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Model 2461 1 kW Pulse Mode Interactive SourceMeter® Instrument

Calibration and Adjustment Manual

2461-905-01 Rev. A / February 2016

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A Greater Measure of Confidence

KEITHLEY
A Tektronix Company

Model 2461

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Safety precautions

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

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read 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 Instruments 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, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with 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 danger. 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 caution, 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 dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

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

Instrumentation and accessories shall not be connected to humans.

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

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

To clean an instrument, use a damp cloth or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., 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 January 2013.

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Section 1

Introduction

In this section:

Welcome

Thank you for choosing a Keithley Instruments product. The Model 2461 1 kW Pulse Mode Interactive SourceMeter® Instrument is a precise, low-noise instrument that combines a stable DC power supply, high-power, high-current source, electronic load, and high-impedance multimeter with pulse, contact check, and digitize capabilities. This instrument features intuitive setup and control, enhanced signal quality and range, and better resistivity and resistance capabilities than similar products on the market.

The Model 2461 can source up to 7 A (10 A pulse), and features 1 A, 4 A, 5 A, 7 A, and 10 A ranges. With 0.012 percent basic accuracy at 6½-digit resolution, the Model 2461 is a good solution for testing a wide variety of materials and devices in applications such as power semiconductors, solar energy, high brightness LEDs, power conversion, electrochemistry, batteries, and more.

Introduction to this manual

This manual provides instructions to help you calibrate and adjust your Keithley Instruments Model 2461. In this manual, the term "calibration" refers to the process of verifying that the accuracy of the instrument is within its one-year accuracy specifications. The term "adjustment" refers to the process of changing the calibration constants so that the accuracy of the instrument is within its one-year accuracy specifications.

This manual presents calibration information, adjustment information, and command descriptions for the calibration and adjustment commands.

NOTE

For additional command descriptions, refer to the *Model 2461 Reference Manual* available on the Downloads, Manuals, and Documentation web page (*http://www.tek.com/downloads*).

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 corporate headquarters of Keithley Instruments (toll-free inside the U.S. and Canada only) at 1-800-935-5595, or from outside the U.S. at +1-440-248-0400. For worldwide contact numbers, visit the Keithley Instruments website (*http://www.tek.com/keithley*).

Factory service

To return the instrument to Keithley Instruments for repair:

- Call the Repair Department at 1-800-833-9200 or send an email to RMAREQUEST@tektronix.com for a Return Material Authorization (RMA) number.
- Carefully pack the instrument in the original packing carton.
- Write `ATTENTION REPAIR DEPARTMENT` and the RMA number on the shipping label.

Section 2

Preparing for calibration verification and adjustment

In this section:

Calibration verification and adjustment test requirements

The following topics describe what you must do to prepare the Model 2461 for calibration verification and adjustment.

Environmental conditions

To ensure accurate results, the calibration verification and adjustment environment must meet the following conditions.

Temperature and relative humidity

Conduct the calibration verification and adjustment procedures in a test environment with:

- A stable ambient temperature of 18 °C to 28 °C (65 °F to 82 °F).
- A relative humidity of less than 70 percent, unless otherwise noted.

Warm up period

Allow the Model 2461 to warm up for at least one hour before conducting the calibration verification or adjustment procedures.

If the instrument has been subjected to temperature extremes (more than 5 °C (41 °F) above T_{cal}), allow additional time for the internal temperature of the instrument to stabilize. Typically, allow an additional hour to stabilize an instrument that is 10 °C (50 °F) outside the specified temperature range.

Also, allow the test equipment to warm up for the amount of time recommended by the manufacturer.

Line power

The Model 2461 requires a line voltage of 100 V to 240 V and a line frequency of 50 Hz or 60 Hz. Calibration verification and adjustment should be done within this range.

NOTE

The instrument automatically senses the line frequency at power up.

Recommended test equipment

The following table summarizes recommended calibration verification and adjustment equipment. Test equipment uncertainty adds to the uncertainty of each measurement. Generally, test equipment uncertainty should be at least four times smaller than the corresponding Model 2461 specifications.

NOTE

Refer to the test equipment manufacturer's specifications to calculate the uncertainty, which varies for each function and range test point.

Description	**Ranges**
Digital multimeter	DC voltage
Keithley Instruments Model 2002 Digital Multimeter	200 mV 2 V 7 V 10 V 20 V 100 V
Digital multimeter	DC current
Any digital multimeter with a test uncertainty ratio (TUR) of 4:1 or better	1 µA 10 µA 100 µA 1 mA 10 mA 100 mA 1 A
For better accuracy on the 4 A, 5 A, 7 A, and 10 A ranges, you can use shunt resistors if the combined uncertainties for the test setup still meet the required test uncertainty ratio of 4:1 or better. This ratio should be based on the Model 2461 one-year accuracy specifications.	4 A 5 A 7 A 10 A
Resistance calibrator	Resistance
Fluke 5730A High-Performance Multifunction Calibrator	1.9 Ω 19 Ω 190 Ω 1.9 kΩ 19 kΩ 190 kΩ 1.9 MΩ 19 MΩ 100 MΩ

Calibration and adjustment connections

Connections for Model 2461 calibration verification and adjustment are the same. The following topics describe the connections you should use for the different ranges and functions.

⚠ 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 Model 2461 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 Model 2461 before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

⚠ WARNING

The maximum common-mode voltage (voltage between LO and chassis ground) is 250 V_{peak}. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.

The front and rear terminals of the Model 2461 are rated for connection to circuits rated Installation Category I only. Do not connect the Model 2461 terminals to CAT II, CAT III, or CAT IV circuits. Connection of the SourceMeter® instrument input/output terminals to circuits higher than CAT I can cause damage to the equipment or expose the operator to hazardous voltage.

⚠ CAUTION

The maximum voltage between input/output HI and LO or 4-wire sense HI and LO is 210 V_{peak}. The maximum voltage between input/output HI and 4-wire sense HI or between input/output LO and 4-wire sense LO is 5 V. Exceeding these voltages may result in instrument damage.

Connections for the 200 mV to 100 V ranges

For calibration verification or adjustment on the 200 mV to 100 V ranges, use either the front-panel or rear-panel connections shown in the following figures.

NOTE

The default voltage source protection value is 40 V. Before testing the 100 V range, be sure to assert the interlock. Without the interlock asserted and the green interlock light on, the Model 2461 is limited to 40 V. For more information on the Model 2461 interlock, see the "Using the Interlock" section in the *Model 2461 Reference Manual*.

Figure 1: Front-panel connections for the 200 mV to 100 V ranges

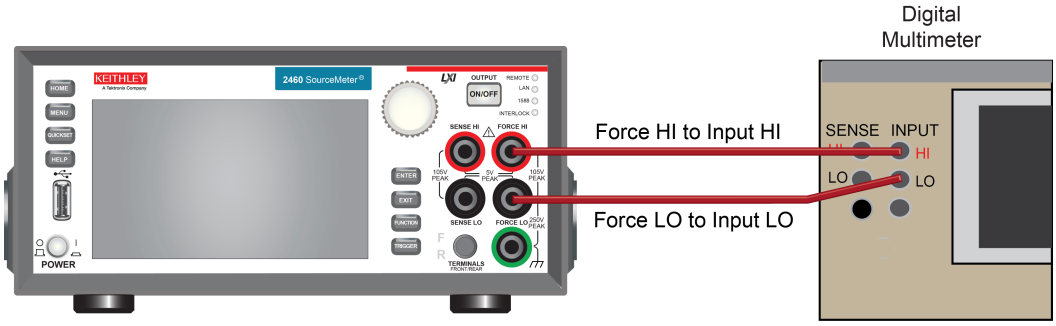
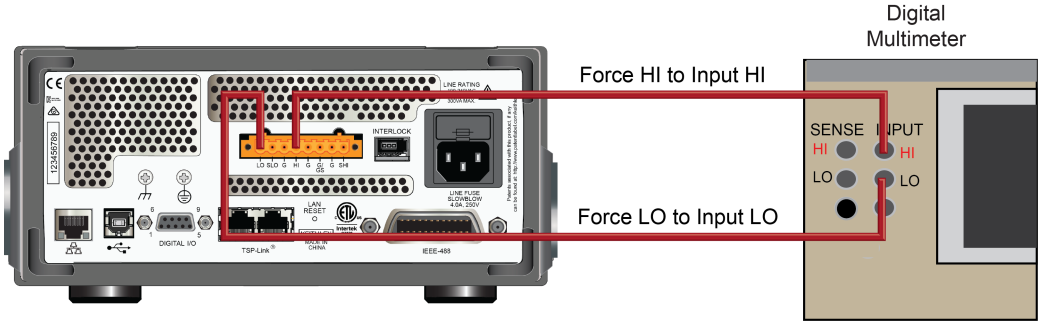


Figure 2: Rear-panel connections for the 200 mV to 100 V ranges



Connections for the 1 µA to 1 A ranges

For calibration verification or adjustment on the 1 µA to 1 A ranges, use either the front-panel or rear-panel connections shown in the following figures.

Figure 3: Front-panel connections for the 1 µA to 1 A ranges

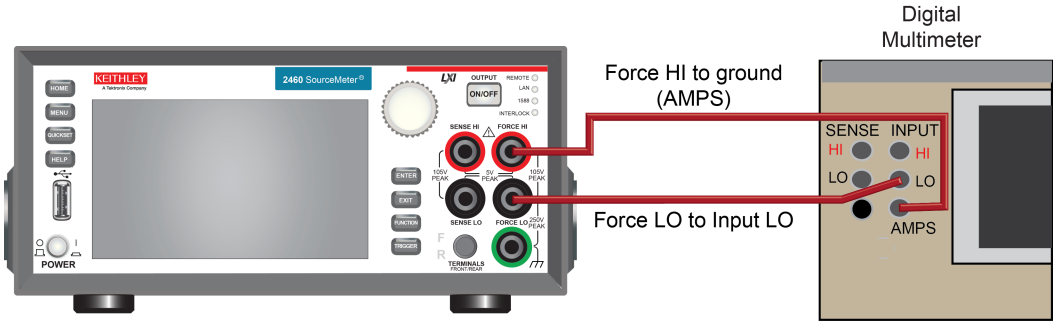
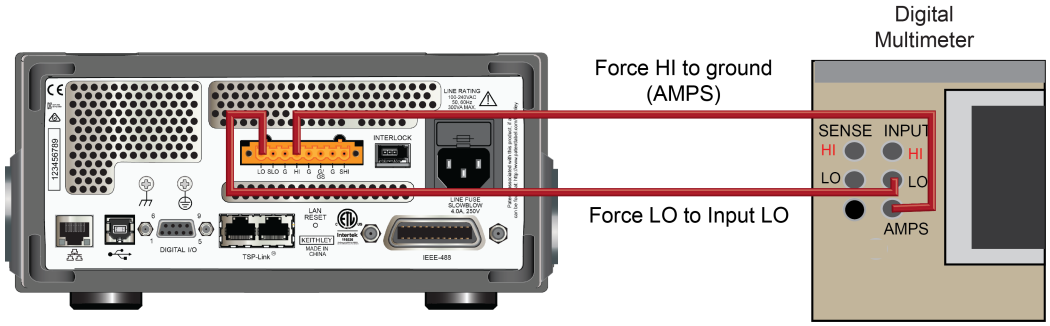


Figure 4: Rear-panel connections for the 1 µA to 1 A ranges



Connections for the 4 A to 10 A ranges

For calibration verification or adjustment on the 4 A to 10 A ranges, use either the front-panel or rear-panel connections shown in the following figures.

Figure 5: Front-panel connections for the 4 A to 10 A ranges

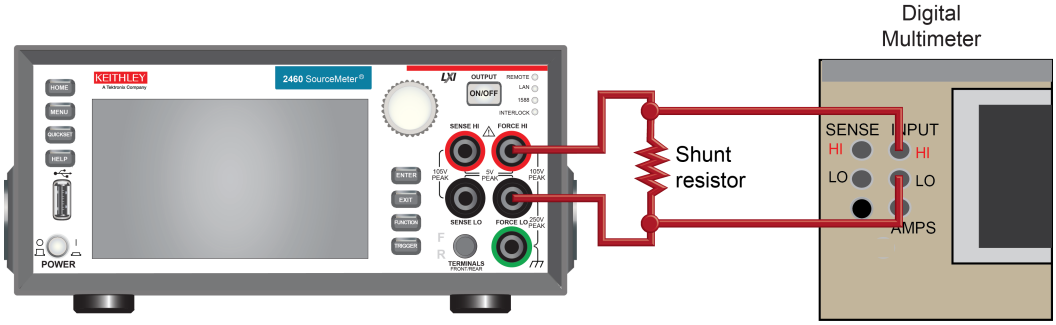
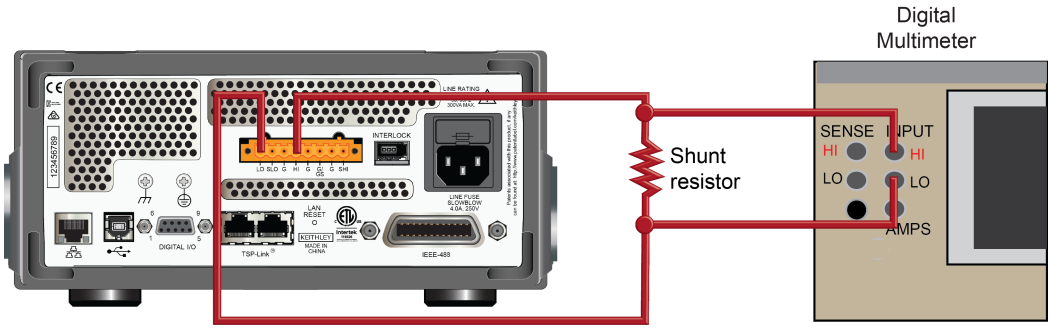


Figure 6: Rear-panel connections for the 4 A to 10 A ranges



Connections for resistance calibration verification and adjustment

For resistance calibration verification or adjustment, use either the front-panel or rear-panel connections shown in the following figures.

Figure 7: Front-panel resistance connections

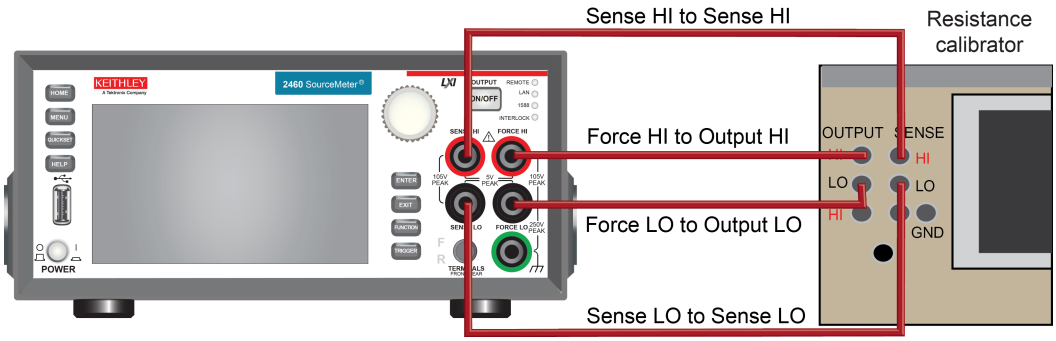
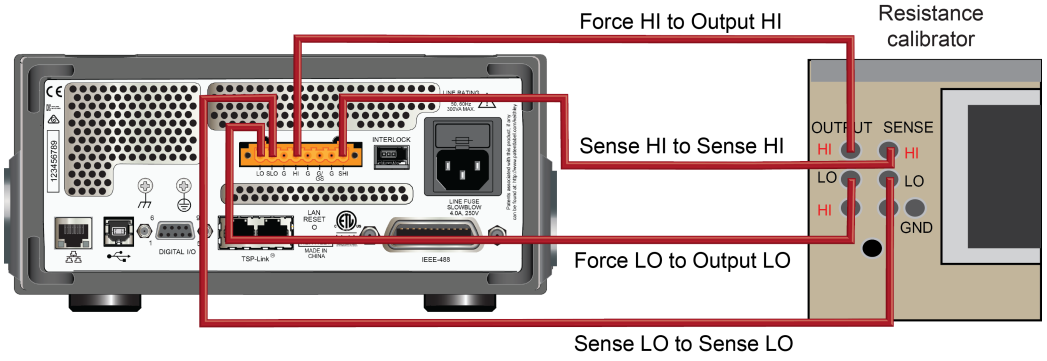


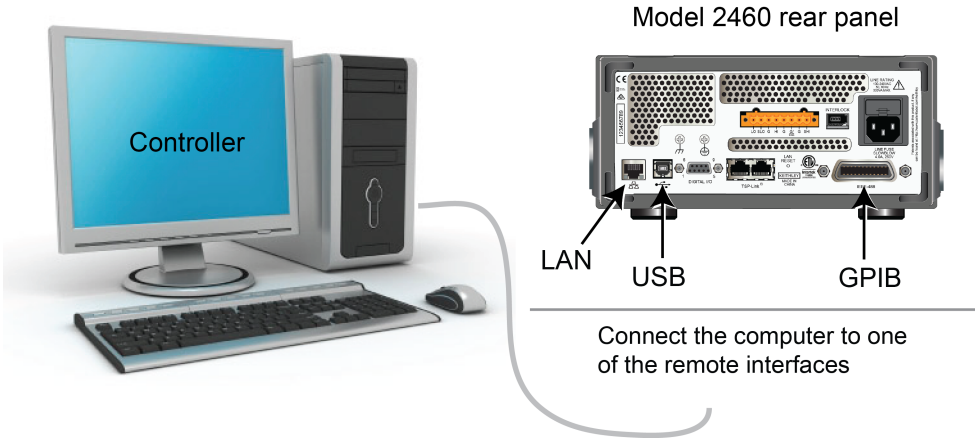
Figure 8: Rear-panel resistance connections



Remote communications connections

The procedures in this manual use SCPI commands sent to the Model 2461 from a remote interface. Select one of the remote interface connections shown below. The instrument automatically detects the connection. For more detailed information about the remote communications connections, see "Remote communications interfaces" in the *Model 2461 Reference Manual*.

Figure 9: Remote communications interfaces



If you are using the IEEE-488 interface, make sure the primary address of the Model 2461 is the same as the address specified in the program you will be using to send commands.

Calibration verification and adjustment considerations

When performing the calibration verification or adjustment procedures:

- Make sure that the test equipment is properly warmed up and connected to the Model 2461 input and output jacks. Ensure that either the front-panel or rear-panel terminals are selected (depending on your connections) with the TERMINALS FRONT/REAR button or using the `:ROUTe:TERMinals` <FRONt or REAR> SCPI command.
- Make sure the Model 2461 is set to the correct source range.
- Make sure the Model 2461 output is turned on before making measurements.
- Make sure the test equipment is set up for the proper function and range.
- Allow the Model 2461 output signal to settle before making a measurement or adjusting each point.
- When using a shunt resistor for current calibration verification and adjustment, make sure the shunt is properly rated for the current and power being measured. Also, consider temperature coefficient and other resistance uncertainty contributors in the overall measurement uncertainty calculation.
- Do not connect test equipment to the Model 2461 through a scanner, multiplexer, or other switching equipment.

Section 3

Calibration

In this section:

Introduction

Use the procedures in this section to verify that Model 2461 accuracy is within the limits stated in the instrument's one-year accuracy specifications. Specifications and characteristics are subject to change without notice; refer to the Downloads, Manuals, and Documentation web page (*http://www.tek.com/downloads*) for the most recent specifications.

You can use these calibration verification procedures to:

- Make sure that the instrument was not damaged during shipment
- Verify that the instrument meets factory specifications
- Determine if adjustment is required
- Verify that adjustment was done properly

⚠ WARNING

The information in this section is intended for qualified service personnel only. Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death if contacted. Use appropriate safety precautions when working with hazardous voltages.

NOTE

If the instrument is still under warranty and its performance is outside specified limits, please contact your local Keithley Instruments office, sales partner, or distributor. You can also call the corporate headquarters of Keithley Instruments (toll-free inside the U.S. and Canada only) at 1-800-935-5595, or from outside the U.S. at +1-440-248-0400. For worldwide contact numbers, visit the Keithley Instruments website (*http://www.tek.com/keithley*).

Calibration verification limits

Before performing the calibration verification test procedures, you must calculate the calibration verification limits using the Model 2461 specifications. The most recent version of the specifications is on the Downloads, Manuals, and Documentation web page (*http://www.tek.com/downloads*).

In the Model 2461 Specifications document, source specifications are expressed as a percent of setting plus voltage, current, or ohms offset. Measure specifications are expressed as a percent of reading plus voltage, current, or ohms offset.

The calculation for calibration verification limits is:

Specification tolerance = ± *[(setting* × *percent of setting specification) + offset specification*

To calculate the calibration verification limits for a range:

1. Select the test setting to verify.
2. Multiply the setting by the percent of setting (for source verification) or percent of reading (for measure verification) value listed in the specification for that range.
3. Add the absolute value of that calculation to the offset specification for the range.
4. Calculate the low limit by subtracting the result of step 3 from the setting value.
5. Calculate the high limit by adding the result of step 3 to the setting value.

Example source limits calculation

As an example of how source limits are calculated, assume you are testing the 20 V DC range using a 95 percent of scale signal value, and the Model 2461 one-year accuracy specification.

Use ±(0.015 % of setting + 2.4 mV offset) to get the calculated output limits:

Output limits = 19 V ± [(19 V × 0.015 %) + 2.4 mV]
Output limits = 19 V ± (0.00285 + 0.0024)
Output limits = 19 V ± 0.00525 V
Output limits = 18.99475 V to 19.00525 V

Example measure or digitize limits calculation

When you verify the measure or digitize functions (voltage, current, and resistance), calculate the upper and lower test limits relative to the reference nominal value determined by the reference instrument. For voltage and current, the reference nominal value is generally a reading from a reference digital multimeter (DMM). For resistance, the reference value is the characterized value of the resistance source.

The calculation of upper and lower test limits is identical to the source limit calculation, except the reference value is used instead of the nominal setting.

As an example, assume that you are testing the 20 kΩ range, and the actual value of the nominal 19 kΩ calibrator resistor is 19.025 kΩ. Using a one-year normal accuracy specification of ±(0.063 % of reading + 3 Ω), the recalculated reading limits are:

Specification tolerance = [(19.025 kΩ × 0.063 %) + 3 Ω]
Reading limits = 19.025 kΩ ±(11.99 kΩ + 3 Ω)
Reading limits = 19.025 kΩ ±14.99 Ω
Reading limits = 19.01001 kΩ to 19.03999 kΩ

Setting the measurement range

When simultaneously sourcing and measuring either voltage or current, the measure range is coupled to the source range, and you cannot independently control the measure range. As a result, you do not set the range when testing voltage or current measurement accuracy.

When selecting the source range, be sure that the limit is set to the appropriate maximum value for that range.

Taking the Model 2461 out of a limit overflow state

Calibration verification measurements should not be made when the Model 2461 is in a limit overflow state. For purposes of the calibration verification tests, the Model 2461 can be taken out of an overflow state by raising the limit value.

NOTE

Do not take the instrument out of an overflow state by decreasing the source value or changing the range. Always use the recommended range and source settings when verifying the instrument.

Remote calibration verification procedure

Use the following procedure to verify instrument calibration by sending SCPI commands over the IEEE-488, USB, or LAN connections.

Step 1. Prepare the Model 2461 for calibration verification

Verify that the calibration verification environment, instrument, and test equipment are set up as described in Preparing for calibration verification and adjustment (on page 2-1).

Step 2. Voltage calibration verification

Follow the steps below to verify that Model 2461 voltage source-measure-digitize accuracy is within specified limits. This test involves setting the output voltage to each full-range value and measuring the voltages with a precision digital multimeter (DMM).

NOTE

To meet digitizer accuracy specifications, digitizer autocalibration (ACAL) must be performed within one week of verification, and the Model 2461 internal temperature must be within 5 °C of the last ACAL temperature. See the *Model 2461 Reference Manual* for information about autocalibration.

Digitizer accuracy is specified for the average of 1000 samples at 1 µS intervals. In the interest of simplicity, this condition is met in the procedure below by setting the digitizer aperture to AUTO and reading a single sample at a 1000 readings/s sample rate. This returns the average of 1000 1 µS samples automatically in a single reading. See the *Model 2461 Reference Manual* for more information about aperture, sample rate, and different methods of acquiring digitizer measurements.

1. With the source output off, connect the Keithley Model 2461 to the DMM as shown in Connections for the 200 mV to 100 V ranges (on page 2-4).

⚠ 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 Model 2461 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 Model 2461 before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

2. Turn on the source output.

NOTE

If the Model 2461 is not already warmed up, allow it to warm up for at least one hour before continuing to the next step.

Complete the calibration verification steps listed in the following table for each voltage range. For each voltage range, perform the complete procedure at 95 percent of the range's positive full-scale value, then at 0 V, then at 95 percent of the range's negative full scale value, and then again at 0 V. For example, for the 200 mV range, complete the procedure four times using each of the following values, in this order: +190 mV, 0 V, –190 mV, 0 V.

Voltage calibration verification procedure

Step	Command or procedure	Description
1	*RST	Restore default settings.
2	:SOUR:FUNC VOLT	Select the source function.
3	:FUNC "VOLT"	Select the measure function.*
4	:SOUR:VOLT:RANG <Range>	Set the source range.**
5	:SYST:RSEN OFF	Disable remote sensing.***
6	:ROUT:TERM <FRONT or REAR>	Select the front-panel or rear-panel terminals to match your test setup.
7	:SOUR:VOLT <Level>	Program the source value.
8	:OUTP:STAT ON	Turn on the source output.
9	Make DMM reading.	Read the actual output of the Model 2461 using the external DMM.
10	:READ?	Have the Model 2461 measure and return its source output.
11	:DIG:FUNC "VOLT"	Select the digitize voltage function.*
12	:DIG:VOLT:APER AUTO	Set the aperture to match the sample rate.
13	:DIG:VOLT:SRAT 1000	Set to 1000 readings/s (1 mS aperture).
14	:DIG:COUNT 1	Digitize one sample when triggered.
15	:READ:DIG?	Return the digitized reading of the source output.
16	:OUTP:STAT OFF	Turn off the source output.
17	Calculate the source error.	Calculate the difference between step 7 and step 9.
18	Calculate the measure error.	Calculate the difference between step 9 and step 10.
19	Calculate the digitizer error.	Calculate the difference between step 9 and step 15.
20	Validate source accuracy.****	Compare the result of step 17 to the source specification.
21	Validate measure accuracy.*****	Compare the result of step 18 to the measure specification.
22	Validate digitizer accuracy.*****	Compare the result of step 19 to the digitize specification.

* The measure range is coupled to the source range when simultaneously sourcing and measuring voltage, so you do not need to set the measure range.

** Where <Range> = 0.2, 2, 7, 10, 20, and 100.

*** With remote sense off, you may need to add a relative offset to compensate for cable noise.

**** The source limits are calculated based on the programmed source value of the Model 2461 for each range (not the actual value).

***** The measure and digitize limits are calculated based on a precise measurement of the programmed value of the Model 2461 by the external reference DMM (not the programmed source value).

Step 3. Current calibration verification

NOTE

Keithley Instruments recommends two different connection configurations for current calibration verification:

- For the 1 µA to 1 A ranges, use the connection diagrams in Connections for the 1 µA to 1 A ranges (on page 2-5).
- For the 4 A to 10 A ranges, use the connection diagrams in Connections for the 4 A to 10 A ranges (on page 2-5).

The following topics describe how to do current calibration verification for each of these configurations.

NOTE

To meet digitizer accuracy specifications, digitizer autocalibration (ACAL) must be performed within one week of verification, and the Model 2461 internal temperature must be within 5 °C of the last ACAL temperature. See the *Model 2461 Reference Manual* for information about autocalibration.

Digitizer accuracy is specified for the average of 1000 samples at 1 µS intervals. In the interest of simplicity, this condition is met in the procedure below by setting the digitizer aperture to AUTO and reading a single sample at a 1000 readings/s sample rate. This returns the average of 1000 1 µS samples automatically in a single reading. See the *Model 2461 Reference Manual* for more information about aperture, sample rate, and different methods of acquiring digitizer measurements.

Current calibration verification for the 1 µA to 1 A ranges

Follow the steps below to verify that Model 2461 current source-measure-digitize accuracy is within specified limits. In this test, you set the output current to each full-range value and measure the current with a precision digital multimeter (DMM).

To calibrate the 1 µA to 1 A ranges:

1. With the source output off, connect the Model 2461 to the DMM using the connection configuration in Connections for the 1 µA to 1 A ranges (on page 2-5).

⚠ 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 Model 2461 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 Model 2461 before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

2. Turn on the Model 2461 source output.

NOTE

If the Model 2461 is not already warmed up, allow it to warm up for at least one hour before continuing to the next step.

3. Complete the calibration steps listed in the following table for each current range. For each current range, perform the complete procedure at 95 percent of the range's positive full-scale value, then at 0 A, then at 95 percent of the range's negative full scale value, and then again at 0 A. For example, for the 1 mA range, complete the procedure four times using each of the following values, in this order: +0.95 mA, 0 A, –0.95 mA, 0 A.

Current calibration verification procedure for the 1 µA to 1 A ranges

Step	Command or procedure	Description
1	*RST	Restore default settings.
2	:SOUR:FUNC CURR	Select the source function.
3	:FUNC "CURR"	Select the measure function.*
4	:SOUR:CURR:RANG <Range>	Set the source range.**
5	:SYST:RSEN OFF	Disable 4-wire remote sensing.
6	:ROUT:TERM <FRONT or REAR>	Select the front-panel or rear-panel terminals to match your test setup.
7	:SOUR:CURR <Level>	Program the source value.
8	:OUTP:STAT ON	Turn on the source output.
9	Make DMM reading.	Read the actual output of the Model 2461 using the external DMM.
10	:READ?	Have the Model 2461 measure and return its source output.
11	:DIG:FUNC "CURR"	Select digitize current function.*
12	:DIG:CURR:APER AUTO	Set aperture to match sample rate.
13	:DIG:CURR:SRAT 1000	Set 1000 readings/s (1 mS aperture).
14	:DIG:COUNT 1	Digitize one sample when triggered.
15	:READ:DIG?	Return the digitized reading of the source output.
16	:OUTP:STAT OFF	Turn off the source output.
17	Calculate the source error.	Calculate the difference between step 7 and step 9.
18	Calculate the measure error.	Calculate the difference between step 9 and step 10.
19	Calculate the digitizer error.	Calculate the difference between step 9 and Step 15.
20	Validate source accuracy.***	Compare the result of step 17 to the source specification.
21	Validate measure accuracy.****	Compare the result of step 18 to the measure specification.
22	Validate digitizer accuracy ****	Compare the result of step 19 to the digitizer specification.

* The measure range is coupled to the source range when simultaneously sourcing and measuring current, so you do not need to set the measure range.

** Where <Range> = 1e-6, 10e-6, 100e-6, 1e-3, 10e-3, 100e-3, and 1.

*** The source limits are calculated based on the programmed source value of the Model 2461 for each range (not the actual value).

**** The measure limits are calculated based on a precise measurement of the programmed value of the Model 2461 (not the programmed value).

Current calibration verification for the 4 A to 10 A ranges

Follow the steps below to verify that Model 2461 current source-measure accuracy is within specified limits. In this test, you set the output current to each full-range value and measure the voltage drop across a shunt resistor with a precision digital multimeter (DMM) and then calculate the current.

NOTE

When verifying the 4 A to 10 A ranges using a shunt resistor, use the following formula to calculate the current:

Current (I) = Voltage (V) / Resistance (R)

Where:

Resistance is either the value stated by the specifications for the shunt resistor, or for greater measurement accuracy, resistance is the measured resistance value of the shunt resistor.

1. With the source output off, connect the Model 2461 to the DMM using the connection configuration in Connections for the 4 A to 10 A ranges (on page 2-5).

⚠ 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 Model 2461 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 Model 2461 before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

2. Turn on the Model 2461 source output.

NOTE

If the Model 2461 is not already warmed up, allow it to warm up for at least one hour before continuing to the next step.

3. Complete the calibration verification steps listed in the following table for each current range. For each current range, perform the complete procedure at 95 percent of the range's positive full-scale value, then at 0 A, then at 95 percent of the range's negative full scale value, and then again at 0 A. For example, for the 5 A range, complete the procedure four times using each of the following values, in this order: +4.75 A, 0 A, -4.75 A, 0 A.

NOTE

Although the Model 2461 will accept commands in the following procedure to set the 10 A source-measure-digitize range, the Model 2461 output current is limited to 7 A for DC operation. Because of this limit, use ±7 A (instead of ±9.5 A) as the full-scale source output when verifying the 10 A range.

Current calibration verification procedure for the 4 A to 10 A ranges

Step	Command or procedure	Description
1	*RST	Restore default settings.
2	:SOUR:FUNC CURR	Select the source function.
3	:FUNC "CURR"	Select the measure function.*
4	:SOUR:CURR:RANG <Range>	Set the source range.**
5	:SYST:RSEN OFF	Disable 4-wire remote sensing.
6	:ROUT:TERM <FRONT or REAR>	Select the front-panel or rear-panel terminals to match your test setup.
7	:SOUR:CURR <Level>	Program the source value.
8	:OUTP:STAT ON	Turn on the source output.
9	Make DMM reading.	Read the actual output of the Model 2461 using the external DMM.
10	(calculated I) = (DMM V reading) / R	Calculate the shunt current.
11	:READ?	Have the Model 2461 measure and return its source output.
12	:DIG:FUNC "CURR"	Select the digitize current function.*
13	:DIG:CURR:APER AUTO	Set aperture to match sample rate.
14	:DIG:CURR:SRAT 1000	Set 1000 readings/s (1 mS aperture).
15	:DIG:COUNT 1	Digitize one sample when triggered.
16	:READ:DIG?	Return the digitized reading of the source output.
17	:OUTP:STAT OFF	Turn off the source output.
18	Calculate the source error.	Calculate the difference between step 7 and step 10.
19	Calculate the measure error.	Calculate the difference between step 10 and step 11.
20	Calculate the digitizer error.	Calculate the difference between step 10 and step 16.
21	Validate source accuracy.***	Compare the result of step 18 to the source specification.
22	Validate measure accuracy.****	Compare the result of step 19 to the measure specification.
23	Validate digitizer accuracy.****	Compare the result of step 20 to the digitizer specification.

* The measure range is coupled to the source range when simultaneously sourcing and measuring current.

*** Where <Range> = 4, 5, and 7.

**** The source limits are calculated based on the programmed source value of the Model 2461 for each range (not the actual source value).

***** The measure limits are calculated based on a precise measurement of the programmed value of the Model 2461 (not the programmed value).

Step 4. Resistance measurement calibration verification

Follow the steps below to verify that Model 2461 resistance measurement accuracy is within specified limits. In this procedure, you apply accurate resistances from a resistance calibrator and then verify that Model 2461 resistance measurements are within required limits.

1. With the source output off, connect the Model 2461 to the resistance calibrator using the connection configuration in Connections for resistance calibration verification and adjustment (on page 2-6).

⚠ 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 Model 2461 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 Model 2461 before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

2. Turn on the Model 2461 source output.

NOTE

If the Model 2461 is not already warmed up, allow it to warm up for at least one hour before continuing to the next step.

3. On the resistance calibrator, select the external sense mode.
4. Send the commands summarized in the following table in the order listed to verify resistance measurement accuracy.

Resistance calibration verification procedure using a resistance calibrator*

Step	Command or procedure	Description
1	*RST	Restore default settings.
2	:FUNC "RES"	Select the resistance function.
3	:RES:RANG:AUTO OFF	Disable autoranging.
4	:RES:RANG <Range>	Set the resistance range.
5	:RES:RSEN ON	Enable 4-wire remote sensing.
6	:ROUT:TERM <FRONT or REAR>	Select the front-panel or rear-panel terminals to match your test setup.
7	Program calibrator value.	Set the resistance calibrator value.
8	:OUTP:STAT ON	Turn on the source output.
9	:READ?	Have the Model 2461 measure and return its source output.
10	:OUTP:STAT OFF	Turn off the source output.
11	Calculate the measure error.	Calculate the difference between step 7 and step 9.
12	Validate measure accuracy.	Compare the result of step 11 to the calibrator specification.

* Perform the complete procedure for each range, where <Range> = 20, 200, 2K, 20K, 200K, 2M, 20M, and 200M.

NOTE

It may not be possible to set the resistance calibrator to the specified value. Use the closest possible setting and modify reading limits accordingly.

5. Verify that the Model 2461 resistance reading is within the limits in the following table.

Ohms measurement accuracy limits

Model 2461 range	Calibrator resistance*
2 Ω	1.9 Ω
20 Ω	19 Ω
200 Ω	190 Ω
2 kΩ	1.9 kΩ
20 kΩ	19 kΩ
200 kΩ	190 kΩ
2 MΩ	1.9 MΩ
20 MΩ	19 MΩ
200 MΩ	100 MΩ

* Nominal resistance value. Calculate specification tolerance and upper and lower test limits using actual resistance values.

Section 4

Adjustment

In this section:

Introduction

Use the procedures in this section to adjust the Model 2461. These procedures require accurate test equipment to measure precise DC voltages and currents. Adjustment can be completed either from the front panel or by sending SCPI calibration adjustment commands over the IEEE-488, USB, or LAN port using a computer. This manual describes using SCPI commands from a remote interface to adjust the instrument.

⚠ WARNING

The information in this section is intended for qualified service personnel only. Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death if contacted. Use appropriate safety precautions when working with hazardous voltages.

Unlocking calibration for adjustment

Before adjusting the Model 2461, you must unlock the calibration constants by entering or sending a password using the following command (`KI002400` is the default password; if you have changed your password, use it instead):

```
CALibration:UNLock "KI002400"
```

When calibration constants are unlocked, the instrument is in the state shown in the following table. If you try to change any of these settings with calibration unlocked, error +510, “Not permitted with cal unlocked” is returned.

NOTE

With calibration unlocked, the sense function and the source function and range are the same. For example, when `:SOURce:FUNCtion` is set to `VOLTage`, the `:SENSe:FUNCtion` setting is `"VOLTage:DC"`. When `:SOURce:FUNCtion` is set to `CURRent`, the `:SENSe:FUNCtion` setting is `"CURR:DC"`. This also applies to the range settings (for example, `:SOURce:VOLTage:RANGe` and `:SENSe:VOLTage:RANGe`; `SOURce:CURRent:RANGe` and `:SENSe:CURRent:RANGe`).

Calibration unlocked states

Mode	State	Equivalent remote command
Concurrent functions	Off	`:SENSe:FUNCtion:CONCurrent Off`
Sense function sense	Source	`:SENSe:FUNCtion <source_function>`
Volts NPLC sense	1.0	`:SENSe:VOLTage:NPLC 1.0`
Volts measure range	Same as source V range value	`:SENSe:VOLTage:RANGe <source_v_range>`
Current NPLC sense	1.0	`:SENSe:CURRent:NPLC 1.0`
Current measure range	Same as source I range value	`:SENSe:CURRent:RANGe <source_i_range>`
Count	10	`:SENSe:AVERage:COUNt 10`
Filter control	Repeat	`:SENSe:AVERage:TCONtrol Repeat`
Filter averaging	On	`:SENSe:AVERage:STATe On`
Source V mode	Fixed	`:SOURce:VOLTage:MODE Fixed`
Volts autorange	Off	`:SOURce:VOLTage:RANGe:AUTO Off`
Source I mode	Fixed	`:SOURce:CURRent:MODE Fixed`
Current autorange	Off	`:SOURce:CURRent:RANGe:AUTO Off`
Autozero	On	`:SYSTem:AZERo On`

Changing the password

You can change the default password from the front panel or using a remote interface.

To change the calibration password using SCPI commands, first send the present password, and then send the new password.

For example, the following command sequence changes the password from the `"KI002400"` default password to `"KI_CAL"`:

```
CALibration:PASSword "KI002400"
CALibration:PASSword "KI_CAL"
```

You can use any combination of letters and numbers up to a maximum of eight characters.

Resetting the calibration password

⚠ CAUTION

If you change the Model 2461 calibration password and forget it, you must return the Model 2461 to the local Keithley Worldwide Service Center to be reset. There is no user-serviceable procedure to restore the default calibration password on the Model 2461.

Querying calibration and adjustment dates and count

To query the adjustment date, send the following SCPI command:

```
CALibration:ADJust:DATE?
```

To query the number of times the Model 2461 has been adjusted, send the following SCPI command:

```
CALibration:ADJust:COUNt?
```

To query the calibration verification date, send the following SCPI command:

```
CALibration:VERify:DATE?
```

You can also view the calibration verification and adjustment dates and adjustment count on the front panel by pressing the **MENU** key and selecting **System Information**.

Adjustment errors

The Model 2461 checks for errors after each adjustment step, minimizing improper adjustment due to operator error.

Front-panel error reporting

If an error is detected during adjustment, the instrument displays an appropriate error message. Once the error is displayed, you can dismiss the error message and repeat the adjustment step that caused the error with the corrected parameter or corrected command syntax.

Remote error reporting

You can detect errors while using a remote interface by testing the state of the Error Available Bit (EAV) (bit 2) in the status byte (use the `*STB?` query to request the status byte). Query the instrument for the type of error by using the appropriate `:SYSTem:ERRor?` query. The Model 2461 will respond with the error number and a text message describing the error.

Remote adjustment

Use the following procedure to perform remote adjustment by sending SCPI commands over the IEEE-488, USB, or LAN connection. The remote commands and appropriate parameters are separately summarized for each step.

You can use the following tables to document each calibration adjustment value as the calibration adjustment procedure is executed.

Voltage calibration adjustment data table

Source range	Source voltage	Digital multimeter (DMM) voltage reading*
0.2 V	+200.00 mV	_____ mV
	+000.00 mV	_____ mV
	–200.00 mV	_____ mV
	–000.00 mV	_____ mV
2 V	+2.0000 V	_____ V
	+0.0000 V	_____ V
	–2.0000 V	_____ V
	–0.0000 V	_____ V
7 V	+7.000 V	_____ V
	+0.000 V	_____ V
	–7.000 V	_____ V
	–0.000 V	_____ V
10 V	+10.00 V	_____ V
	+0.000 V	_____ V
	–10.00 V	_____ V
	–0.000 V	_____ V
20 V	+20.000 V	_____ V
	+00.000 V	_____ V
	–20.000 V	_____ V
	–00.000 V	_____ V
100 V	+100.00 V	_____ V
	+000.00 V	_____ V
	–100.00 V	_____ V
	–000.00 V	_____ V

* DMM reading used in corresponding adjustment step. See procedure.

Current calibration adjustment data table

Source range	Source current	DMM current reading*
1 µA	+1.0000 µA	_____ µA
	+0.0000 µA	_____ µA
	–1.0000 µA	_____ µA
	–0.0000 µA	_____ µA
10 µA	+10.000 µA	_____ µA
	+00.000 µA	_____ µA
	–10.000 µA	_____ µA
	–00.000 µA	_____ µA
100 µA	+100.00 µA	_____ µA
	+000.00 µA	_____ µA
	–100.00 µA	_____ µA
	–000.00 µA	_____ µA
1 mA	+1.0000 mA	_____ mA
	+0.0000 mA	_____ mA
	–1.0000 mA	_____ mA
	–0.0000 mA	_____ mA
10 mA	+10.000 mA	_____ mA
	+00.000 mA	_____ mA
	–10.000 mA	_____ mA
	–00.000 mA	_____ mA
100 mA	+100.00 mA	_____ mA
	+00.000 mA	_____ mA
	–10.000 mA	_____ mA
	–00.000 mA	_____ mA
1 A	+100.00 mA	_____ A
	+000.00 mA	_____ A
	–100.00 mA	_____ A
	–000.00 mA	_____ A

* DMM reading used in corresponding adjustment step. See the adjustment procedure in Remote adjustment procedure (on page 4-7).

Source range	Source current	DMM current reading*
4 A	+4.0000 A	_____ A
	+000.00 A	_____ A
	–4.0000 A	_____ A
	–000.00 A	_____ A
5 A	+5.0000 A	_____ A
	+000.00 A	_____ A
	–5.0000 A	_____ A
	–000.00 A	_____ A
7 A	+7.0000 A	_____ A
	+000.00 A	_____ A
	–7.0000 A	_____ A
	–000.00 A	_____ A
10 A	n/a	There are no adjustment steps for the 10 A range.

* DMM reading used in corresponding adjustment step. See the adjustment procedure in Remote adjustment procedure (on page 4-7).

Calibration adjustment commands summary

The following table summarizes the Model 2461 calibration adjustment commands. For more detailed descriptions of the commands, see the Command reference (on page 5-1) section.

SCPI command	Description
`:CALibration:PASSword <change code to unlock>`	**Unlock calibration:*** Changes the password if calibration constants are already unlocked. The default password is `KI002400`.
`:CALibration:ADJust:COUNt?`	Query the number of times the Model 2461 calibration constants have been adjusted. **Note:** The adjust count is incremented automatically each time a customer adjustment is completed. The adjust count can only be reset at the Keithley Instruments factory.
`:CALibration:ADJust:DATE` `:CALibration:ADJust:DATE?`	Set or query the date the Model 2461 calibration constants were last adjusted (year, month, day).
`:CALibration:VERify:DATE` `:CALibration:VERify:DATE?`	Set or query the date the Model 2461 calibration constants were last verified (year, month, day).
`:CALibration:LOCK` `:CALibration:LOCK?`	Set or query whether or not the Model 2461 calibration constants are locked or unlocked.
`:CALibration:UNLock <password>`	Unlock the Model 2461 calibration constants.
`:CALibration:SAVE`	Save the updated calibration constants to nonvolatile memory.*
`:CALibration:ADJust:SENSe`	Set the new adjusted sense data value.
`:CALibration:ADJust:SENSe:DATA?`	Query the new adjusted sense data.
`:CALibration:DIGitize:ADJust:SENSe`	Adjust digitizer circuits.
`:CALibration:ADJust:SOURce`	Set the new adjusted source data value.
`:CALibration:ADJust:SOURce:DATA?`	Query the new adjusted source data.

* Adjustment data is not saved if calibration constants were not unlocked with the `:CALibration:UNLock <password>` command.

⚠ CAUTION

If you change the default calibration password and you forget the new password, you must return the Model 2461 to the Keithley Worldwide Service Center to reset the calibration password. This password is unique to calibration and is not the same as the instrument password that is described in the Model 2461 Reference Manual.

Remote adjustment procedure

Use the following procedure to adjust the Model 2461.

Step 1. Prepare the Model 2461 for adjustment

Verify that the adjustment environment, instrument, and test equipment are set up as described in Preparing for calibration verification and adjustment (on page 2-1).

Step 2. Voltage adjustment

1. With the source output off, connect the Keithley Model 2461 to the digital multimeter (DMM) as shown in Connections for the 200 mV to 100 V ranges (on page 2-4).

⚠ 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 Model 2461 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 Model 2461 before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

2. Turn on the Model 2461 source output.

NOTE

If the Model 2461 is not already warmed up, allow it to warm up for at least one hour before continuing to the next step.

3. On the DMM, select the DC volts function.
4. Initialize voltage adjustment by sending the commands summarized in the following table in the order listed.

NOTE

When the `:CALibrate:UNLock` command is sent, the instrument assumes the operating states listed in the "Calibration unlocked states" table in Unlocking calibration for adjustment (on page 4-1).

Voltage adjustment initialization commands

Command	Description
`*RST`	Restore instrument defaults.
`:SOUR:FUNC VOLT`	Activate the voltage source.
`:SENS:CURR:RANG 0.1`	Make sure the 1 A range is not active.
`:SOUR:VOLT:PROT:LEV NONE`	Allow maximum source voltage.
`:SYST:RSEN OFF`	Disable remote sensing.*
`:CAL:UNL "KI002400"`	Unlock the calibration constants.
`:ROUT:TERM <FRONT or REAR>`	Select the front-panel or rear-panel terminals to match your test setup.
`:OUTP:STAT ON`	Turn the source output on.

* Remote sensing may be used, but is not required when using a recommended digital multimeter.

5. Complete the range adjustment steps listed in the following table for each range. Do the following for each range:
   - Send the `:SOURce:VOLTage:RANGe` command to select the source and sense range to adjust. For example, for the 2 V range, send the following command:
     ```
     :SOUR:VOLT:RANG 2
     ```
   - Program the source to output the negative full-range value using the `:SOURce:VOLTage` command. For example, send the following command:
     ```
     :SOUR:VOLT -2
     ```
   - Record the DMM reading in the "Voltage calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Use the DMM reading as the parameter for the `:CALibration:ADJust:SOURce` and `:CALibration:ADJust:SENSe` commands. For example, typical values for the 2 V range would be:
     ```
     :CAL:ADJ:SOUR -1.998
     :CAL:ADJ:SENS -1.998
     ```
   - Set the voltage source to 0 V output using the `:SOURce:VOLTage` command:
     ```
     :SOUR:VOLT 0.0
     ```
   - Record the DMM reading in the "Voltage calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Send the source and sense calibration adjustment commands using the DMM reading for the parameter. For example:
     ```
     :CAL:ADJ:SOUR 0.001
     :CAL:ADJ:SENS 0.001
     ```
   - Set the source to the positive full-range value using the `:SOURce:VOLTage` command. For example:
     ```
     :SOUR:VOLT 2
     ```
   - Record the DMM reading in the "Voltage calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Send the source and sense commands using the DMM reading as the parameter. For example:
     ```
     :CAL:ADJ:SOUR 1.997
     :CAL:ADJ:SENS 1.997
     ```
   - Send the `:SOURce:VOLTage` command to set the source voltage to 0 V:
     ```
     :SOUR:VOLT 0.0
     ```
   - Record the DMM reading in the "Voltage calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Send the `:CALibration:ADJust:SOURce` command using the DMM reading as the command parameter. For example:
     ```
     :CAL:ADJ:SOUR -1.02e-3
     ```

Voltage range calibration adjustment commands

Step	Command	Description
1	`:SOUR:VOLT:RANG <Range>`	Select the source range.
2	`:SOUR:VOLT -<Range>`	Establish negative polarity.
3	DMM reading 1.**	Read the actual output value on the DMM.
4	`:CAL:ADJ:SOUR <DMM_Reading1>`	Adjust the source function negative full scale.
5	`:SYST:ERR?`	Check Model 2461 for errors.
6	`:CAL:ADJ:SENS <DMM_Reading1>`	Adjust the sense function negative full scale.
7	`:SYST:ERR?`	Check Model 2461 for errors.
8	`:SOUR:VOLT 0.0`	Set the output to 0 V.
9	DMM reading 2.**	Read the actual output value on the DMM.
10	`:CAL:ADJ:SOUR <DMM_Reading2>`	Adjust the source function negative zero.
11	`:SYST:ERR?`	Check Model 2461 for errors.
12	`:CAL:ADJ:SENS <DMM_Reading2>`	Adjust the sense function negative zero.
13	`:SYST:ERR?`	Check Model 2461 for errors.
14	`:SOUR:VOLT +<Range>`	Establish positive polarity.
15	DMM reading 3.**	Read the actual output value on the DMM.
16	`CAL:ADJ:SOUR <DMM_Reading3>`	Adjust the sense function positive full scale.
17	`:SYST:ERR?`	Check Model 2461 for errors.
18	`CAL:ADJ:SENS <DMM_Reading3>`	Adjust the source function positive full scale.
19	`:SYST:ERR?`	Check Model 2461 for errors.
20	`:SOUR:VOLT 0.0`	Set the output to 0 V.
21	DMM reading 4.**	Read the actual output value on the DMM.
22	`:CAL:ADJ:SOUR <DMM_Reading4>`	Adjust the source positive zero.
23	`:SYST:ERR?`	Check Model 2461 for errors.

* Perform the complete procedure for each range, where `<Range>` = 0.2, 2, 7, 10, 20, and 100.
** The `<DMM_Reading`*n*`>` parameter is the DMM reading from the previous step.

NOTE

Each range requires:

- Four `CAL:ADJ:SOURce` commands (full scale and zero for each polarity)
- Three `CAL:ADJ:SENSe` commands (full scale for each polarity, and zero)

Step 3. Current adjustment

NOTE

Keithley Instruments recommends two different connection configurations for current adjustment:

- For the 1 µA to 1 A ranges, use the connection diagrams in Connections for the 1 µA to 1 A ranges (on page 2-5).
- For the 4 A to 10 A ranges, use the connection diagrams in Connections for the 4 A to 10 A ranges (on page 2-5).

The following topics describe how to do current adjustment for each of these configurations.

Current adjustment for the 1 µA to 1 A ranges

1. With the source output off, connect the Model 2461 to the digital multimeter (DMM) using the connection configuration in Connections for the 1 µA to 1 A ranges (on page 2-5).

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 Model 2461 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 Model 2461 before handling cables. Putting the equipment into standby does not guarantee that the outputs are powered off if a hardware or software fault occurs.

2. Turn on the Model 2461 source output.

NOTE

If the Model 2461 is not already warmed up, allow it to warm up for at least one hour before continuing to the next step.

3. On the DMM, select the DC current function.
4. Send the commands summarized in the following table in the order listed to initialize current adjustment.

Current adjustment initialization commands

Command	Description
`*RST`	Restore instrument defaults.
`:SOUR:FUNC CURR`	Select the source current mode.
`:FUNC "CURR"`	Select the measure function.*
`:CAL:UNL "KI002400"`	Unlock the calibration constants.
`:ROUT:TERM <FRONT or REAR>`	Select the front-panel or rear-panel terminals that match your test setup.
`:OUTP:STAT ON`	Turn source output on.

* The measure range is coupled to the source range when simultaneously sourcing and measuring current, so you do not need to set the measure range.

5. Adjust each current range using the procedure summarized in the following table. Do the following for each range:
   - Send the `:SOURce:CURRent:RANGe` command to select the source and sense range to adjust. For example, for the 1 mA range, the command is:
     ```
     :SOUR:CURR:RANG 1e-3
     ```
   - Program the source to output the negative full-range value using the `:SOURce:CURRent` command. For example:
     ```
     :SOUR:CURR -1e-3
     ```
   - Record the DMM reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Use the DMM reading as the parameter for the `:CALibration:ADJ:SOURce` and `:CALibration:ADJ:SENSe` commands. For example, a typical value for the 1 mA range would be:
     ```
     :CAL:ADJ:SOUR -1.025e-3
     :CAL:ADJ:SENS -1.025e-3
     ```
   - Set the current source to 0 A output using the `:SOURce:CURRent 0.0` command.
   - Record the DMM reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Send the source and sense adjustment commands using the DMM reading for the parameter. For example:
     ```
     :CAL:ADJ:SOUR 1e-6
     :CAL:ADJ:SENS 1e-6
     ```
   - Set the source to the positive full-range value using the `:SOURce:CURRent` command. For example, for the 1 mA range:
     ```
     :SOUR:CURR 1e-3
     ```
   - Record the DMM reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Send the source and sense commands using the DMM reading as the parameter. For example:
     ```
     :CAL:ADJ:SOUR 1.03e-3
     :CAL:ADJ:SENS 1.03e-3
     ```
   - Send the `:SOURce:CURRent` command to set the source current to 0 A:
     ```
     :SOURce:CURRent 0.0
     ```
   - Record the DMM reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Send the `:CALibration:ADJ:SOURce` command using the DMM reading as the command parameter. For example:
     ```
     :CAL:ADJ:SOUR -1.02e-3
     ```

Current range calibration adjustment commands

Step	Command/procedure*	Description
1	`:SOUR:CURR:RANG <Range>`	Select the source range.
2	`:SOUR:CURR -<Range>`	Establish negative polarity.
3	DMM reading 1.**	Read the actual output value on the DMM.
4	`CAL:ADJ:SOUR <DMM_Reading>`	Adjust the source function negative full scale.
5	`:SYSTem:ERRor?`	Check Model 2461 for errors.
6	`CAL:ADJ:SENS <DMM_Reading>`	Adjust the sense function negative full scale.
7	`:SYSTem:ERRor?`	Check Model 2461 for errors.
8	`:SOUR:CURR 0.0`	Set the output to 0 A.
9	DMM reading 2.**	Read the actual output value on the DMM.
10	`:CAL:ADJ:SOUR <DMM_Reading>`	Adjust the source function negative zero.
11	`:SYSTem:ERRor?`	Check Model 2461 for errors.
12	`:CAL:ADJ:SENS <DMM_Reading>`	Adjust the sense function negative zero.
13	`:SYSTem:ERRor?`	Check Model 2461 for errors.
14	`:SOUR:CURR +<Range>`	Establish positive polarity.
15	DMM reading 3.**	Read the actual output value on the DMM.
16	`:CAL:ADJ:SOUR <DMM_Reading>`	Adjust the sense function positive full scale.
17	`:SYSTem:ERRor?`	Check Model 2461 for errors.
18	`:CAL:ADJ:SENS <DMM_Reading>`	Adjust the source function positive full scale.
19	`:SYSTem:ERRor?`	Check Model 2461 for errors.
20	`:SOUR:CURR 0.0`	Set the output to 0 A.
21	DMM reading 4.**	Read the actual output value on the DMM.
22	`:CAL:ADJ:SOUR <DMM_Reading>`	Adjust the source positive zero.
23	`:SYSTem:ERRor?`	Check Model 2461 for errors.

* Perform the complete procedure for each range, where <Range> = 1e-6, 10e-6, 100e-6, 1e-3, 10e-3, 100e-3, and 1.
** The <DMM_Reading*n*> parameter is the DMM reading from the previous step.

Current adjustment for the 4 A to 10 A ranges

NOTE

When adjusting the 4 A to 10 A ranges using a shunt resistor, use the following formula to calculate the current:

Current = Voltage / Resistance

Be sure to include shunt resistance uncertainty in the measurement uncertainty calculation when using a current shunt.

1. With the source output off, connect the Model 2461 to the digital multimeter (DMM) using the connection configuration in Connections for the 4 A to 10 A ranges (on page 2-5).
2. Turn on the Model 2461 source output.

NOTE

If the Model 2461 is not already warmed up, allow it to warm up for at least one hour before continuing to the next step.

3. On the DMM, select the DC current function.
4. Send the commands summarized in the following table in the order listed to initialize current adjustment.

Current adjustment initialization commands

Command	Description
`*RST`	Restore instrument defaults.
`:SOUR:FUNC CURR`	Select the source current mode.
`:FUNC "CURR"`	Select the measure function.*
`:CAL:UNL "KI002400"`	Unlock the calibration constants.
`:ROUT:TERM <FRONT or REAR>`	Select the front or rear-panel terminals that match your test setup.
`:OUTP:STAT ON`	Turn source output on.

* The measure range is coupled to the source range when simultaneously sourcing and measuring current, so you do not need to set the measure range.

5. Adjust each current range using the procedure summarized in the following table. Do the following for each range:
   - Send the `:SOURce:CURRent:RANGe` command to select the source and sense range to adjust. For example, for the 4 A range, the command is:
     `:SOUR:CURR:RANG 4`
   - Program the source to output the negative full-range value using the `:SOURce:CURRent` command. For example:
     `:SOUR:CURR -4`
   - Measure the voltage across the shunt resistor, and then calculate the current.
   - Record the calculated current reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
   - Use the calculated current value as the parameter for the `:CALibration:ADJustment:SOURce` and `:CALibration:ADJustment:SENSe` commands. For example, a typical value for the 4 A range would be:

```
:CAL:ADJ:SOUR -4.025
:CAL:ADJ:SENS -4.025
```

- Set the current source to 0 A output using the `:SOURce:CURRent` command:

  ```
  :SOURce:CURRent 0.0
  ```

- Measure the voltage across the shunt resistor, and then calculate the current.
- Record the calculated current reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
- Send the source and sense adjustment commands using the calculated current reading for the parameter. For example:

  ```
  :CAL:ADJ:SOUR 1e-6
  :CAL:ADJ:SENS 1e-6
  ```

- Set the source to the positive full-range value using the `:SOURce:CURRent` command. For example, for the 4 A range:

  ```
  :SOUR:CURR 4
  ```

- Measure the voltage across the shunt resistor, and then calculate the current.
- Record the calculated current reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
- Send the source and sense commands using the DMM reading as the parameter. For example:

  ```
  :CAL:ADJ:SOUR 4.03
  :CAL:ADJ:SENS 4.03
  ```

- Send the `:SOURce:CURRent` command to set the source current to 0 A:

  ```
  :SOUR:CURR 0.0
  ```

- Measure the voltage across the shunt resistor, and then calculate the current.
- Record the calculated current reading in the "Current calibration adjustment data" table in Remote adjustment (on page 4-4).
- Send the `:CALibration:ADJustment:SOURce` command using the calculated current value as the command parameter. For example:

  ```
  :CAL:ADJ:SOUR -1.02e-3
  ```

Current range calibration adjustment commands

Step	Command/procedure*	Description
1	`:SOUR:CURR:RANG <Range>`	Select the source range.
2	`:SOUR:CURR -<Range>`	Establish negative polarity.
3	DMM reading 1.**	Using the DMM, measure voltage across the shunt resistor.
4	(calculated I) = V (DMM reading 1) / R	Calculate the shunt resistor current.***
5	`:CAL:ADJ:SOUR <calculated I>`	Adjust the source function negative full scale.
6	`:SYSTem:ERRor?`	Check Model 2461 for errors.
7	`:CAL:ADJ:SENS <calculated I>`	Adjust the sense function negative full scale.
8	`:SYSTem:ERRor?`	Check Model 2461 for errors.
9	`:SOUR:CURR 0.0`	Set the output to 0 A.
10	DMM reading 2.**	Using the DMM, measure the voltage across the shunt resistor.
11	(calculated I) = V (DMM reading 2) / R	Calculate the shunt resistor current.
12	`:CAL:ADJ:SOUR <calculated I>`	Adjust the source function negative zero.
13	`:SYSTem:ERRor?`	Check Model 2461 for errors.
14	`:CAL:ADJ:SENS <calculated I>`	Adjust the sense function negative zero.
15	`:SYSTem:ERRor?`	Check Model 2461 for errors.
16	`:SOUR:CURR +<Range>`	Establish positive polarity.
17	DMM reading 3.**	Using the DMM, measure voltage across the shunt resistor.
18	(calculated I) = V (DMM reading 3) / R	Calculate the shunt resistor current.
19	`:CAL:ADJ:SOUR <calculated I>`	Adjust the sense function positive full scale.
20	`:SYSTem:ERRor?`	Check Model 2461 for errors.
21	`:CAL:ADJ:SENS <calculated I>`	Adjust the source function positive full scale.
22	`:SYSTem:ERRor?`	Check Model 2461 for errors.
23	`:SOUR:CURR 0.0`	Set the output to 0 A.
24	DMM reading 4.**	Using the DMM, measure the voltage across the shunt resistor.
25	(calculated I) = V (DMM reading 4) / R	Calculate the shunt resistor current.
26	`:CAL:ADJ:SOUR <calculated I>`	Adjust the source positive zero.
27	`:SYSTem:ERRor?`	Check Model 2461 for errors.

* Perform the complete procedure for each range, where <Range> = 4, 5, and 7. There are no adjustment steps for the 10 A range.

** The <DMM_Reading*n*> parameter is the DMM reading from the previous step.

*** To get more accurate readings when using a shunt resistor, measure the resistance of the shunt resistor (rather than using manufacturer specifications) and use that value in the shunt resistor current calculation.

Step 4. Digitizer adjustment

All digitizer ranges are adjusted with a single command:

```
CALibration:DIGitize:ADJust:SENSe
```

This step is an internal adjustment requiring about 10 seconds to complete. The Model 2461 does not source any output and there is no need to connect external equipment during this step.

NOTE

This command must be sent after all normal voltage and current measure adjustment steps have completed without error. It must be the last adjustment command before saving adjustment dates and calibration constants.

Step 5. Program calibration verification and adjustment dates

Use the following commands to set the calibration verification and adjustment dates.

`:CALibration:VERification:DATE <year>, <month>, <day>` (calibration date)

`:CALibration:ADJust:DATE <year>, <month>, <day>` (adjust date)

Note that the year, month, and day must be separated by commas. The allowable range for the year is from 1995 to 2094, the month is from 1 to 12, and the day is from 1 to 31. The calibration date is the same as a calibration without adjustment, otherwise known as verification.

NOTE

The adjustment count is automatically incremented each time a customer calibration adjustment is executed and the adjustment date is set with the commands above. Calling the `CALibration:ADJust:DATE` and `CALibration:SAVE` commands in sequence automatically increments the adjustment count. The Model 2461 may need to be power cycled before the new dates will show on the front-panel display.

Step 6. Save calibration constants

Adjustment is now complete, so you can store the calibration constants in nonvolatile memory by sending the following command:

```
CALibration:SAVE
```

NOTE

Adjustment is temporary unless you send the `:SAVE` command. Also, adjustment data is not saved if calibration is locked, invalid data exists, or all steps were not completed.

Step 7. Lock-out adjustment

To lock out further adjustment, send the following command after completing the adjustment procedure:

```
CALibration:LOCK
```

Single-range adjustment

Normally, the complete adjustment procedure should be performed to ensure that the entire instrument is properly adjusted. In some instances, however, you may want to adjust only certain ranges.

To adjust only some of the ranges, complete the entire unlock, adjust, save, and lock procedure for the range or ranges to be adjusted. Note that you must complete all four source adjustment steps and all three sense adjustment steps for each range to be adjusted. Also, be sure to set calibration verification and adjustment dates and save calibration constants after adjusting the ranges.

Section 5

Command reference

In this section:

Introduction

This section contains detailed information about the Model 2461 remote calibration verification and adjustment commands, error messages, and methods to detect the end of each adjustment step.

See Adjustment (on page 4-1) for detailed calibration adjustment procedures.

Model 2461 calibration verification and adjustment commands

Model 2461 calibration verification and adjustment commands are used to save calibration constants, lock-out calibration, and program date parameters.

:CALibration:ADJust:COUNt?

This command queries the number of times the Model 2461 has been adjusted.

Type	Affected by	Where saved	Default value
Query only	Not applicable	Not applicable	Not applicable

Usage

```
CALibration:ADJust:COUNt?
```

Details

Use this command to determine the total number of times the instrument has been adjusted.

Example

`:CAL:ADJ:COUN?`	Request the calibration adjustment count. Output: 2 Indicates that the instrument has been adjusted two times.

Also see

:CALibration:ADJust:DATE (on page 5-2)

:CALibration:ADJust:DATE

This command stores the user-specified adjustment date.

Type	Affected by	Where saved	Default value
Command and query	Not applicable	Nonvolatile memory	Not applicable

Usage

```
:CALibration:ADJust:DATE <year>, <month>, <day>
:CALibration:ADJust:DATE?
```

`<year>`	The year the instrument was adjusted; `1995` to `2094`
`<month>`	The month the instrument was adjusted; `1` to `12`
`<day>`	The day the instrument was adjusted; `1` to `31`

Details

Use this command to store the adjustment date in the instrument nonvolatile memory. Calibration constants must be unlocked with the `:CALibration:UNLock` command before sending this command.

You must send the `:CALibration:SAVE` command after making changes, or your changes will not be saved through a power cycle.

The `year`, `month`, and `day` parameters must be delimited by commas.

You can use the query form of this command to get the last saved adjustment date.

Example

`:CAL:ADJ:DATE 2015, 11, 18`
`:CAL:SAVE`
`:CAL:ADJ:DATE?`
	Set the adjustment date to November 18, 2015.
	Save the adjustment date.
	Query the adjustment date.
	Output:
	`2015,11,18`

Also see

:CALibration:PASSword (on page 5-9)
:CALibration:SAVE (on page 5-10)
:CALibration:UNLock (on page 5-11)

:CALibration:ADJust:SENSe

This command adjusts the sense function.

Type	Affected by	Where saved	Default value
Command only	Not applicable	Nonvolatile memory	Not applicable

Usage

```
CALibration:ADJust:SENSe <range>
CALibration:ADJust:SENSe <negZero>
CALibration:ADJust:SENSe <negFullScale>
CALibration:ADJust:SENSe <posZero>
CALibration:ADJust:SENSe <posFullScale>
```

`<range>`	The sense range to adjust
`<negZero>`	The negative zero value of the selected range (from digital multimeter reading)
`<negFullScale>`	The negative full-scale value of the selected range (from digital multimeter reading)
`<posZero>`	The positive zero value of the selected range (from digital multimeter reading)
`<posFullScale>`	The positive full-scale value of the selected range (from digital multimeter reading)

Details

Calibration constants must be unlocked with the `:CALibration:UNLock` command before sending this command.

To use this command:

1. Set the source output value.
2. Select the range to adjust.
3. Send the `CALibration:ADJust:SENSe` command with each of the parameters in the usage table above.
4. Repeat this procedure for each of the ranges.

If the specified parameters do not fit within the allowed ranges for the parameter, error -222, "Parameter data out of range" is generated. Once the Model 2461 has successfully selected the appropriate parameter range, it checks to see if autorange for the active sense function is enabled. If it is enabled, error -221, "Settings conflict" is generated. If no error occurs, that active sense function range point is adjusted using the corresponding parameter.

You must send the `:CALibration:SAVE` command after making changes, or your changes will not be saved through a power cycle.

Parameters for a given sense function and range may be sent in any order. However, once one `CALibration:ADJust:SENSe` command executes, the other parameters must also be executed or an error -200, “Execution error” is generated when the `CALibration:SAVE` command is processed at the end of the adjustment procedure.

Example

`CAL:ADJ:SENS +2.00003`	Adjust the 2 V sense range.

Also see

:CALibration:ADJust:SENSe:DATA? (on page 5-4)
:CALibration:SAVE (on page 5-10)
:CALibration:UNLock (on page 5-11)

:CALibration:ADJust:SENSe:DATA?

This command queries the calibration constants for the active sense range.

Type	Affected by	Where saved	Default value
Query only	Not applicable	Not applicable	Not applicable

Usage

```
CALibration:ADJust:SENSe:DATA?
```

Details

This command requests the calibration constants for the active range of the sense function. Constants returned are the positive full-scale value, the positive zero value, the negative full-scale value, and negative zero value.

The returned constants are in comma-delimited ASCII floating-point format.

Example

`:SENS:FUNC "CURR:DC"`
`:SENS:VOLT:DC:RANG 0.2`
`:CAL:ADJ:SENS:DATA?`
	Select the DC current sense function.
	Select the 200 mV range.
	Request the calibration constants.
	Example output:
	`-7.058334E-06,-1.790742E-10,-7.058321E-06,+0.000000E+00`

Also see

:CALibration:ADJust:SENSe (on page 5-3)

:CALibration:ADJust:SOURce

This command adjusts the source function.

Type	Affected by	Where saved	Default value
Command only	Not applicable	Nonvolatile memory	Not applicable

Usage

```
CALibration:ADJust:SOURce <range>
CALibration:ADJust:SOURce <negZero>
CALibration:ADJust:SOURce <negFullScale>
CALibration:ADJust:SOURce <posZero>
CALibration:ADJust:SOURce <posFullScale>
```

`<range>`	The source range to adjust
`<negZero>`	The negative zero value of the selected range (from digital multimeter reading)
`<negFullScale>`	The negative full-scale value of the selected range (from digital multimeter reading)
`<posZero>`	The positive zero value of the selected range (from digital multimeter reading)
`<posFullScale>`	The positive full-scale value of the selected range (from digital multimeter reading)

Details

Calibration constants must be unlocked with the `:CALibration:UNLock` command before sending this command.

If the specified parameters do not fit within the allowed ranges for the parameter, error -222, "Parameter data out of range" is generated. Once the Model 2461 has successfully selected the appropriate parameter range, it checks to see if autorange for the active source function is enabled and that the output state is set to `ON`. If autorange is enabled or the output is set to `OFF`, error -221, "Settings conflict" is generated. If no error occurs, the specified range point for the active source function is adjusted using the corresponding parameter.

You must send the `:CALibration:SAVE` command after making changes, or your changes will not be saved through a power cycle.

Because the source is adjusted for both positive and negative values, two zero adjustment points are required. The Model 2461 automatically uses the appropriate zero parameter based on whether the source polarity is positive or negative.

Example

`CAL:ADJ:SOUR +2.00003`	Adjust the 2 V source range.

Also see

:CALibration:ADJust:SOURCe:DATA? (on page 5-6)
:CALibration:SAVE (on page 5-10)
:CALibration:UNLock (on page 5-11)

:CALibration:ADJust:SOURCe:DATA?

This command queries the calibration constants for the active source range.

Type	Affected by	Where saved	Default value
Query only	Not applicable	Not applicable	Not applicable

Usage

```
CALibration:ADJust:SOURce:DATA?
```

Details

This command requests the calibration constants for the active range of the source function. Constants returned are the positive full-scale value, the positive zero value, the negative full-scale value, and negative zero value.

The returned constants are in comma-delimited ASCII floating-point format.

Example

`:SENS:FUNC CURR`
`:SENS:VOLT:RANG 1`
`:CAL:ADJ:SOUR:DATA?`
	Select the current source function.
	Select the 1 A range.
	Request the calibration constants.
	Example output:
	`+3.018486E+05,+1.297160E+03,`
	`-3.018662E+05,+1.248219E+03`

Also see

:CALibration:ADJust:SOURce (on page 5-5)

:CALibration:DIGitize:ADJust:SENSe

This command adjusts the Model 2461 digitizer function.

Type	Affected by	Where saved	Default value
Query only	Not applicable	Not applicable	Not applicable

Usage

```
:CALibration:DIGitize:ADJust:SENSe
```

Details

This command must be sent after all other `:CALibration:ADJust` commands for all ranges have been completed successfully.

The Model 2461 does not source any output and there is no need to connect external equipment during this adjustment step.

This command initiates an internal operation to adjust digitizer circuits to match the readings of integration analog-to-digital circuits.

This command requires about 10 seconds to complete.

Example

`-- Perform all other adjustment steps first.` `:CAL:DIG:ADJ:SENS; *OPC?`	The `*opc?` query returns "1" when the adjustment command is finished. This command may require a longer timeout value than most commands.

Also see

:CALibration:ADJust:SENSe (on page 5-3)
:CALibration:ADJust:SOURce (on page 5-5)

:CALibration:LOCK

This command locks calibration constants.

Type	Affected by	Where saved	Default value
Command and query	Not applicable	Nonvolatile memory	0

Usage

```
CALibration:LOCK
CALibration:LOCK?
```

Query returns	`0` = Calibration unlocked `1` = Calibration locked

Details

Use this command to prevent comprehensive adjustment.

Send the `CALibration:LOCK?` query to determine if the calibration constants are locked. Calibration constants are locked if `1` is returned; calibration constants are unlocked if `0` is returned.

⚠ CAUTION

If you change the Model 2461 calibration password and forget it, you must return the Model 2461 to the local Keithley Worldwide Service Center to be reset. There is no user-serviceable procedure to restore the default calibration password on the Model 2461.

Example

`:CAL:LOCK`	Lock the calibration constants.

Also see

:CALibration:PASSword (on page 5-9)
:CALibration:UNLock (on page 5-11)

:CALibration:PASSword

This command changes the calibration password.

Type	Affected by	Where saved	Default value
Command only	Not applicable	Nonvolatile memory	KI002400

Usage

```
CALibration:PASSword "<password>"
```

`<password>`	The calibration password; can contain up to 8 characters; default is `KI2400`

Details

Use this command to change the calibration password, which is used to lock the calibration constants.

To change the password, you must first send the existing password, and then send the command again with the new password.

The password parameter must be enclosed in quotation marks.

Example

`:CAL:PASS "KI002400"` `:CAL:PASS "Cal123"`	Send the existing password. Send the command again with the new password; password is changed to `Cal123`.

Also see

:CALibration:LOCK (on page 5-8)
:CALibration:UNLock (on page 5-11)

:CALibration:SAVE

This command saves calibration constants to nonvolatile memory after completing the adjustment procedure.

Type	Affected by	Where saved	Default value
Command and query	Not applicable	Nonvolatile memory	Not applicable

Usage

```
:CALibration:SAVE
:CALibration:SAVE?
```

Details

Use this command to store internally calculated calibration constants that were derived during the comprehensive adjustment procedure to nonvolatile memory. Calibration constants are retained indefinitely once saved.

The `:CALibration:SAVE` command is usually sent after all other adjustment steps have been completed, but before sending the `:CALibration:LOCK` command.

Adjustment is only temporary until the `:CALibration:SAVE` command is sent to permanently store the calibration constants.

Adjustment data will not be saved if one of the following conditions occurs:

- Calibration was not unlocked by sending the `:CALibration:UNLock` command before adjustment
- Invalid data exists (for example, an adjustment step failed or was aborted)
- An incomplete number of adjustment steps were performed (for example, if a negative full-scale step was omitted)

Example

`:CAL:SAVE`	Save the calibration constants.

Also see

:CALibration:LOCK (on page 5-8)
:CALibration:UNLock (on page 5-11)

:CALibration:UNLock

This command unlocks the calibration constants.

Type	Affected by	Where saved	Default value
Command only	Not applicable	Nonvolatile memory	Not applicable

Usage

```
:CALibration:UNLock "<password>"
```

`<password>`	The calibration password; the default password is `KI002400`

Details

Use this command to unlock the calibration constants so that comprehensive adjustment can be done.

Send the `CALibration:LOCK?` query to determine if the calibration constants are locked. Calibration constants are locked if `1` is returned; calibration constants are unlocked if `0` is returned.

The password parameter must be enclosed in quotation marks.

Example

`:CAL:UNL "KI002400"`	Unlock the calibration constants.

Also see

:CALibration:LOCK (on page 5-8)
:CALibration:PASSword (on page 5-9)

:CALibration:VERify:DATE

This command stores the user-specified calibration verification date.

Type	Affected by	Where saved	Default value
Command and query	Not applicable	Nonvolatile memory	Not applicable

Usage

```
:CALibration:VERify:DATE <year>, <month>, <day>
:CALibration:VERify:DATE?
```

`<year>`	The year the instrument was verified; `1995` to `2094`
`<month>`	The month the instrument was verified; `1` to `12`
`<day>`	The day the instrument was verified; `1` to `31`

Details

Use this command to store the calibration verification date in the instrument nonvolatile memory. Calibration constants must be unlocked with the `:CALibration:UNLock` command before sending this command.

You must send the `:CALibration:SAVE` command after making changes, or your changes will not be saved through a power cycle.

The `year`, `month`, and `day` parameters must be delimited by commas.

You can use the query form of this command to get the last saved calibration verification date.

Example

`:CAL:VER:DATE 2015, 11, 18`
`:CAL:SAVE`
`:CAL:VER:DATE?`
	Set the calibration verification date to November 18, 2015.
	Save the calibration verification date.
	Query the calibration verification date.
	Output:
	`2015,11,18`

Also see

:CALibration:PASSword (on page 5-9)
:CALibration:SAVE (on page 5-10)
:CALibration:UNLock (on page 5-11)

Section 6

Routine maintenance

In this section:

Introduction

The information in this section describes routine maintenance that can be done by the operator.

Line fuse replacement

A fuse located on the Model 2461 rear panel protects the power line input of the instrument.

⚠ WARNING

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

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

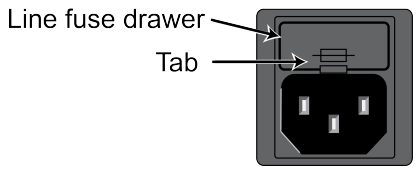
Use a 5 x 20 mm slow-blow fuse rated at 250 V at 4 A.

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

Complete the following steps to replace the line fuse:

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

Figure 10: Model 2461 line fuse



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

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

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