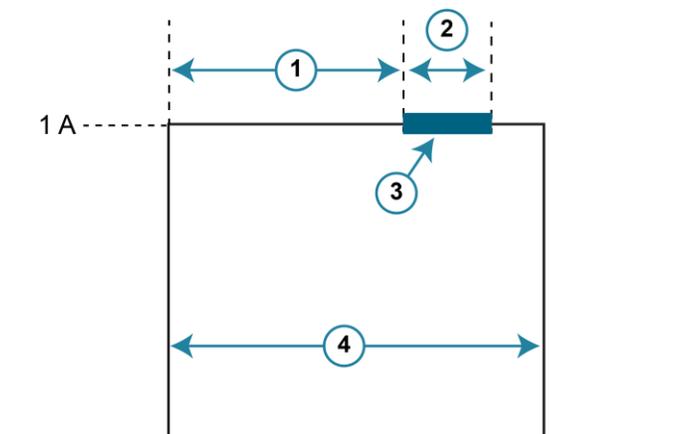
```

Example 2: Generate a pulse with a voltage protection level

This example demonstrates how to use the 2601B-PULSE pulser to generate a current pulse with a voltage protection level.

The code in this example generates a single 50 μs , 1 A pulse on the 1 A range, with an 8 V protection level. The measurement occurs 35 μs after the start of the pulse and has a 10 μs aperture. When the pulse is complete, it checks whether the pulse terminated early due to the voltage protection level. The following figure depicts the pulse action in the example.

Figure 54: Generating a single current pulse with a 35 μs delay and a 10 μs measure aperture



1	35 μs measure delay
2	10 μs aperture
3	Reading
4	50 μs pulse width

To program the example pulse, send the following commands:

```
-- Restore instrument defaults and clear measure buffer.
reset()
smua.nvbuffer1.clear()

-- Set the number of pulses to 1.
smua.trigger.count = 1

-- Enable source level changes.
smua.trigger.source.action = smua.ENABLE

-- Trigger the source action when the SMU moves
-- from the arm layer to the trigger layer.
smua.trigger.source.stimulus = smua.trigger.ARMED_EVENT_ID

-- Set the pulser source to the 1 A range.
smua.pulser.rangei = 1

-- Set the pulser to source a 1 A pulse.
smua.trigger.source.listi({1})

-- Set the pulser voltage protection limit to 8 V.
smua.pulser.protect.sensev = 8
-- Set the source pulse width to 50 microseconds.
smua.trigger.source.pulsewidth = 50e-6
-- Enable measurements.
smua.trigger.measure.action = smua.ENABLE

-- Specify a 35 microsecond pulser measure delay and a
-- 10 microsecond measurement aperture.
smua.pulser.measure.delay = 35e-6
smua.pulser.measure.aperture = 10e-6

-- Set to measure voltage and save the results in nvbuffer1.
smua.trigger.measure.v(smua.nvbuffer1)

-- Enable the pulser.
smua.pulser.enable = smua.ENABLE

-- Turn the source output on and initiate the trigger model.
smua.source.output = smua.OUTPUT_ON
smua.trigger.initiate()

-- Wait for pulser commands to complete.
waitcomplete()

-- Turn the source output off.
smua.source.output = smua.OUTPUT_OFF

-- Output the voltage reading stored in the buffer.
print(smua.nvbuffer1[1])

-- Check whether the pulse terminated early because of the voltage
-- protection limit and output the result.
print(smua.pulser.protect.tripped)
```

Using the trigger model

The source-measure unit (SMU) in the 2601B-PULSE has a remote trigger model that supports a wide range of triggering features for source sweeps, triggered measurements, and pulse actions.

Measurements using the trigger model can be made synchronously with sourcing actions or they can be made asynchronously. The following figures graphically illustrate both modes of the remote trigger model.

Figure 55: Trigger model: Synchronous mode

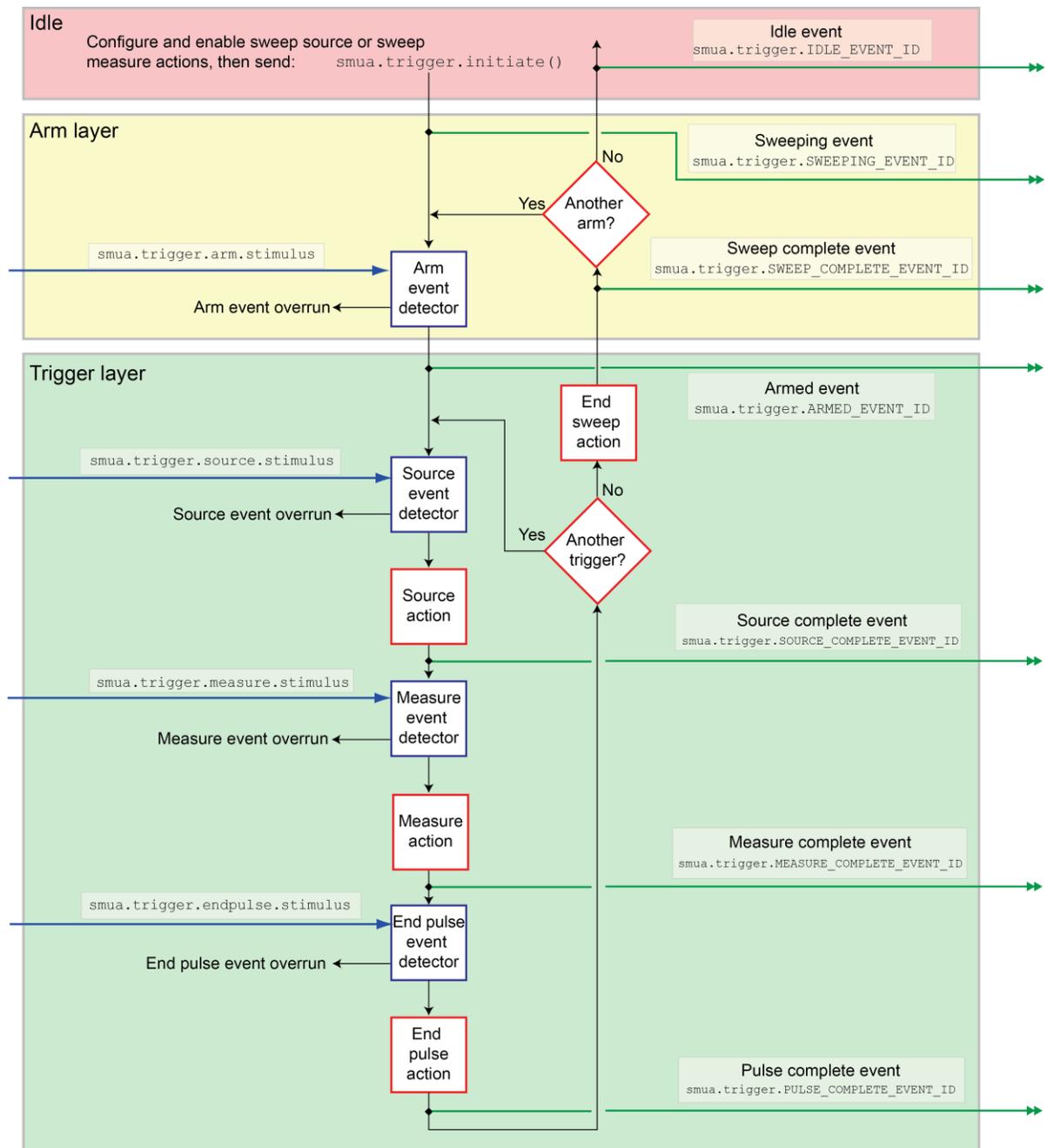
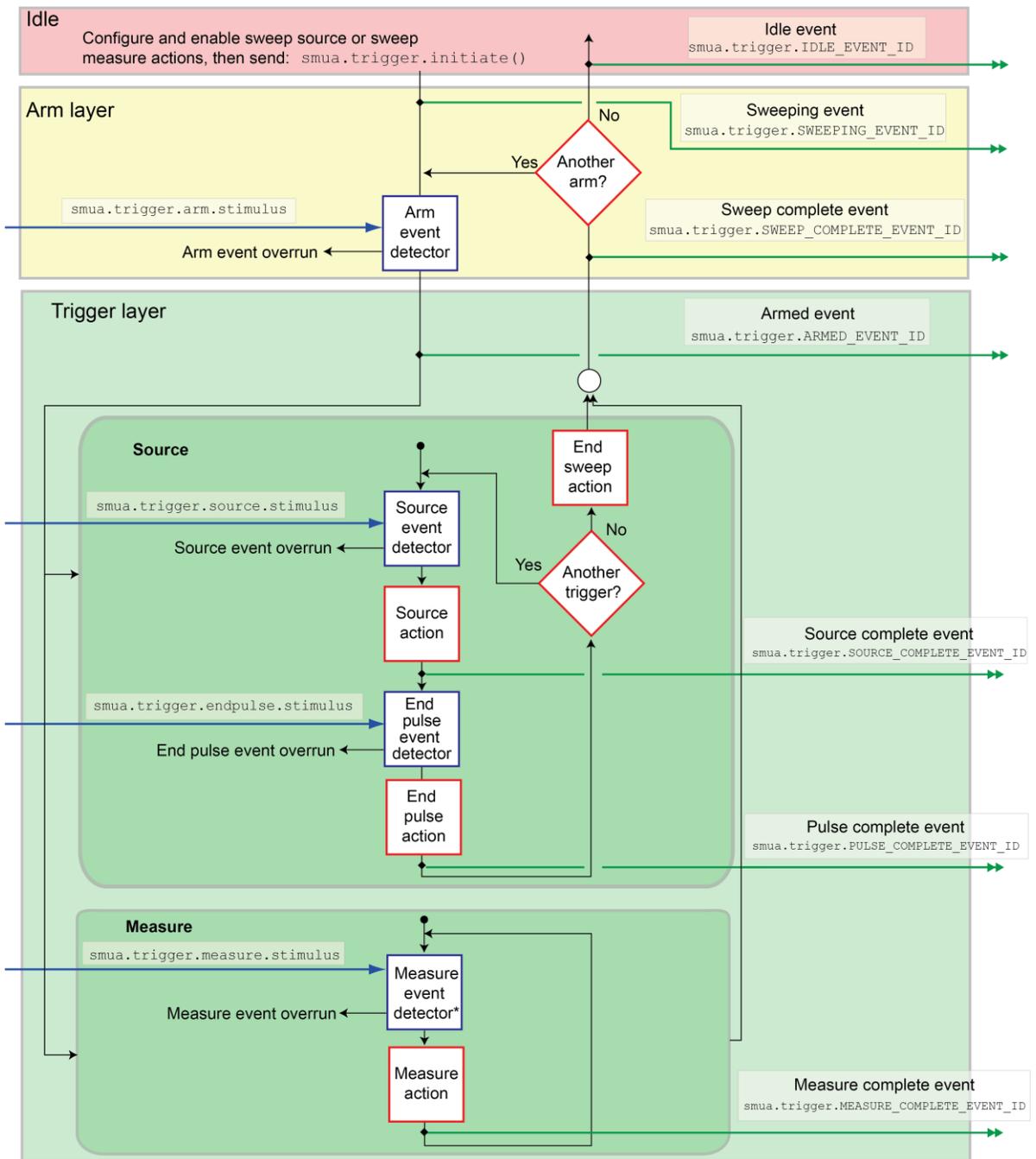


Figure 56: Trigger model: Asynchronous mode



When the `smua.trigger.measure.action` attribute is set to `smua.DISABLE` or `smua.ENABLE`, the trigger model operates in synchronous measurement mode. When it is set to `smua.ASYNC`, it operates in asynchronous mode.

Trigger model sections

As shown in the previous figures, the trigger model consists of the sections idle, arm layer, and trigger layer.

The SMU is in the idle state if a sweep is not in process. Use the `smua.trigger.initiate()` function to move the SMU from the idle state to the arm layer.

Each sweep starts and ends in the arm layer.

All source, measurement, and pulse actions occur in the trigger layer. The source outputs the programmed voltage or current source value. Measurements can be current, voltage, resistance, or power. The end pulse action sources the idle (or bias) level when the instrument generates pulses.

The trigger model dictates the sequence of operation for the SMU when it is configured to perform a sweep. When the SMU comes to an event detector, it suspends operation and waits for the event you assigned to the stimulus input. If no event is assigned, the SMU continues uninterrupted past the event detector and through the trigger model. When the SMU comes to an action block, it performs the appropriate action, if enabled. The SMU loops through the arm and trigger layers until the programmed arm and trigger counts are satisfied.

Configuring source and measure actions

You can configure the source action using any of the following functions:

```
smua.trigger.source.linearY()  
smua.trigger.source.logY()  
smua.trigger.source.listY()
```

Where:

Y = Source function (v = voltage, i = current)

Source functions cannot be changed within a sweep.

To enable the source action, set the `smua.trigger.source.action` attribute to `smua.ENABLE`.

The source-measure unit (SMU) can be configured to perform any or all available measurements during a sweep using the `smua.trigger.measure.Y()` function. To enable the measure action for a simple synchronous sweep, set the `smua.trigger.measure.action` attribute to `smua.ENABLE`.

To enable the measure action for an asynchronous sweep, set the `smua.trigger.measure.action` attribute to `smua.ASYNC`.

NOTE

In asynchronous mode, trigger your measurements before the source completes the sweep (before the end sweep action occurs). If the source loop has completed its end sweep action, the measure loop terminates unless the measure action block is actively measuring. If this is the case, the active measurement is allowed to complete before returning to the arm layer.

NOTE

For more information about the sweep functions, see the "Sweep operations" section in the *Model 2601B-PULSE Reference Manual*.

When the pulser is disabled, configured source and measure delays are imposed when the SMU executes the source and measure action blocks.

Regardless of the pulser state, if the measure count setting is greater than one, the measure count is satisfied each time the measure action is performed.

The arm and trigger counts must be set to control how many times the SMU executes the source and measure actions. The arm count indicates the number of times to execute the complete sweep. The trigger count sets the number of loops in the trigger layer. Typically, you set the trigger count to be equal to the number of points in the configured sweep. If the trigger count is not equal to the number of points configured in the sweep, then one of the following occurs:

- If the trigger count is greater than the number of points in a sweep as configured by `smua.trigger.source.linearY()`, `smua.trigger.source.logY()`, or `smua.trigger.source.listY()`, then the SMU satisfies the trigger count by restarting the sweep values from the beginning.
- If the trigger count is less than the number of source values configured, then the SMU satisfies the trigger count and ignores the remaining source values.

For example, configure a three-point linear voltage sweep from 1 to 3 V, with the trigger count set to 2. The SMU outputs 1 V, 2 V. If the trigger count is set to 6, the SMU outputs the values 1 V, 2 V, 3 V, 1 V, 2 V, 3 V, repeating the source values twice in a single sweep.

Enabling pulse sweeps using the end pulse action

When the pulser is disabled, you can enable pulse sweeps by using the end pulse action. When the pulser is enabled, the instrument always behaves as if the endpulse action is set to `smua.SOURCE_IDLE`.

The command below illustrates how to configure pulse mode sweeps by setting the end pulse action:

```
smua.trigger.endpulse.action = smua.SOURCE_IDLE
```

You can use timers to configure the pulse width and period.

To disable pulse sweeps, set the `smua.trigger.endpulse.action` attribute to `smua.SOURCE_HOLD`.

When the pulser is enabled, you can use the `smua.trigger.source.pulsewidth` attribute to control the pulse width. The `smua.trigger.source.pulsewidth` and `smua.pulser.measure.delay` attributes provide more precise timing than you can achieve using the `smua.trigger.endpulse.action` attribute.

For more information on timers, refer to "Timers" in the *Model 2601B-PULSE Reference Manual*.

In this section:

Introduction	5-1
Displaying the serial number	5-1
Line fuse replacement.....	5-1
Front-panel tests	5-3
Upgrading the firmware.....	5-4

Introduction

The information in this section describes routine maintenance of the instrument that the operator can perform. It also contains information on how to optimize your measurements.

Displaying the serial number

The instrument serial number is on a label on the rear panel of the instrument. You can also access the serial number from the front panel using the front-panel keys and menus.

To display the serial number on the front panel:

1. If the 2601B-PULSE is in remote operation, press the **EXIT (LOCAL)** key once to place the instrument in local operation.
2. Press the **MENU** key.
3. Use the navigation wheel to scroll to the **SYSTEM-INFO** menu item.
4. Press the **ENTER** key. The SYSTEM INFORMATION menu is displayed.
5. Scroll to the **SERIAL#** menu item.
6. Press the **ENTER** key. The 2601B-PULSE serial number is displayed.

Line fuse replacement

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

⚠ WARNING

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

⚠ WARNING

To prevent injury, death, or instrument damage, use only the correct fuse type, as shown in the following table.

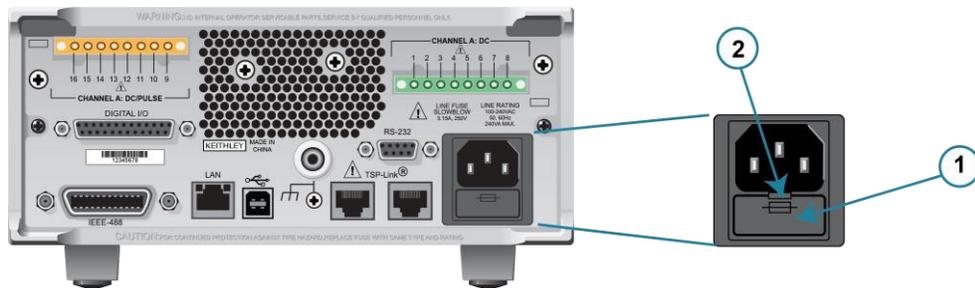
Line fuse

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

To replace the line fuse:

1. Power off the instrument and remove the line cord.
2. The fuse drawer (item 1 in the following figure) is below the ac receptacle. A small tab is on the top of the fuse drawer (item 2). Use a thin-bladed knife or a screwdriver to pry this tab away from the ac receptacle.

Figure 57: Line fuse replacement



3. Slide the fuse drawer out to gain access to the fuse. The fuse drawer does not pull completely out of the power module.
4. Snap the fuse out of the drawer and replace it with the same type.
5. Push the fuse drawer back into the module.

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

Front-panel tests

The front-panel tests test the functionality of the front-panel keys and the display.

NOTE

In the following procedures, highlight the menu item and press the **ENTER** key to select it. You can also select a menu item by pressing the navigation wheel.

Keys test

This test checks the functionality of each front-panel key.

Perform the following steps to run the KEYS test:

1. If the instrument is in remote mode, press the **EXIT (LOCAL)** key once to place the instrument in local mode.
2. Press the **MENU** key.
3. Navigate through the menus by turning the navigation wheel. Press the **ENTER** key to select the menu items as follows: **DISPLAY > TEST > DISPLAY-TESTS**.
4. Turn the navigation wheel until the **KEYS** menu item is highlighted.
5. To start the test, press the **ENTER** key. When you press a key while the test is active, the label name for that key is displayed to indicate that it is functioning properly. When you release the key, the message `No keys pressed` is displayed.
6. To test the **EXIT (LOCAL)** key, press the **EXIT (LOCAL)** key once.
7. To exit the test, press the **EXIT (LOCAL)** key twice consecutively. You exit the test and the instrument returns to the **FRONT PANEL TESTS** menu.
8. Press the **EXIT (LOCAL)** key multiple times to exit out of the menu structure.

Display patterns test

This test lets you verify that each pixel and indicator in the vacuum fluorescent display is working properly.

Perform the following steps to run the display test:

1. If the instrument is in remote mode, press the **EXIT (LOCAL)** key once to place the instrument in local mode.
2. Press the **MENU** key.
3. Navigate through the menus by turning the navigation wheel, and then pressing the **ENTER** key to select the items as follows: **DISPLAY > TEST > DISPLAY-TESTS**.
4. Turn the navigation wheel until the **DISPLAY-PATTERNS** menu item is highlighted.

5. To start the display test, press the **ENTER** key. There are three parts to the display test. Each time the **ENTER** key or the navigation wheel is pressed, the next part of the test sequence is selected. The test sequence is as follows:
 - Checkerboard pattern and the indicators that are on during normal operation
 - Checkerboard pattern (alternate pixels on) and all the numeric indicators (which are not used) are illuminated
 - Each digit and adjacent indicators are sequenced; all the pixels of the selected digit are on
6. When finished, abort the display test by pressing the **EXIT (LOCAL)** key. The instrument returns to the FRONT PANEL TESTS menu. Continue pressing the **EXIT (LOCAL)** key to exit out of the menu structure.

Upgrading the firmware

You can load a newer or older version of firmware to the instrument. The process takes about five minutes.

To load the firmware, you can use a USB flash drive or select a file from a computer.

From the front panel, you must use the USB flash drive. Make sure the USB flash drive is empty except for the firmware file.

From the web interface, Test Script Builder, or remote interface, you can select the file from the computer.

Firmware files are available for download from the [Product Support and Downloads web page \(tek.com/product-support\)](http://tek.com/product-support) in the category "Software." After downloading the file, unzip the file. The file with the extension `.x` is the firmware file.

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.

If you are loading an older version, check the release notes and verify that the version of firmware you are loading is compatible with your hardware.

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

To upgrade or downgrade the firmware using the front panel:

1. Turn the instrument power off. Wait a few seconds.
2. Turn the instrument power on.
3. Copy the firmware file to a USB flash drive.
4. Disconnect the input and output terminals to and from the instrument.
5. If the instrument is in remote mode, press the **EXIT (LOCAL)** key once to place the instrument in local mode.
6. Insert the flash drive into the USB port on the front panel of the 2601B-PULSE.
7. From the front panel, press the **MENU** key
8. Turn the navigation wheel to go to the **UPGRADE** menu item, and then press the **ENTER** key.
9. Turn the navigation wheel to select the file on the USB flash drive that contains the appropriate version of firmware.
10. Press the **ENTER** key to select **Yes**. The status of the upgrade is displayed.

The instrument reboots automatically when the upgrade is complete.

To upgrade or downgrade the firmware from the web interface:

1. Turn the instrument power off. Wait a few seconds.
2. Turn the instrument power on.
3. Open a web browser on the host computer.
4. Enter the IP address of the instrument in the web browser address box. For example, if the instrument IP address is 192.168.1.101, enter 192.168.1.101 in the browser address box.
5. Press **Enter** on the computer keyboard to open the web interface of the instrument.
6. From the left navigation area, select **Flash Upgrade**.
7. Choose **Select File**. A file selection dialog box is displayed.
8. Select the firmware file.
9. Select **Start**. A progress dialog box is displayed. When the upgrade begins, you can also see progress on the front-panel display.

After the instrument automatically restarts, it is ready for use.

Using TSB to upgrade the firmware

After downloading the flash file from tek.com/keithley, you can use Test Script Builder (TSB) to upgrade the firmware of your 2601B-PULSE.

To upgrade the firmware using Test Script Builder:

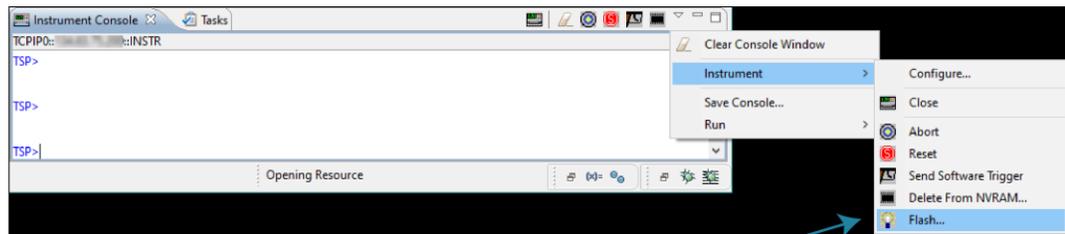
1. Start Test Script Builder.
2. On the Instrument Console toolbar, click the **Open Instrument** icon.

Figure 58: Open Instrument icon



3. Select your instrument from the **Select Instrument** dialog box.
4. On the Instrument Console toolbar, select the down arrow and select **Instrument > Flash**.

Figure 59: Flash menu option



5. For **Select or enter a firmware image file**, use the browser to select the new firmware.
6. For **Select a replacement mode**, select **Upgrade** to install a newer version of firmware or **Downgrade** to install an older of firmware.
7. Wait until the upgrade or downgrade is complete and the instrument shows the opening display.

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Additional 2601B-PULSE information

For additional information about the 2601B-PULSE, refer to the Keithley Instruments website (tek.com/keithley), which contains the most up-to-date information. From the website, you can access:

- The *Model 2601B-PULSE Reference Manual*, which contains complete instrument information, including descriptions of the TSP commands.
- *The Low Level Measurements Handbook: Precision DC Current, Voltage, and Resistance Measurements*
- *Semiconductor Device Test Applications Guide*
- Application notes
- Updated drivers
- Information about related products, including:
 - Series 2600B System SourceMeter® Instruments
 - The Model 4200A-SCS Semiconductor Characterization System
 - The 2651A High Power System SourceMeter® Instrument
 - The 2657A High Power System SourceMeter® Instrument
 - The 2400 Series SMU SourceMeter Instruments

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

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