

# Model 2110 5½ Digit Multimeter

## Reference Manual

2110-901-01 Rev. C / August 2013



2110-901-01

A Greater Measure of Confidence



Model 2110  
5½ Digit Multimeter  
Reference Manual

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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 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 of January 2013.

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## Introduction

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## Welcome

Thank you for using a Keithley Instruments product. The Model 2110 Digit Multimeter (DMM) features 12 measurement functions and 7 math functions, and has dual-line display capability, which allows it to display two different measurements concurrently.

The Model 2110 provides superior measurement accuracy and speed necessary for a broad range of applications, ranging from production testing to bench-top applications. The Model 2110 meets application requirements for production engineers, research and development engineers, test engineers, scientists, students and anyone else making measurements in either system applications or on the bench.

## Contact information

If you have any questions after reviewing this information, please use the following sources:

1. [Keithley Instruments website](http://www.keithley.com) (<http://www.keithley.com>).
2. [Keithley web forum](http://forum.keithley.com) (<http://forum.keithley.com>).
3. Call Keithley Instruments corporate headquarters (toll-free inside the U.S. and Canada only) at 1-888-KEITHLEY (1-888-534-8453), or from outside the U.S. at +1-440-248-0400. For worldwide contact numbers, visit the [Keithley Instruments website](http://www.keithley.com) (<http://www.keithley.com>).

## CD-ROM contents

A CD-ROM is shipped with each Model 2110 order.

### The Model 2110 Product Information CD-ROM contains:

- **Reference Manual:** Includes a description of connections, operation information, programming information, and maintenance information. Users looking for basic operating information, programmers looking for a command reference, and users looking for an in-depth description of the way the instrument works (including troubleshooting and optimization) should refer to the Reference Manual.
- **Calibration Manual:** Includes procedures to verify that the Model 2110 accuracy is within the limits stated in the instrument's one-year accuracy specifications.
- **Drivers and release notes:** IVI Instrument Driver, driver for National Instruments LabVIEW™, and related release notes.
- **Keithley I/O layer and release notes.**
- **Start-up Software and PC Utilities:** Includes KI-Tool and KI-Link application and Microsoft® Excel Add-In utility.
- **Additional product information:** The product specifications are also included on the CD-ROM.

For the latest drivers and additional support information, see the [Keithley Instruments website](http://www.keithley.com) (<http://www.keithley.com>).

## Organization of manual sections

The information in this manual is organized into the following major categories:

- **General overview:** Describes the components of the instrument and basic operation.
- **Basic DMM operation:** Introduces some basic measurement functions of the instrument. You will learn how to use your instrument to measure voltage, current, resistance, frequency, period, continuity, diodes, capacitance, and temperature. You will learn about triggering and data buffering. You will also learn about enhancing measurement performance.
- **Theory of operation:** Describes basic DMM measurement techniques and concepts.
- **Remote commands:** Describes the IEEE Std 488.2 common commands. Provides an alphabetical listing of all commands available for the Model 2110. Provides information about using remote commands to control the instrument.
- **Troubleshooting guide:** Describes self-test procedure and error codes.
- **Maintenance:** Information on instrument maintenance, including line fuse replacement and firmware upgrades.
- **Status model:** Description of the Model 2110 status model.

Bookmarks for each section of this manual are provided in the PDF version of the documentation. The manual sections are also listed in the Table of Contents located at the beginning of this manual.

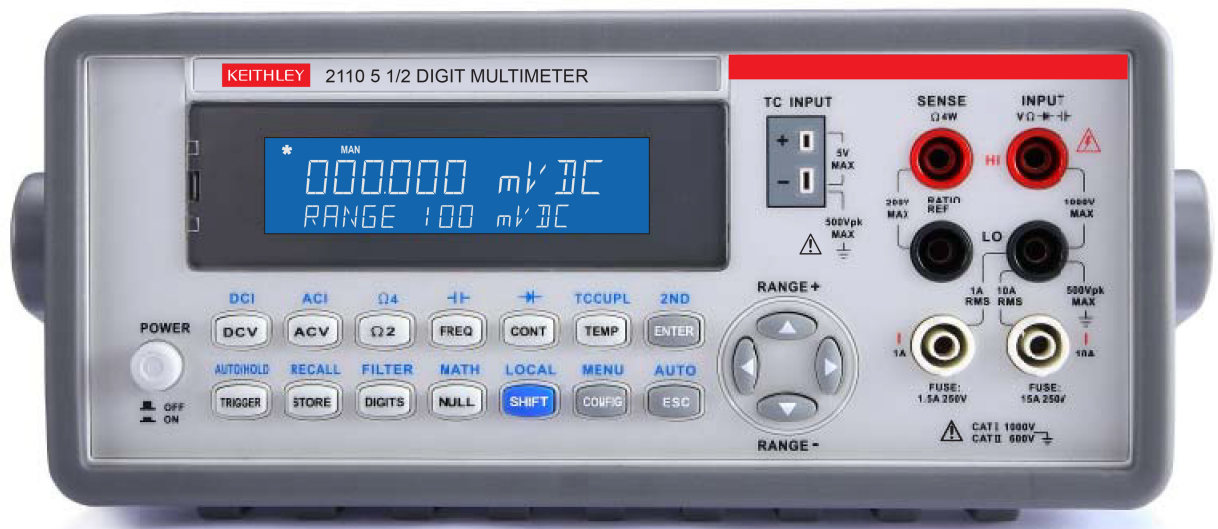
For more information about bookmarks, see Adobe® Acrobat® or Reader® help.

## Capabilities and features

The Keithley Instruments Model 2110 is a rugged and versatile 5½-digit resolution digital multimeter with a dual-line liquid-crystal display (LCD), built-in USB interface, and optional GPIB interface.

The Model 2110 has 0.0012% one-year basic DC voltage accuracy and 0.020% one-year basic resistance accuracy up to the 1 MΩ range. At 5½ digits, the Model 2110 delivers over 200 readings per second via the USB remote interface. At the fast 4½ digit setting, readings can be stored internally at a rate of 50,000 per second. This is ideal for production applications and monitoring applications, where speed is critical.

**Figure 1: Keithley Model 2110 5 ½ Digit Multimeter**



## Measurement ranges and functions

The Model 2110 provides a wide number of measurement ranges and functions including:

- DC voltage: 0.1 V, 1 V, 10 V, 100 V, and 1000 V
- AC voltage: 0.1 V, 1 V, 10 V, 100 V, and 750 V
- DC current: 10 mA, 100 mA, 1 A, 3 A, and 10 A
- AC current: 1 A, 3 A, and 10 A
- Two and 4-wire resistance: 100  $\Omega$ , 1 k $\Omega$ , 10 k $\Omega$ , 100 k $\Omega$ , 1 M $\Omega$ , 10 M $\Omega$ , and 100 M $\Omega$
- Frequency: 3 Hz to 300 kHz
- Capacitance measurement: 1 nF, 10 nF, 100 nF, 1  $\mu$ F, 10  $\mu$ F, 100  $\mu$ F, 1 mF, 10 mF
- Temperature measurement using RTDs, thermistors, and thermocouples (direct measurement using built-in cold junction compensation to improve accuracy); supports J-, R-, S-, T-, E-, N-, B-, C-, and K-type thermocouples
- Period measurement
- Diode measurement
- Continuity measurement
- Programmable A-D converter and filter settings for signal-to-noise optimization

## Mathematical operations

The Model 2110 allows you to perform the following seven mathematical operations on measurement readings: Percentage, Average (Min/Max, Count), NULL, Limits, mX+b, dB, and dBm.

## Startup software and PC utilities

The following start-up software and PC utilities are included:

- KI-Tool and KI-Link software allow you to quickly control the instrument over GPIB (if equipped) or USB, record measurements, and display time-series plots of the data. KI-Link is an add in for Microsoft® Word and Microsoft Excel.
- LabVIEW™ and IVI drivers allow more advanced customers even more control over the instrument.

## Standard accessories

The following standard accessories are supplied with the Model 2110.

- Safety test leads
- USB cable
- Power cable

## Optional accessories

The following optional accessories are available for the Model 2110.

| Keithley part number | Optional accessory                  |
|----------------------|-------------------------------------|
| 4299-3               | Single Rack Mount Kit               |
| 4299-4               | Dual Rack Mount Kit                 |
| 4299-7               | Dual Fixed Rack Mount Kit           |
| 8605                 | High Performance Modular Test Leads |
| 8606                 | High Performance Modular Probe Kit  |
| 5805                 | Kelvin Probes, 0.9 m (3 ft)         |
| 5805-12              | Kelvin Probes, 3.6 m (12 ft)        |
| 5808                 | Low Cost, Single Pin, Kelvin Probes |
| 5809                 | Low Cost, Kelvin Clip Lead Set      |
| 8680                 | RTD Probe Adapter                   |
| 8681                 | Low Cost RTD                        |
| 7007-1               | Shielded GPIB Cable, 1 m (3.3 ft)   |
| 7007-2               | Shielded GPIB Cable, 2 m (6.6 ft)   |
| 6517-TP              | Thermocouple Bead Probe (K-Type)    |

## General information

### Displaying the instrument's serial number

*To display the serial number on the front panel:*

1. If the Model 2110 is in remote operation, press the **SHIFT** (LOCAL) key once to place the instrument in local operation.
2. Press the **SHIFT** key.
3. Press the **CONFIG (MENU)** key. The display shows **MENU**.
4. Use the right and left **RANGE** keys to display **SYSTEM**.
5. Press the **ENTER** key.
6. Use the right and left **RANGE** keys to display **SERIAL**.
7. Press the **ENTER** key. The display shows the serial number on the second row.

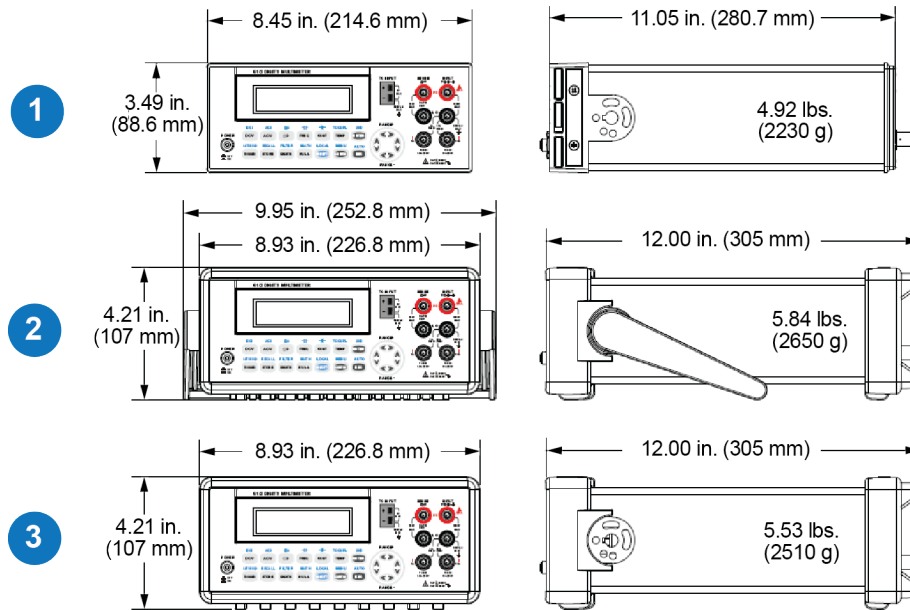
### Dimensions

The following figure shows dimensions for the Model 2110. The figure includes designators to indicate:

1. Dimensions without the handle and the front and rear bumpers.
2. Dimensions with the handle and the front and rear bumpers.
3. Dimensions with the front and rear bumpers, but without the handle.



**Figure 2: Dimensions**



### Power-on settings

See the following table for information about the Model 2110 factory default settings. These settings are also restored when the instrument is turned on and when the instrument receives a \*RST command from a remote interface.

| Function   |           | Default     |
|--|-----------|-------------|
| Function displayed after the instrument is turned on |           | DC voltage  |
| Auto zero  |           | ON          |
| Frequency and period source                          |           | AC voltage  |
| Output format  |           | ASCII       |
| Ratio  |           | OFF         |
| AC voltage   | Frequency | 20 Hz       |
|  | AC digits | 5.5         |
|  | Range     | 10 V        |
| DC voltage   | DC digits | 5.5 (1 PLC) |
|  | Range     | 1 V         |
| AC current   | Frequency | 20 Hz       |
|  | AC digits | 5.5         |
|  | Range     | 1 A         |
| DC current   | DC digits | 5.5 (1 PLC) |
|  | Range     | 1 A         |
| Frequency and period                                 | Digits    | 5.5         |
|  | Range     | 10 V        |
|  | Gate time | 0.1 s       |
| Capacitance  | Digits    | 4.5         |
|  | Range     | 10 nF       |

| Function         |              | Default       |
|------------------|--------------|---------------|
| Diode test       | Digits       | 5.5           |
|                  | Range        | 1 mA          |
|                  | Rate         | 0.2 PLC       |
| Resistance       | Digits       | 5.5 (1 PLC)   |
|                  | Range        | 1 k $\Omega$  |
| Temperature      | Digits       | 4.5 (1 PLC)   |
|                  | Thermocouple | K type        |
| Triggers         | Source       | Immediate     |
|                  | Delay        | Auto          |
| Input resistance |              | 10 M $\Omega$ |

## General specifications

| Item   | Limitation and description  |
|--|---|
| Input bias current                             | <30 pA at 25 °C   |
| Input protection                               | 1000 V all ranges (2W input)  |
| AC CMRR  | 70 dB (for 1 k $\Omega$ unbalanced LO lead)                                       |
| Power supply                                   | 100 V, 120 V, 220 V (230 V), 240 V $\pm$ 10%                                      |
| Power line frequency                           | 50/60 Hz auto detected $\pm$ 10%  |
| Power consumption                              | 25 VA maximum   |
| Digital I/O interface                          | USB-compatible type B connection, GPIB (optional)                                 |
| Environment                                    | For indoor use only   |
| Operating temperature                          | 0 °C to 40 °C   |
| Operating humidity                             | Maximum relative humidity 80% for temperature up to 31 °C                         |
| Storage temperature                            | -40 °C to 70 °C   |
| Operating altitude                             | Up to 2000 m above sea level  |
| Bench dimensions<br>(with handles and bumpers) | 107 mm high x 252.8 mm wide x 305 mm deep (3.49 in. x 9.95 in. x 12.00 in.)       |
| Weight   | 2.23 kg (4.92 lb)   |
| Safety   | Conforms to European Union Low Voltage Directive<br>UL listed to UL 61010-1: 2004 |
| Pollution degree                               | 2   |
| EMC  | Conforms to European Union EMC Directive  |
| Warranty                                       | One year  |



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# General overview

### In this section:

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|  |      |
|--|------|
| Turning your instrument on and off ..... | 2-1  |
| Front panel overview .....               | 2-5  |
| Rear panel overview .....                | 2-18 |
| System operations .....                  | 2-20 |

## Turning your instrument on and off

The following topics describe how to power your instrument on and off and configure the line voltage.

### Connecting line power

Follow the procedure below to connect the Model 2110 to line power and to turn on the instrument. The Model 2110 operates from a line voltage of 100 V to 240 V at a frequency of 50 Hz or 60 Hz. Line voltage is set on the rear panel. Make sure the operating voltage in your area is compatible.

Make sure the instrument is positioned so that it is easy to reach any disconnecting devices, such as the power cord and the power switch.

#### CAUTION

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

#### CAUTION

Remove voltage from the front panel input terminals before switching the equipment off. Failure to do so could result in the equipment being damaged.

#### **To turn a Model 2110 on and off:**

1. Before plugging in the power cord, make sure that the front-panel **POWER** switch is in the **OFF** position.
2. Connect the Model 2110 protective earth (safety ground) located on the rear panel (see [Rear panel overview](#) (on page 2-18)).
3. Connect the female end of the supplied power cord to the AC receptacle on the rear panel.
4. Connect the male end of the power cord to a grounded AC outlet.

**⚠ WARNING**

*The power cord supplied with the Model 2110 contains a separate protective earth (safety ground) wire for use with grounded outlets. When proper connections are made, the instrument chassis is connected to power-line ground through the ground wire in the power cord. In addition, a redundant protective earth connection is provided through a screw on the rear panel. This terminal should be connected to a known protective earth. In the event of a failure, not using a properly grounded protective earth and grounded outlet may result in personal injury or death due to electric shock.*

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

5. To turn your instrument on, press the front-panel **POWER** switch to place it in the ON position.
6. To turn your instrument off, press the front-panel **POWER** switch to place it in the OFF position.

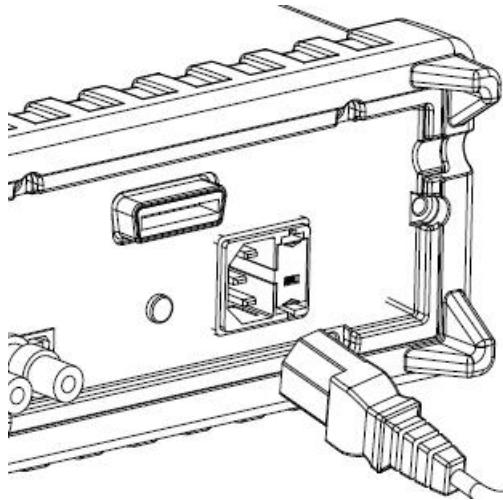
**Voltage selection****⚠ WARNING**

*Before changing the voltage setting, ensure that the instrument is disconnected from the AC power.*

**To set the line voltage:**

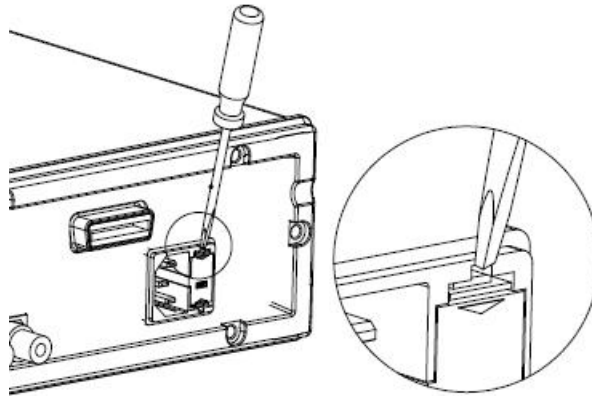
1. Verify that the instrument is disconnected from AC power, as shown in the following figure.

**Figure 3: Disconnect AC power**



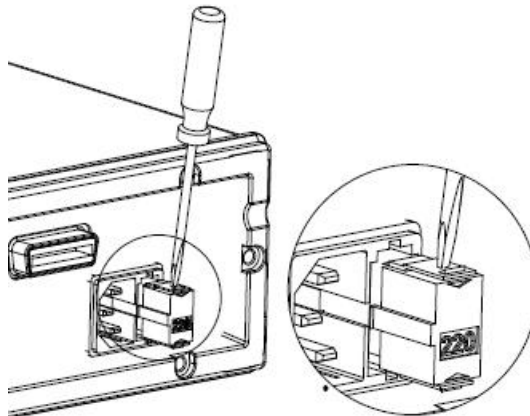
2. Press the latch to unlatch the voltage setting selector container, as shown in the following figure (a flat blade screwdriver may be required).

**Figure 4: Unlatching voltage selector**



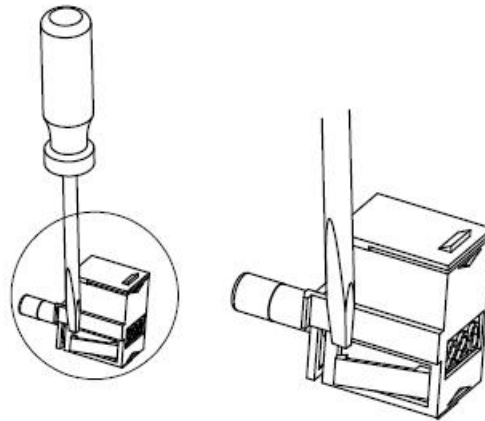
3. Remove the voltage setting selector container, as shown in the following figure.

**Figure 5: Remove voltage selector**



- Open the clips on the sides and remove the voltage setting selector from the container, as shown in the following figure.

**Figure 6: Open clips**

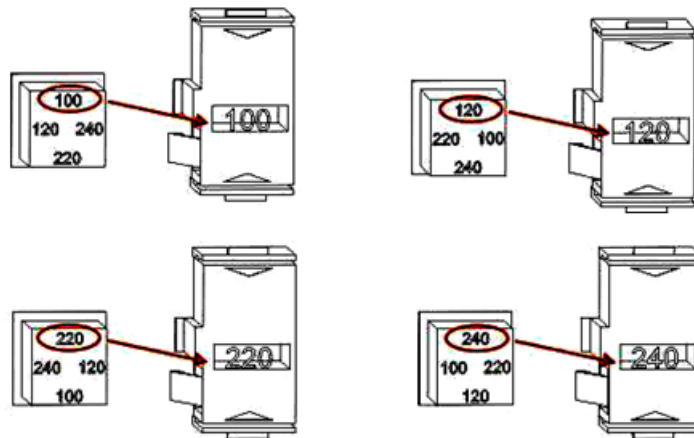


- Turn the voltage setting to the correct setting.

## NOTE

The instrument has four possible voltage settings: 100 V, 120 V, 220 V, and 240 V. It can be set to any of these working voltages.

**Figure 7: Turn voltage selector**



- Insert the voltage setting selector back into the socket and close the cap.

## Fuse replacement

A fuse is located in the voltage selector assembly. This fuse protects the power line input of the instrument. If the line fuse needs to be replaced, refer to [Line fuse replacement](#) (on page A-1).

### Power-up sequence

Self-test procedures are built into the Model 2110 for checking that the logic and measurement hardware are functioning properly. Every time the instrument power is turned on, a set of test procedures is performed to make sure the basic functions of the instrument work properly. If any error occurs during self-test procedures, it indicates that parts of the instrument are not operating properly and need to be serviced.

Refer to [Error codes](#) (on page 6-3) for information about self-test error codes.

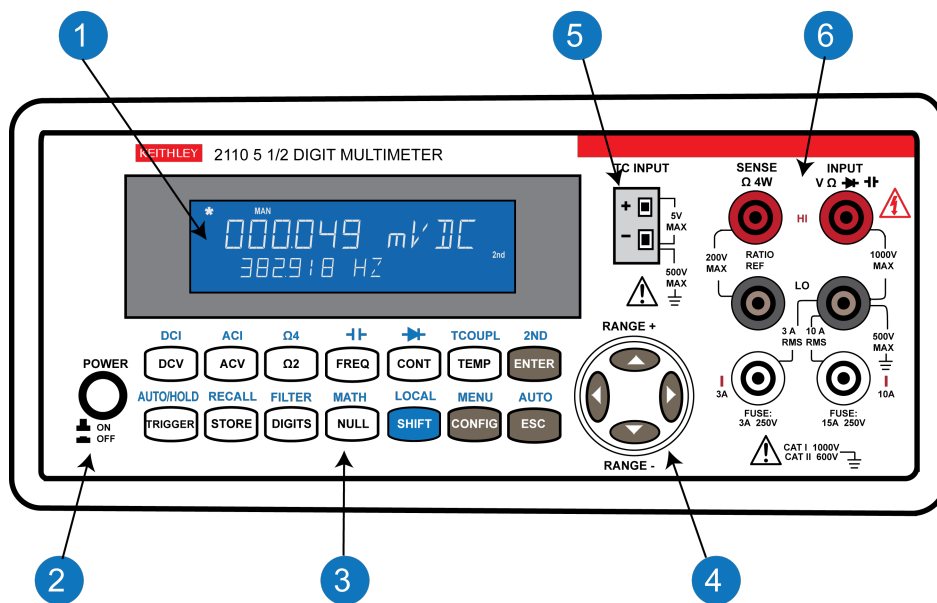
**⚠ CAUTION**

Erroneous self-test failures may occur if the power line voltage is set incorrectly. Errors may also occur because of signals present on the input terminal during self-test procedures. Long test leads can act as an antenna, causing pick-up of AC signals.

### Front panel overview

This topic describes the keys, connections, and fuse device on the front panel. The following figure shows the front panel. A brief description of the front-panel features follows the figure.

**Figure 8: Front panel**

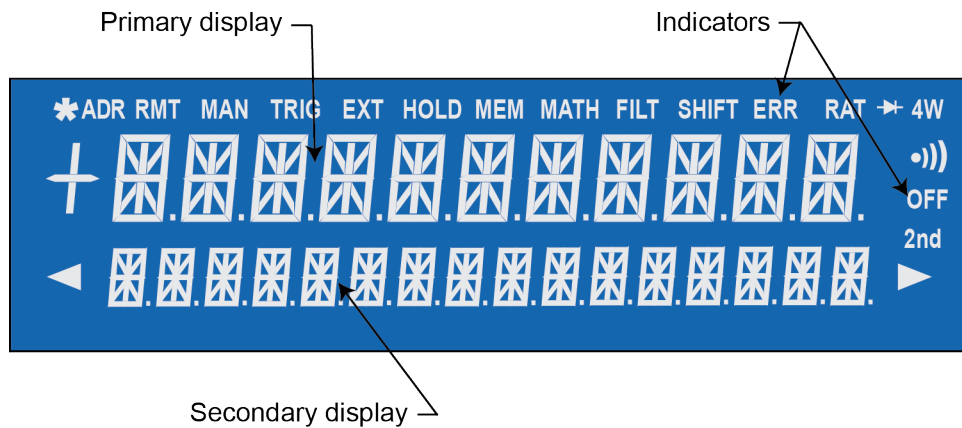




## (1) Display

The instrument display has a primary and a secondary display area. There are additional indicators at the upper side (top) and right side of the display to show the state or the condition of an ongoing measurement. They are explained individually in the following sections. The following figure shows the display with all indicators lit and all character segments lit.

Figure 9: Display



### Primary display

The primary display shows readings and units. The primary display can show a maximum of 11 characters.

### Secondary display

The secondary display shows the range of the measurements; condition, secondary readings and units; or information about an ongoing configuration. The secondary display can show a maximum of 16 characters.

### Indicators

When you are using the instrument, the lit indicators show active functions. For example, in the following figure, the **MAN** indicator shows that the manual range is selected and the **2nd** indicator shows that the second function is in use.

Figure 10: Display typical



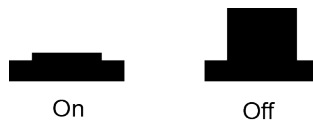
The following table describes the meaning of each lit indicator.

| Indicator    | Indicates   |
|--------------|---|
| <b>ADR</b>   | Instrument is controlled via the GPIB Interface.    |
| <b>RMT</b>   | Remote interface operation via the USB Interface.   |
| <b>MAN</b>   | Manual range mode is selected.                      |
| <b>TRIG</b>  | External triggering is enabled.                     |
| *            | The instrument has received a trigger.              |
| <b>HOLD</b>  | Reading hold function is enabled.                   |
| <b>MEM</b>   | Internal memory is in use.                          |
| <b>MATH</b>  | MATH operation is enabled.                          |
| <b>FILT</b>  | The digital filter is enabled.                      |
| <b>SHIFT</b> | The SHIFT key was just pressed.                     |
| <b>ERR</b>   | An error occurred.                                  |
| <b>RAT</b>   | RATIO operation is taken.                           |
| ▶            | Diode testing operation was initiated.              |
| <b>4W</b>    | 4-wire mode is selected for resistance measurement. |
| •)))         | Continuity testing is enabled.                      |
| <b>OFF</b>   | Front-panel display is turned off.                  |
| <b>2nd</b>   | Second function is in use.                          |

## (2) The Power key

Power switch. The in position turns the instrument ON; the out position turns it OFF.

Figure 11: Power switch



## (3) The function and operation keys

The front panel has keys that allow you to select various functions and operations.

### Function

The function keys are white. Pressing a function key causes the instrument to perform a specific function. For example, pressing the **DCV** function key selects the DC voltage function.

### Operation

The operation keys are gray. Pressing an operation key causes the instrument to perform a specific operation. For example, after selecting DC voltage function, press **Config** to enter the configuration menu for the DC voltage function.

### Shift key

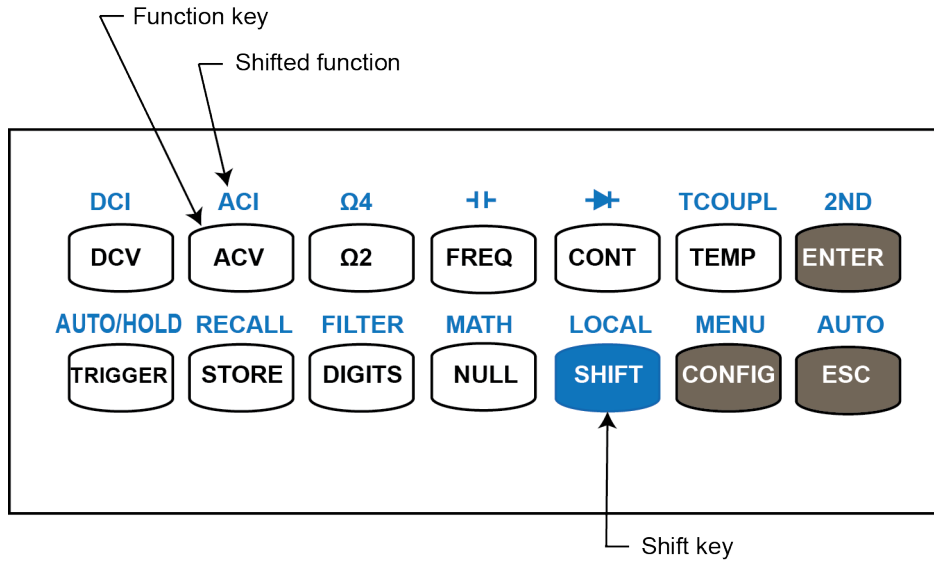
The **SHIFT** key is blue. All keys have a shifted function or operation printed in blue above the key. The SHIFT key allows you to perform the shifted function or operation.

**Shifted keys**

To perform a shifted function or operation, press **SHIFT** and then press the key with the label for the function you want to perform printed above it. The procedures in this manual that require you to use a shifted key sequence list the key name followed by the shifted key name in parentheses. For example, to measure AC current, press **SHIFT** and then press the **ACV (ACI)** key.

See the following figure for the location of the keys.

**Figure 12: Function and operation keys**



The following table describes the functions and shifted functions associated with each key. The shifted functions are shown with a shaded background.

| Key                 | Function   |
|---------------------|--|
| DCV                 | Selects DC voltage measurement.  |
| ACV                 | Selects AC voltage measurement.  |
| $\Omega 2$          | Selects 2-wire resistance measurement.   |
| FREQ                | Selects frequency measurement.   |
| CONT                | Selects the continuity test.   |
| TEMP                | Selects RTD temperature measurement.   |
| ENTER               | Accepts selection, moving to next choice or back to measurement display.   |
| DCI                 | Selects DC current measurement.  |
| ACI                 | Selects AC current measurement.  |
| $\Omega 4$          | Selects 4-wire resistance measurement.   |
| $\text{—} \text{—}$ | Selects capacitance measurement.   |
| $\text{—} \text{—}$ | Selects diode test.  |
| TCOUP               | Selects thermocouple temperature measurement.  |
| 2ND                 | Sets secondary measurement.  |
| TRIGGER             | Sets the external trigger mode. When the TRIG indicator is lit, you can trigger the instrument by pulsing the EXT TRIG input or by pushing the TRIGGER button to generate manual triggers.   |
| STORE               | Stores a specified number of subsequent readings.  |
| DIGITS              | Changes display resolution. Note that changing the display resolution also changes the integration time. If you change the digits to 4½, the integration time is set to 0.02 PLC. If digits are set to 5½, the integration time is set to 1 PLC. |
| NULL                | Activates the null function in order to offset the measurement error due to the test leads.  |
| SHIFT               | Used to access shifted-functions printed in blue over each key.  |
| CONFIG              | Configures the settings of selected measurement function. Refer to the topics in <a href="#">Basic measurement functions</a> (on page 3-1) for configuration details.  |
| ESC                 | Cancels selection, moving back to measurement display.   |
| AUTO/HOLD           | Enables or disables the reading hold function.   |
| RECALL              | Displays stored readings.  |
| FILTER              | Enables or disables averaging digital filter.  |
| MATH                | Enables or disables mathematical operations/tests, including PERCENT, AVERAGE, NULL, LIMITS, mX+b, dB, and dBm.  |
| LOCAL               | Switches the instrument to the local mode from the USB or GPIB remote mode.  |
| MENU                | Offers system-wide settings, trigger settings, and interface configurations. Refer to <a href="#">(7) Menu overview</a> (on page 2-10) for information about menus.  |
| AUTO                | Enables or disables autorange.   |

## (4) RANGE and scroll keys

| Keys    | Description  |
|---------|--|
| ◀ and ▶ | Use ▶ and ◀ keys to scroll through options.  |
| ▲ and ▼ | Use ▲ and ▼ keys to change the range while measuring.<br>Use ▲ and ▼ keys to change a digit when setting parameters and entering values. |

### NOTE

If there are editable characters left or right of the one selected, arrow shaped indicators will display on the second line to indicate the presence and location of the additional characters.

## (5) TC input

The TC INPUT terminals provide thermocouple temperature measurement. The terminals come with built-in cold junction compensation, so no extra thermocouple adapter is needed.

### ⚠ WARNING

*To prevent electrical shock that could cause injury or death, never apply voltages to the LO INPUT terminal while a thermocouple is connected.*

## (6) Terminals and fuses

The instrument has the following connections on the front panel:

### HI and LO INPUT terminals

Use for all measurements except current and TC. The maximum input voltage is 1000 V for voltage measurements; 200 V for 4-wire measurement.

### ⚠ CAUTION

Voltages applied to the LO INPUT terminal will cause erroneous thermocouple measurements.

### HI and LO SENSE terminals

Use to make 4-wire resistance measurement and DC voltage ratio measurement.

### 3A and 10A current Input terminals

Use for all DC and AC current measurements.

## (7) Menu overview

The menus and submenus provide a way for you to configure system-wide settings, trigger settings, and remote interface configurations.

## Menu navigation

### Selecting menus

To select menus and submenus, use the keys as follows:

- To navigate to the Main menu, press **SHIFT**, and then press **CONFIG (MENU)**.
- Press the ► ◀ keys to display submenus.
- Press **ENTER** to choose a submenu.
- If there are additional submenus, press the ► ◀ keys to display the submenu you want, and then press **ENTER** to select it.
- If you need to change digits in a value, press the ▲ ▼ keys to change each digit. Refer to the next topic ([Setting a numeric value](#) (on page 2-11)) for more information about values.
- At any time, press **ESC** to cancel changes.
- When you are finished, press **ESC** to back out of the menu structure.

### Setting a numeric value

Some configuration options require numeric values, or if the configuration options have default values, the values may need to be changed. To change the values, you adjust the value one digit at a time.

To adjust the digits use the ▲ ▼ keys, as follows:

1. Use the ► ◀ keys to display the value that you want to edit.
2. Press the **ENTER** key to enter edit mode.
3. Use the ► ◀ keys to select the digit to edit.
4. Use the ▲ ▼ keys to set the appropriate value.
5. Press the **ENTER** key to select the value or press the **ESC** key to cancel the change.

## Main menu

You can configure instrument operation through the front panel by pressing keys to display menus. Refer to the following table for information about:

- Keys that you press to display menus. These keys are in a **BOLD** font. If the configuration option relates to the key's shifted function, the key's shifted function is listed in parenthesis after the key name.
- Menus are indented and listed under the key that you press to display them.
- Some menus have submenus. Submenus are indented under the menus.

| Keys, menus, and selection | Description   |
|----------------------------|---|
| <b>DCV</b>                 | Press the <b>DCV</b> key.   |
| <b>CONFIG</b>              | Press the <b>CONFIG</b> key to display configuration options.   |
| NPLC                       | Use ► and ◀ keys to select resolution adjustment. Refer to <a href="#">Resolution and integration time</a> (on page 3-41) for information about the number of power line cycles (NPLC). |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| RATIO                      | Select <b>RATIO</b> . Refer to <a href="#">Ratio measurements</a> (on page 3-4) for details.  |

| Keys, menus, and selection  | Description  |
|---|--|
| <b>ACV</b><br><b>CONFIG</b><br>BAND WIDTH<br>RANGE  | Press the <b>ACV</b> key.<br>Press the <b>CONFIG</b> key to display configuration options.<br>Use ► and ◀ keys to select bandwidth. Refer to <a href="#">Bandwidth and resolution for AC measurements</a> (on page 3-44) for details.<br>Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| <b>Ω2</b><br><b>CONFIG</b><br>NPLC<br>RANGE   | Press the <b>Ω2</b> key.<br>Press the <b>CONFIG</b> key to display configuration options.<br>Use ► and ◀ keys to select resolution adjustment. Refer to <a href="#">Resolution and integration time</a> (on page 3-41) for information about the number of power line cycles (NPLC).<br>Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.  |
| <b>FREQ</b><br><b>CONFIG</b><br>PERIOD<br>APERTURE<br>RANGE<br>INPUT JACK   | Press the <b>FREQ</b> key.<br>Press the <b>CONFIG</b> key to display configuration options.<br>Refer to <a href="#">Aperture and resolution for frequency and period measurements</a> (on page 3-45) for details.<br>Refer to <a href="#">Frequency and period measurements</a> (on page 3-12) for information about RANGE and INPUT JACK selections.  |
| <b>CONT</b><br><b>CONFIG</b><br>CONT RES  | Press the <b>CONT</b> key.<br>Press the <b>CONFIG</b> key to display configuration options.<br>Select CONT RES. Use the ◀ and ►, ▲, and ▼ keys to set the threshold resistance (1 Ω to 1000 Ω).  |
| <b>TEMP</b><br><b>CONFIG</b><br>SENSOR<br>PT100, D100, F100,<br>PT385, PT3916<br>USER<br><br>R-ZERO, ALPHA,<br>BETA, DELTA<br><br>SPRTD<br><br>R-ZERO, A4, B4,<br>AX, BX, CX, DX<br>NTCT<br><br>A, B, C<br><br>UNITS<br>C, F, K<br>TRANSDUCER | Press the <b>TEMP</b> key.<br>Press the <b>CONFIG</b> key to display configuration options.<br>Use ► and ◀ keys to select a sensor type. Refer to <a href="#">Temperature measurement</a> (on page 3-17) for details.<br><br>Select to enter coefficient values for RTD user-defined sensor types. Refer to the documentation supplied by the manufacturer of the RTD for information about the coefficient values.<br>Select coefficient and enter values. Then use ► and ◀ keys to select the digit. Then use ▲ and ▼ to increase or decrease the number.<br>Select to configure the standard platinum RTD (SPRTD) sensor. Refer to <a href="#">Temperature measurement</a> (on page 3-17) and <a href="#">RTD coefficients and temperature calculation</a> (on page 3-19) for details.<br>Use ► and ◀ keys to select the digit. Then use ▲ and ▼ to increase or decrease the number.<br>Select to configure a negative temperature coefficient thermistor (NTCT). Refer to <a href="#">Temperature measurement</a> (on page 3-17) for details.<br>Use ► and ◀ keys to select the digit. Then use ▲ and ▼ to increase or decrease the number.<br>Select UNITS to configure the temperature unit type.<br>Units for temperature measurement (Celsius, Fahrenheit, or Kelvin)<br>Select transducer. Where: FRTD = 4-wire as the RTD measurement and RTD = 2-wire as the RTD measurement. |

| Keys, menus, and selection   | Description   |
|--|---|
| <b>SHIFT</b><br><br><b>DCV (DCI)</b><br><b>CONFIG</b><br>NPLC<br><br>RANGE | Press the <b>SHIFT</b> key to access the shifted function for the next key you press.<br>Press the <b>DCV (DCI)</b> key.<br>Press the <b>CONFIG</b> key to configure DC current measurements.<br>Use ► and ◀ keys to select resolution adjustment. Refer to <a href="#">Resolution and integration time</a> (on page 3-41) for information about the number of power line cycles (NPLC).<br>Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details. |
| <b>ACV (ACI)</b><br><b>CONFIG</b><br><br>BAND WIDTH<br><br>RANGE           | Press the <b>ACV (ACI)</b> key.<br>Press the <b>CONFIG</b> key to configure the instrument for AC current measurements.<br>Use ► and ◀ keys to select bandwidth. Refer to <a href="#">Bandwidth and resolution for AC measurements</a> (on page 3-44) for details.<br>Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| <b>Ω (Ω4)</b><br><b>CONFIG</b><br><br>NPLC<br><br>RANGE                    | Press the <b>Ω (Ω4)</b> key.<br>Press the <b>CONFIG</b> key to configure the instrument for resistance measurements.<br>Use ► and ◀ keys to select resolution adjustment. Refer to <a href="#">Resolution and integration time</a> (on page 3-41) for information about the number of power line cycles (NPLC).<br>Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.  |
| <b>FREQ (Hz)</b><br><b>CONFIG</b><br><br>RANGE<br><br>RANGE AUTO           | Press <b>FREQ (Hz)</b> key.<br>Press the <b>CONFIG</b> key to configure the instrument for capacitance measurements.<br>Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.<br>Use ► and ◀ keys to select RANGE AUTO (autorange) or use ► and ◀ keys to display additional selections.  |
| <b>CONT (▶)</b><br><b>CONFIG</b><br><br>VF-LOW<br>VF-HI                    | Press <b>CONT (▶)</b> key.<br>Press the <b>CONFIG</b> key to configure the instrument for diode measurements.<br>Refer to <a href="#">Diode measurements</a> (on page 3-15) for details.  |
| <b>TEMP (TCOUP)</b><br><b>CONFIG</b><br><br>TYPE<br>UNITS                  | Press <b>TEMP (TCOUP)</b> key.<br>Press the <b>CONFIG</b> key to configure the instrument for thermocouple measurements.<br>Refer to <a href="#">Thermocouple measurements</a> (on page 3-22) for details.<br>Specify units for temperature measurement (C, F or K).  |



| Keys, menus, and selection | Description   |
|----------------------------|---|
| <b>ENTER (2ND)</b>         | Press <b>ENTER (2ND)</b> key.   |
| <b>CONFIG</b>              | Refer to <a href="#">Secondary measurement function</a> (on page 3-26) for details.   |
| OFF                        | Select OFF to turn off the dual measurement function off.   |
| DCV                        | Select DCV to configure DC voltage as the second function.  |
| DCI                        | Select DCI to configure DC current as the second function.  |
| NPLC                       | Use ► and ◀ keys to select resolution adjustment. Refer to <a href="#">Resolution and integration time</a> (on page 3-41) for information about the number of power line cycles (NPLC). |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| 2W RES                     | Select 2W RES to configure 2-wire resistance as the second function.  |
| NPLC                       | Use ► and ◀ keys to select resolution adjustment. Refer to <a href="#">Resolution and integration time</a> (on page 3-41) for information about the number of power line cycles (NPLC). |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| 4W RES                     | Select 4W RES to configure 4-wire resistance as the second function.  |
| NPLC                       | Use ► and ◀ keys to select resolution adjustment. Refer to <a href="#">Resolution and integration time</a> (on page 3-41) for information about the number of power line cycles (NPLC). |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| ACV                        | Select ACV to configure AC voltage as the second function.  |
| BAND WIDTH                 | Use ► and ◀ keys to select bandwidth. Refer to <a href="#">Bandwidth and resolution for AC measurements</a> (on page 3-44) for details.   |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| ACI                        | Select ACI to configure AC current as the second function.  |
| BAND WIDTH                 | Use ► and ◀ keys to select bandwidth. Refer to <a href="#">Bandwidth and resolution for AC measurements</a> (on page 3-44) for details.   |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| FREQ                       | Select FREQ to configure frequency as the second function.  |
| APERTURE                   | Refer to <a href="#">Aperture and resolution for frequency and period measurements</a> (on page 3-45) for details.  |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| PERIOD                     | Select PERIOD to configure period as the second function.   |
| APERTURE                   | Refer to <a href="#">Aperture and resolution for frequency and period measurements</a> (on page 3-45) for details.  |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| CURR FREQ                  | Select CURR FREQ to configure frequency as the second function.   |
| APERTURE                   | Refer to <a href="#">Aperture and resolution for frequency and period measurements</a> (on page 3-45) for details.  |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| CURR PERIOD                | Select CURR PERIOD to configure current period as the second function.  |
| APERTURE                   | Refer to <a href="#">Aperture and resolution for frequency and period measurements</a> (on page 3-45) for details.  |

| Keys, menus, and selection | Description   |
|----------------------------|---|
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| CAP                        | Select CAP to configure capacitance as the second function.   |
| RANGE                      | Use ► and ◀ keys to display additional selections. Refer to <a href="#">Range selection</a> (on page 3-39) for details.   |
| TEMP                       | Select TEMP to configure temperature as the second function.  |
| SENSOR                     | Select the RTD sensor type. Use ► and ◀ keys to display additional selections.  |
| UNITS                      | Specify units for temperature measurement (C, F, or K).   |
| TRANSDUCER                 | Select the temperature transducer type (2-wire RTD or 4-wire RTD).  |
| TCOUPPL                    | Select TCOUPL to configure thermocouple as the second function.   |
| TYPE                       | Select TYPE to configure the thermocouple type.   |
| UNITS                      | Specify units for temperature measurement (C, F, or K).   |
| RJUNCTION                  | Specify reference junction type, real or simulated (REAL or SIMulated).   |
| REAL                       | Select REAL.  |
| SIMULATED                  | Select SIMULATED.   |
| VIEW REAL                  | Select VIEW REAL to view the temperature of the internal reference junction.  |
| <b>TRIGGER (AUTO/HOLD)</b> | Press <b>TRIGGER (AUTO/HOLD)</b> to toggle the reading hold function on and off. Refer to <a href="#">Reading hold</a> (on page 3-35) for details.  |
| <b>STORE (RECALL)</b>      | Press <b>STORE (RECALL)</b> to view stored readings. Refer to <a href="#">Data buffer</a> (on page 3-36) for details.   |
| <b>DIGITS (FILTER)</b>     | Press <b>DIGITS (FILTER)</b> to select the type of filter for the measurement on the selected function, or to turn the filter off. Use ► and ◀ keys to display additional selections. Refer to <a href="#">Digital filter</a> (on page 3-47) for details about moving average and repeat average. |
| OFF                        | Turn the filter off.  |
| MOVING AVERAGE             | Select to configure MOVING AVERAGE. Use ► and ◀ keys to display additional selections.  |
| RUN                        | Select RUN to start the function.   |
| READINGS                   | Enter the number of readings using ▲ ▼ ► ◀ keys.  |
| REPEAT AVERAGE             | Select to configure REPEAT AVERAGE. Use ► and ◀ keys to display additional selections.  |
| RUN                        | Select RUN to start the function.   |
| READINGS                   | Enter the number of readings using ▲ ▼ ► ◀ keys.  |

| Keys, menus, and selection | Description   |
|----------------------------|---|
| <b>NULL (MATH)</b>         | Press ► and ◀ keys to display additional selections. Refer to <a href="#">Math operations</a> (on page 3-48) for details. |
| OFF                        | Turn the math function off.   |
| PERCENT                    | Select to configure PERCENT. Refer to <a href="#">Percent</a> (on page 3-49) for details.                                 |
| RUN                        | Select RUN to start the function.   |
| TARGET                     | Enter the target value using ▲ ▼ ► ◀ keys.  |
| AVERAGE                    | Select to configure AVERAGE. Refer to <a href="#">Average</a> (on page 3-50) for details.                                 |
| RUN                        | Select RUN to start the function.   |
| NULL                       | Select to configure NULL. Refer to <a href="#">Null</a> (on page 3-51) for details.                                       |
| RUN                        | Select RUN to start the function.   |
| LIMITS                     | Select to configure LIMITS. Refer to <a href="#">Limits</a> (on page 3-53) for details.                                   |
| RUN                        | Select RUN to start the function.   |
| HIGH LIMIT                 | Enter the high limit value using ▲ ▼ ► ◀ keys.  |
| LOW LIMIT                  | Enter the low limit value using ▲ ▼ ► ◀ keys.   |
| MX+B                       | Select to configure mX+b. Refer to <a href="#">mX+b</a> (on page 3-54) for details.                                       |
| RUN                        | Select RUN to start the function.   |
| SET M                      | Enter the scale factor (m) value using ▲ ▼ ► ◀ keys.  |
| SET B                      | Enter the scale factor (b) value using ▲ ▼ ► ◀ keys.  |
| dB                         | Select to configure dB. Refer to <a href="#">dB</a> (on page 3-57) for details.   |
| RUN                        | Select RUN to start the function.   |
| dB REL                     | Enter the relative reference using ▲ ▼ ► ◀ keys.  |
| dBm                        | Select to configure dBm. Refer to <a href="#">dBm</a> (on page 3-56) for details.   |
| RUN                        | Select RUN to start the function.   |
| REF RES                    | Enter the reference resistance using ▲ ▼ ► ◀ keys.  |

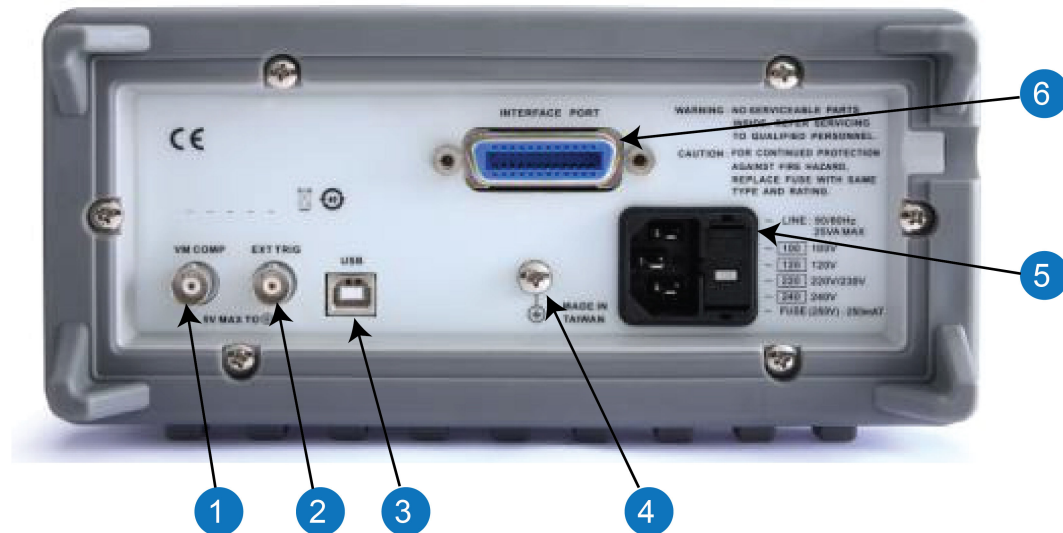
| Keys, menus, and selection | Description  |
|----------------------------|--|
| <b>CONFIG (MENU)</b>       | Press <b>CONFIG (MENU)</b> to select the menu.   |
| SET ADC                    | Select to configure autozero. Refer to <a href="#">Autozero</a> (on page 3-38) for details.  |
| AUTO ZERO                  | Selects the autozero operation. Refer to <a href="#">Autozero</a> (on page 3-38) for details.  |
| ON                         | Turns the function or operation on.  |
| OFF                        | Turn the function off.   |
| TRIG SYS                   | Access trigger system settings. Use ► and ◀ keys to display additional selections.   |
| READ HOLD                  | Set the sensitivity band of the reading hold function. If set, it will hold the stable reading and trigger a beeping sound. Refer to <a href="#">Reading hold</a> (on page 3-35) for details.  |
| STORE RDGS                 | Set number of readings to be stored.   |
| DELAY                      | Access delay time settings for the trigger. Refer to <a href="#">Trigger delay</a> (on page 3-34) for details.   |
| AUTO                       | Select auto delay time for the trigger. AUTO is the default. After selecting AUTO, the menu structure will close.  |
| MANUAL                     | Select manual delay time, and then select the delay time.  |
| SAMPLE CNT                 | Select number of samples per trigger.  |
| TRIG CNT                   | Select number of triggers.   |
| SYSTEM                     | Access system settings. Use ► and ◀ keys to display additional selections.   |
| SCPI ERR                   | Check the error queue. Refer to <a href="#">Error codes</a> (on page 6-3) for information about error queue.   |
| INIT MODE                  | Check the initial mode settings. Refer to <a href="#">Selecting the initial operating mode</a> (on page 2-23) for details.   |
| DEFAULT SET                | Recall the factory settings. Refer to <a href="#">Power-on settings</a> (on page 1-6) for details.   |
| SAVE DATA                  | Save the current settings as the power-on state. Only the primary and secondary measurement function, range, resolution, and math functions are saved. Refer to <a href="#">Selecting the initial operating mode</a> (on page 2-23) for details. |
| SYSTEM VERSION             | Display system version. Refer to <a href="#">Viewing system version</a> (on page 2-24) for details.  |
| INSTRUMENT INFO            | Display instrument manufacturer and model number.  |
| SERIAL                     | Display instrument serial number.  |
| DISPLAY                    | Access display settings. Refer to <a href="#">Turning off measurement display</a> (on page 2-21) for details.  |
| ON                         | Turn display on.   |
| OFF                        | Turn display off.  |
| BEEP                       | Access beeper settings. Refer to <a href="#">Turning the beeper off or on</a> (on page 2-22) for details.  |
| ON                         | Turn beeper on.  |
| OFF                        | Turn beeper off.   |
| SELF TEST                  | Perform a self-test and display results. Refer to <a href="#">Running a self-test</a> (on page 6-2) for details.   |
| LANGUAGE                   | Access remote command language settings. Refer to <a href="#">Selecting the language</a> (on page 2-23) for details.   |
| DEFAULT                    | Set default language. The default language is: Model 2110 SCPI.  |
| COMPATIBLE                 | Set to SCPI-compliant DMM language mode.   |

| Keys, menus, and selection | Description  |
|----------------------------|--|
| INTERFACE                  | Select communication interface. Refer to <a href="#">Rear panel connection details</a> (on page 2-19). |
| USB                        | Access USB settings.   |
| ON                         | Select USB.  |
| OFF                        | Disable USB.   |
| GPIB ADDRESS               | Enter or change GPIB address.  |

## Rear panel overview

The rear panel of the Model 2110 is shown in the following figure. This figure includes important abbreviated information that should be reviewed before using the instrument.

Figure 13: Rear panel



### (1) Voltmeter complete output terminal (VM COMP)

The VM COMP output terminal outputs a low-true pulse after each completed measurement. Refer to [External triggering](#) (on page 3-31) for details.

### (2) External triggering input terminal (EXT TRIG)

Use the EXT TRIG input terminal when choosing external triggering. Refer to [External triggering](#) (on page 3-31) for details.

### (3) USB connection

Use the USB connector to connect the instrument to a remote computer. You can use this connection to switch the instrument to remote mode instead of using the front-panel control. Refer to [USB connector](#) (on page 2-19) for details. For information on using the USB connector as a PASS/FAIL output for limit testing, see [Pass/fail output from USB connector](#) (on page C-5).

#### (4) Protective earth (safety ground)

Ground screw for connection to protective earth (safety ground). Connect to protective earth using recommended wire size (#16 AWG or larger).

#### (5) AC line receptacle, power line fuse, and line voltage setting

Provides:

- AC line receptacle. Use to connect to AC power. Refer to [Turning your instrument on and off](#) (on page 2-1) for details.
- Line voltage setting. Configured for line voltages of 100 V, 120 V 220 V, and 240 V. Refer to [Voltage selection](#) (on page 2-2) for details.
- Fuse. Contains the power line fuse. Refer to [Line fuse replacement](#) (on page A-1) for details.

#### (6) Interface port

If the optional GPIB connection is present in the interface port, you can connect the instrument to a remote computer with an IEEE-488 cable. Refer to [GPIB connector](#) (on page 2-19) for details.

### Rear panel connection details

The following topics describe how to connect the cable connections for the communication interfaces.

To properly set up the communications interfaces after connection, see the information in Communication interfaces.

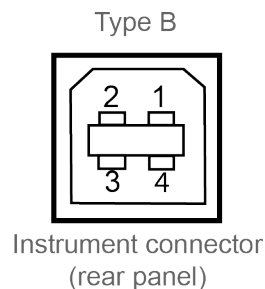
#### USB connector

---

The downstream Type B USB-2.0 receptacle located on the rear panel connects to a host.

Use the rear connector to communicate with the instrument over USB by sending the desired commands. Refer to [USB communications](#) (on page C-1) for information about using this connector.

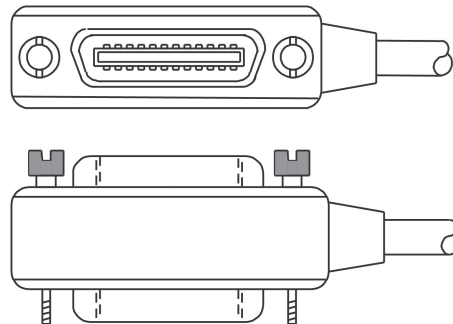
**Figure 14: USB connector**



#### GPIB connector

---

To connect Model 2110 to the GPIB bus, use a cable equipped with standard IEEE-488 connectors, as shown below. Refer to [GPIB setup](#) (on page C-7) for information about using this connector.

**Figure 15: GPIB connector**

---

### Set the GPIB address

---

The GPIB address value is set to 16 at the factory. The address can be set to any address value between 0 and 30. However, the address must be unique in the system. It cannot conflict with the address assigned to another instrument or to the GPIB controller.

**To change the GPIB address:**

1. Press the **SHIFT** key, and then press the **CONFIG (MENU)** key.
2. Use the **▶** and **◀** keys to select **INTERFACE**.
3. Press **ENTER**.
4. Use the **▶** and **◀** keys to select **GPIB**.
5. Press **ENTER**. The display shows GPIB ADDR.
6. Press **ENTER**.
7. Use the **▶** and **◀** keys to change the GPIB address.
8. When the correct GPIB address displays, press **ENTER** to save the address.

The address value is saved in nonvolatile memory and will not change when the power is turned off and then turned on again.

## System operations

This topic provides information about system-related operations. Each system-related operation performs a task that is not measurement-related, but plays an important role in making your measurements.

## Turning off measurement display

You have the option to stop measurements from showing on the display.

When the measurement display is turned off, the **OFF** indicator is lit. This indicator does not mean the display is turned off, but only that the acquired readings will not be sent to the display. Turning off the display does not affect the messages displayed from the RECALL, MENU, and CONFIG front-panel operations.

You can always send a message through the remote interface from your computer to the secondary display, and it will replace the original message.

Measurement display is on by default. If you turn the measurement display off, it stays off until you turn it back on or you turn the instrument power off and then turn it on again.

You can control the display through the front panel or through the remote interface. The remote interface operation overrides the front-panel setting.

### Front-panel operation

---

*To turn the measurement display on or off, use the following procedure:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the **▶** and **◀** keys to display SYSTEM, and then press the **ENTER** key.
3. Use the **▶** and **◀** keys to display DISPLAY, and then press the **ENTER** key.
4. If you want to turn the measurement display on, use the **▶** and **◀** keys to display ON, and then press the **ENTER** key. Go to Step 6.
5. If you want to turn measurement display off, use the **▶** and **◀** keys to display OFF, and then press the **ENTER** key.
6. When finished, press **ESC**.

### Remote operation

---

*To turn measurement display off, use the following command:*

```
DISPlay OFF
```

*To turn measurement display on, use the following command:*

```
DISPlay ON
```

*To display the message (maximum 16 characters) you type in on the secondary display, use the following command:*

```
DISPlay:TEXT <a quoted string>
```

*To clear the message displayed, use the following command:*

```
DISPlay:TEXT:CLear
```



## Turning the beeper off or on

The Model 2110 beeps when certain conditions are met or when an error occurs.

You can only turn off the beeper for some operations. The beeper sound remains in other operations, such as front-panel key-presses.

The beeper is turned on by default. The beeper state is stored in nonvolatile memory, and the default will be restored when the instrument has been turned off or after a remote interface reset.

When the beeper is turned off, you will not hear beeps when the following conditions occur:

- A stable reading is detected and held.
- The test voltage is within the limits in diode testing.
- The source signal fails the limit testing.

Turning the beeper off has no effect on the following conditions:

- An error occurs.
- Any button on the front panel is pressed.
- The threshold value is exceeded in continuity testing.

You can control the beeper from either the front panel or the remote interface operation.

### Front-panel operation

---

*To turn the beeper on or off, use the following procedure:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the **▶** and **◀** keys to display SYSTEM, and then press the **ENTER** key.
3. Use the **▶** and **◀** keys to display BEEP, and then press the **ENTER** key.
4. If you want to turn the beeper on, use the **▶** and **◀** keys to display ON, and then press the **ENTER** key. Go to Step 6.
5. If you want to turn the beeper OFF, use the **▶** and **◀** keys to display OFF, and then press the **ENTER** key.
6. When finished, press **ESC**.

### Remote operation

---

*To turn the beeper off, use the following command:*

```
SYSTem:BEEPer:STATe OFF
```

*To turn the beeper on, use the following command:*

```
SYSTem:BEEPer:STATe ON
```

## Selecting the initial operating mode

The Model 2110 provides the option to save the current operating settings or restore the factory default settings when the instrument is turned on. Refer to [Power-on settings](#) (on page 1-6) for information about default settings.

*To select the initial mode, use the following procedure:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the **▶** and **◀** keys to display SYSTEM, and then press the **ENTER** key.
3. Use the **▲** and **▼** keys to display INIT MODE, and then press the **ENTER** key.
4. If you want to save the current settings, use the **▶** and **◀** keys to display SAVE DATA, and then press the **ENTER** key. Go to Step 6.
5. If you want to restore the default settings, use the **▶** and **◀** keys to display DEFAULT SET, and then press the **ENTER** key.
6. When finished, press **ESC**.

## Selecting the language

You can choose the following languages for programming the remote commands.

- **Default:** Select DEFAULT for compatibility with all Model 2110 features and functions and KI-Tool and KI-Link software.
- **Compatible:** Select COMPATIBLE for SCPI-compliant DMM language mode. When you select COMPATIBLE, the SYST:IDNS "<Manufacturer>,<Model>" allows you to modify the \*IDN? return string to any manufacturer and model number.

You can also set the language from the remote interface. To set compatible mode, send the command L1. To return to the default \*IDN? string, send the command L0.

The language setting is stored in nonvolatile memory.

*To select the language, use the following procedure:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the **▶** and **◀** keys to display SYSTEM, and then press the **ENTER** key.
3. Use the **▶** and **◀** keys to display LANGUAGE, and then press the **ENTER** key.
4. If you want to use the default language, use the **▶** and **◀** keys to display DEFAULT, and then press the **ENTER** key. Go to Step 6.
5. If you want to use the compatible language, use the **▶** and **◀** keys to display COMPATIBLE, and then press the **ENTER** key.
6. When finished, press **ESC**.

## Viewing errors in the error queue

When the **ERR** indicator on the display is lit, it indicates that the instrument has detected an error condition.

In general, the **ERR** indicator and error queue operate as follows:

- The instrument turns the **ERR** indicator off after you view the error queue.
- If there are no error messages in the error queue when you view the queue, the display shows **NO ERRORS**.
- If there are more than 20 errors found, the last error in the error queue will be replaced with the error **-350**. The **-350** error indicates too many errors.

The instrument clears the error queue when the instrument is turned off, or when the following command is received:

```
*CLS
```

For more information about error conditions, refer to [Error codes](#) (on page 6-3).

*To view messages in the error queue, perform the following steps:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the **▶** and **◀** keys to display **SYSTEM**, and then press the **ENTER** key.
3. Use the **▶** and **◀** keys to display **SCPI ERR**, and then press the **ENTER** key. The display shows:
  - **ERROR CODE** - Refer to [Error codes](#) (on page 6-3) for information.
  - **NO ERRORS** - Indicates that there are no error messages in the queue.

## Viewing system version

The Model 2110 system version is a number that indicates the version of firmware installed on each of the instrument's processors.

*To view the system version, use the following procedure:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the **▶** and **◀** keys to display **SYSTEM**, and then press the **ENTER** key.
3. Use the **▶** and **◀** keys to display **SYSTEM VER**, and then press the **ENTER** key. The display shows numbers in the following format:

x.xx-yy-zz

Where:

x.xx - indicates the measurement processor

yy - indicates the I/O processor

zz - indicates the front-panel processor

---

## Basic DMM operation

### In this section:

---

|   |      |
|---|------|
| Basic measurement functions .....       | 3-1  |
| Triggering and data buffer .....        | 3-28 |
| Enhancing measurement performance ..... | 3-37 |

## Basic measurement functions

The Model 2110 5½ Digit Multimeter can perform the following measurements:

- Voltage (DC and AC)
- Ratio (DC voltage input / DC voltage reference)
- Current (DC and AC)
- Resistance (2-wire and 4-wire)
- Frequency and period (voltage input or current input)
- Continuity
- Diode testing
- Temperature (RTD and thermocouple)
- Capacitance

## Voltage measurements

The instrument can measure DC voltage (DCV) up to 1000 V and AC voltage (ACV) up to 750 V (measurement CAT II at maximum 600 V).

- DC voltage (DCV) measurement ranges: 100 mV, 1 V, 10 V, 100 V, and 1000 V
- AC voltage (ACV) measurement ranges: 100 mV, 1 V, 10 V, 100 V, and 750 V AC-coupled true RMS (1000 V peak)

### WARNING

*Do not apply more than 1000 V (peak; measurement CAT II at maximum 600 V) to the instrument. Applying higher voltage is an electric shock hazard and could result in personal injury or death. It may also damage the instrument.*

---

**NOTE**

To eliminate thermal EMFs caused by the differences between two metals, use copper test leads to connect your source signal to the Model 2110.

**NOTE**

Use the following procedure and commands to perform basic measurements. Refer to [Enhancing measurement performance](#) (on page 3-37) for details about setting measurement speed and resolution. It also provides information on using other features and settings to optimize measurement performance.

**CAUTION**

Remove voltage from the front-panel input terminals before switching the equipment off. Failure to do so could result in the equipment being damaged.

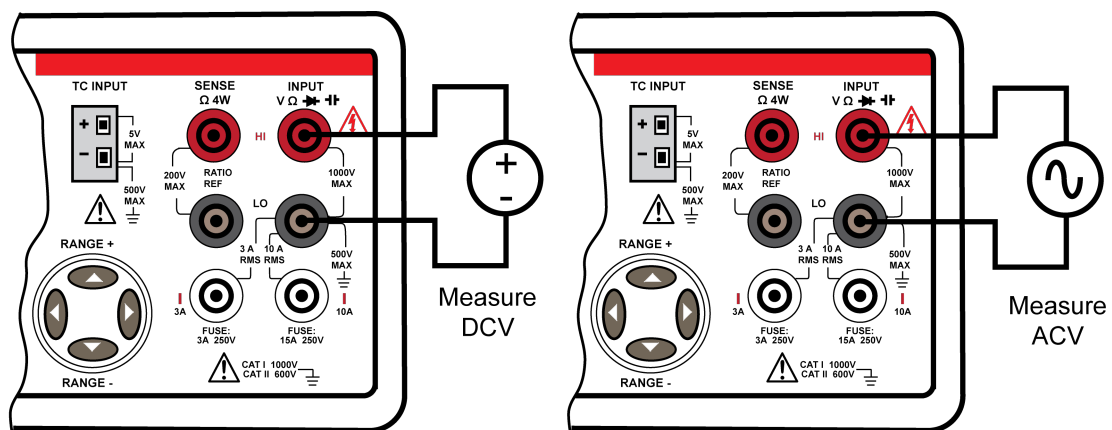
**Front-panel operation**

*Perform the following steps to measure voltage:*

1. Press the **DCV** key to measure DC voltage or the **ACV** key to measure AC voltage.
2. Select a measurement range (auto or manual):
  - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press **SHIFT** and then **ESC (AUTO)** to select autorange.
  - For manual ranging, press the **RANGE ▲** and **▼** keys to select a measurement range.
3. As shown below, connect the signal to the instrument and observe the reading on the display. If the input signal exceeds the selected range, the overflow message **OVLD** is displayed.

**Connections for DC and AC voltage measurements**

**Figure 16: Connections for DCV and ACV measurements**



Input resistance:  
10 MΩ on all ranges

Input impedance:  
1 MΩ in parallel with < 100 pF

## Remote operation

### NOTE

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to select the function (DCV or ACV), set a measure range, set resolution, and perform a measurement:

|                             |   |
|-----------------------------|---|
| FUNCTION "VOLTage[:DC]"     | Select DCV function                     |
| FUNCTION "VOLTage:AC"       | Select ACV function                     |
| VOLTage[:DC]:RANGe <n>      | Set DCV range                           |
| VOLTage:AC:RANGe <n>        | Set ACV range                           |
| <n> = -1000 to 1000         | Specify expected DCV reading            |
| = 0 to 750                  | Specify expected ACV reading            |
| VOLTage[:DC]:RANGe:AUTO <b> | Enable or disable autorange for DCV     |
| VOLTage:AC:RANGe:AUTO <b>   | Enable or disable autorange for ACV     |
| <b> = 0 or OFF              | Disable autorange                       |
| = 1 or ON                   | Enable autorange                        |
| READ?                       | Perform measurement and acquire reading |

Measurement configuration commands can also be used to perform measurements. Use the following commands to select a function (DCV or ACV), set the measure range, set measurement resolution, perform a measurement, and acquire the reading.

|   |                        |
|---|------------------------|
| MEASure:VOLTage[:DC]? <range>, <resolution> |                        |
| MEASure:VOLTage:AC? <range>, <resolution>   |                        |
| <range> = -1000 to 1000                     | Expected DCV reading   |
| = 0 to 750                                  | Expected ACV reading   |
| <resolution> = (see Note)                   | Measurement resolution |

### NOTE

The resolution setting range for <resolution> depends on the selected function and range. The maximum value for DC measurement is  $3.00e-04$  x full-scale range, and the minimum value is  $3.00e-07$  x full-scale range. For example, for the DCV 1000 V range, the minimum value is  $(3.00e-07 \times 1000 \text{ V} = 3.00e-04)$ . The maximum value is  $(3.00e-04 \times 1000 \text{ V} = 3.00e-01)$ . Therefore, <resolution> =  $3.00e-04$  to  $3.00e-01$  for the DCV 1000 V range.

The maximum value for AC measurement is  $1.00e-04$  x full-scale range, and the minimum value is  $1.00e-06$  x full-scale range. For example, for the ACV 750 V range, the minimum value is  $(1.00e-06 \times 750 \text{ V} = 7.50e-04)$ . The maximum value is  $(1.00e-04 \times 750 \text{ V} = 7.50e-02)$ . Therefore, <resolution> =  $7.50e-04$  to  $7.50e-02$  for the ACV 750 V range.

## Ratio measurements

This feature calculates the ratio of an input DC voltage to a reference DC voltage using the following equation:

$$\text{Ratio} = \frac{\text{DC input voltage}}{\text{DC reference voltage}}$$

### NOTE

This function only applies to DC voltage measurement.

### NOTE

Use the following procedure and commands to perform basic measurements. Refer to [Enhancing measurement performance](#) (on page 3-37) for details about setting measurement speed and resolution. It also provides information on using other features and settings to optimize measurement performance.

## Front-panel operation

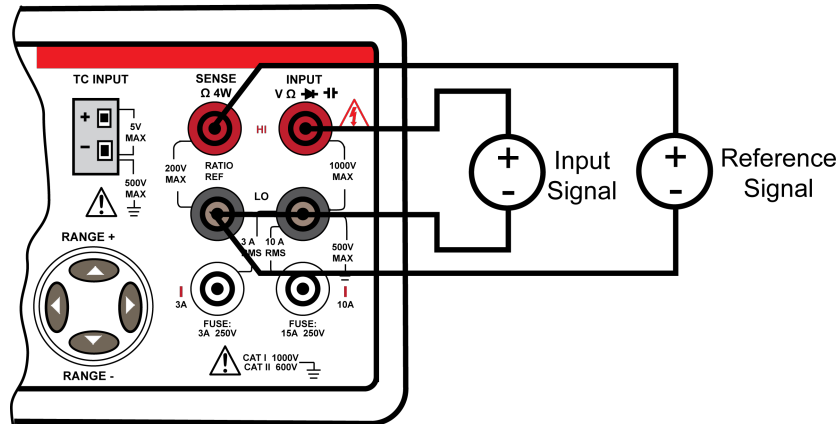
**Perform the following steps to perform ratio calculations:**

1. Press **DCV** to select the DC voltage function.
2. Select a measurement range (auto or manual) for the input signal:
  - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press **SHIFT** and then **ESC (AUTO)** to select autorange.
  - For manual ranging, press the **RANGE ▲** and **▼** keys to select a measurement range.
3. As shown below, connect the input and reference signals to the instrument:
  - a. Connect the DC input signal to the INPUT HI and LO terminals.
  - b. Connect the reference signal to the SENSE HI and LO terminals.
  - c. Connect the SENSE LO terminal to the INPUT LO terminal.
4. Press **CONFIG** and use the **◀** and **▶** keys to display **RATIO**, and then press **ENTER** (RAT indicator turns on).
5. Observe the ratio reading on the display.

To disable ratio, press any function key.

**Connections for ratio measurements**

**Figure 17: Connections for ratio measurements**



Input resistance:  
10 MΩ on all ranges

**NOTE**

The reference signal must be between -2.1 V and 2.1 V.

**Remote operation**

**NOTE**

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to select the ratio function, set a measurement range, and perform a calculation:

- |  |  |
|--|--|
| <code>FUNCTION "VOLTage[:DC]:RATio"</code>     | Select ratio function                            |
| <code>VOLTage[:DC]:RANGe &lt;n&gt;</code>      | Set DCV range for the input signal               |
| <n> = -1000 to 1000                            | Expected DCV reading for the input signal        |
| <code>VOLTage[:DC]:RANGe:AUTO &lt;b&gt;</code> | Enable or disable autorange for the input signal |
| <b> = 0 or OFF                                 | Disable autorange                                |
| = 1 or ON                                      | Enable autorange                                 |
| <code>READ?</code>                             | Perform ratio calculation and acquire reading    |



A measurement configuration command can also be used for ratio calculations. Use the following command to select the ratio function, set the measure range, set measurement resolution, perform a calculation, and acquire the reading.

MEASure:VOLTage[:DC]:RATio? <range>, <resolution>

|              |                 |  |
|--------------|-----------------|--|
| <range>      | = -1000 to 1000 | Expected DCV reading of the input signal |
| <resolution> | = (See Note)    | Measurement resolution                   |

## NOTE

The resolution setting range for <resolution> depends on the selected function and range. The maximum value for DC measurement is  $3.00e-04$  x full-scale range, and the minimum value is  $3.00e-07$  x full-scale range. For example, for ratio 1000 V range, the minimum value is  $(3.00e-07 \times 1000 \text{ V} = 3.00e-04)$ . The maximum value is  $(3.00e-04 \times 1000 \text{ V} = 3.00e-01)$ . Therefore, <resolution> =  $3.00e-04$  to  $3.00e-01$  for the ratio 1000 V range.

## Current measurements

The instrument is capable of measuring DC and AC current up to 10 A.

- DC current measurement ranges: 10 mA, 100 mA, 1 A, 3 A, and 10 A
- AC current measurements: 1 A, 3 A, and 10 A

## NOTE

Use the following procedure and commands to perform basic measurements. Refer to [Enhancing measurement performance](#) (on page 3-37) for details about setting measurement speed and resolution. It also provides information on using other features and settings to optimize measurement performance.

## Front-panel operation

*Perform the following steps to measure current:*

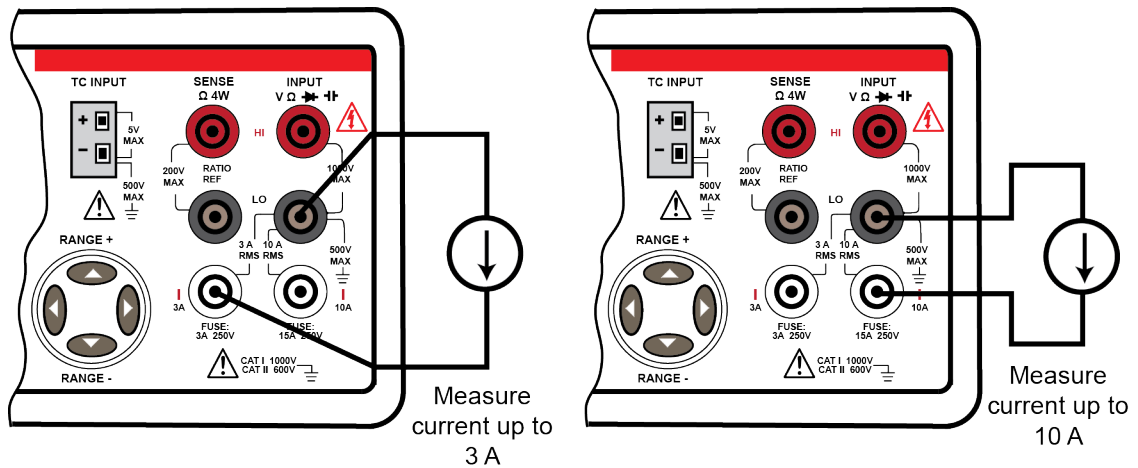
1. Select a current measurement function:
  - Press **SHIFT** and then **DCV (DCI)** to measure DC current.
  - Press **SHIFT** and then **ACV (ACI)** to measure AC current.
2. Select a measurement range (auto or manual):
  - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press **SHIFT** and then **ESC (AUTO)** to select autorange.
  - For manual ranging, press the **RANGE ▲** and **▼** keys to select a measurement range.
3. Connect the signal to the instrument as shown below and observe the reading shown on the display. If the input signal exceeds the selected range, the overflow message **OVLd** will be displayed.

### Connections for DC and AC current measurements

**⚠ CAUTION**

The maximum input on the 3 A input terminals is 3 A, 250 V. The maximum input on the 10 A input terminals is 10 A. Exceeding these input levels will damage the current fuses.

**Figure 18: Connections for DCI and ACI**



### Remote operation

**NOTE**

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to select the function (DCI or ACI), set a measure range, and perform a measurement:

|  |  |
|--|--|
| <pre>FUNCTION "CURRENT[:DC]"</pre>           | <p>Select the DCI function</p>                     |
| <pre>FUNCTION "CURRENT:AC"</pre>             | <p>Select the ACI function</p>                     |
| <pre>CURRENT[:DC]:RANGE &lt;n&gt;</pre>      | <p>Set the DCI range</p>                           |
| <pre>CURRENT:AC:RANGE &lt;n&gt;</pre>        | <p>Set the ACI range</p>                           |
| <pre>    &lt;n&gt; = -10 to 10</pre>         | <p>Expected DCI reading</p>                        |
| <pre>    &lt;n&gt; = 0 to 10</pre>           | <p>Expected ACI reading</p>                        |
| <pre>CURRENT[:DC]:RANGE:AUTO &lt;b&gt;</pre> | <p>Enable or disable autorange for DCI</p>         |
| <pre>CURRENT:AC:RANGE:AUTO &lt;b&gt;</pre>   | <p>Enable or disable autorange for ACI</p>         |
| <pre>    &lt;b&gt; = 0 or OFF</pre>          | <p>Disable autorange</p>                           |
| <pre>    &lt;b&gt; = 1 or ON</pre>           | <p>Enable autorange</p>                            |
| <pre>READ?</pre>                             | <p>Perform the measurement and acquire reading</p> |

Measurement configuration commands can also be used to perform measurements. Use the following commands to select a function (DCI or ACI), set the measure range, set measurement resolution, perform a measurement, and acquire the reading.

```
MEASure:CURRent[:DC]? <range>, <resolution>
```

```
MEASure:CURRent:AC? <range>, <resolution>
```

|              |              |                        |
|--------------|--------------|------------------------|
| <range>      | = -10 to 10  | Expected DCI reading   |
|              | = 0 to 10    | Expected ACI reading   |
| <resolution> | = (see Note) | Measurement resolution |

## NOTE

The resolution setting range for <resolution> depends on the selected function and range. The maximum value for DC measurement is  $3.00e-04$  x full-scale range, and the minimum value is  $3.00e-07$  x full-scale range. For example, for DCI 10 A range, the minimum value is ( $3.00e-07$  x 10 A =  $3.00e-07$ ). The maximum value is ( $3.00e-04$  x 10 A =  $3.00e-03$ ). Therefore, <resolution> =  $3.00e-06$  to  $3.00e-03$  for the DCI 10 A range.

The maximum value for AC measurement is  $1.00e-04$  x full-scale range, and the minimum value is  $1.00e-06$  x full-scale range. For example, for ACI 10 A range, the minimum value is ( $1.00e-06$  x 10 A =  $1.00e-05$ ). The maximum value is ( $1.00e-04$  x 10 A =  $1.00e-03$ ). Therefore, <resolution> =  $1.00e-05$  to  $1.00e-03$  for the ACI 10 A range.

## Resistance measurements

There are two measurement methods for resistance:

- 2-wire ohms
- 4-wire ohms

As shown in the figure in [Connections for resistance measurements](#) (on page 3-10), one pair of test leads are used for 2-wire ohms measurement. A test current is applied and the voltage across the resistance under test is measured on the same leads.

As shown in the figure in [Connections for resistance measurements](#) (on page 3-10), two pairs of test leads are used for 4-wire ohms measurements. One pair of test leads applies the test current, and the other set measures the voltage. As a result, 4-wire ohms is more accurate for low-resistance measurements. The disadvantages of 4-wire ohms are a longer settling time and the need to use an extra set of test leads.

The table below lists the measurement ranges (2-wire and 4-wire) and test currents for the instrument.

| Resistance ranges and test currents |              |
|-------------------------------------|--------------|
| Resistance range                    | Test current |
| 100 $\Omega$                        | 1 mA         |
| 1 k $\Omega$                        | 1 mA         |
| 10 k $\Omega$                       | 100 $\mu$ A  |
| 100 k $\Omega$                      | 10 $\mu$ A   |
| 1 M $\Omega$                        | 1 $\mu$ A    |
| 10 M $\Omega$                       | 0.1 $\mu$ A  |
| 100 M $\Omega$                      | 0.1 $\mu$ A  |

### NOTE

Use the following procedure and commands to perform basic measurements. Refer to [Enhancing measurement performance](#) (on page 3-37) for details about setting measurement speed and resolution. It also provides information on using other features and settings to optimize measurement performance.

## Front-panel operation

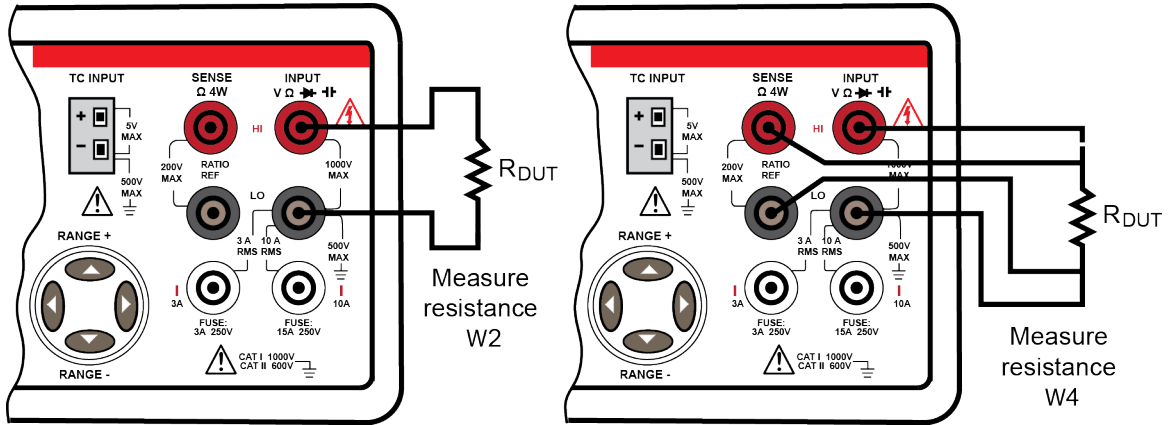
*Perform the following steps to measure resistance:*

1. Connect the device under test to the instrument, as shown below.
2. Select a resistance measurement function:
  - Press  **$\Omega$**  to select 2-wire ohms.
  - Press **SHIFT** and then  **$\Omega$**  ( **$\Omega$** ) to select 4-wire ohms.
3. Select a measurement range (auto or manual):
  - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press **SHIFT** and then **ESC (AUTO)** to select autorange.
  - For manual ranging, press the **RANGE ▲** and **▼** keys to select a measurement range.
4. Observe the reading shown on the display.

### Connections for resistance measurements

Source current flows from INPUT HI to INPUT LO as shown in the following figure.

**Figure 19: Connections for resistance measurements**



## Remote operation

### NOTE

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to select the function (W2 or W4), set a measure range, and perform a measurement:

|                            |   |
|----------------------------|---|
| FUNCtion "RESistance"      | Select 2-wire ohms (W2)                 |
| FUNCtion "FRESistance"     | Select 4-wire ohms (W4)                 |
| RESistance:RANGe <n>       | Set W2 range                            |
| FRESistance:RANGe <n>      | Set W4 range                            |
| <n> = 0 to 100e6           | Expected ohms reading                   |
| RESistance:RANGe:AUTO <b>  | Enable or disable autorange for Ω2      |
| FRESistance:RANGe:AUTO <b> | Enable or disable autorange for Ω4      |
| <b> = 0 or OFF             | Disable autorange                       |
| = 1 or ON                  | Enable autorange                        |
| READ?                      | Perform measurement and acquire reading |

Measurement configuration commands can also be used to perform measurements. Use the following commands to select a function (W2 or W4), set the measure range, set measurement resolution, perform a measurement, and acquire the reading.

|  |                        |
|--|------------------------|
| MEASure:RESistance? <range>, <resolution>  |                        |
| MEASure:FRESistance? <range>, <resolution> |                        |
| <range> = 0 to 100e6                       | Expected ohms reading  |
| <resolution> = (See Note)                  | Measurement resolution |

### NOTE

The resolution setting range for <resolution> depends on the selected function and range. The maximum value for DC measurement is 3.00e-04 x full-scale range, and the minimum value is 3.00e-07 x full-scale range. For example, for the Ω2 and Ω4 1.00e+08 Ω range, the minimum value is (3e-07 x 1.00e+08 Ω = 30). The maximum value is (3.00e-04 x 1.00e+08 Ω = 3.00e+04). Therefore, <resolution> = 30 to 3.00e+04 for the Ω2 and Ω4 1.00e+08 Ω range.

## Frequency and period measurements

The instrument measures frequency from 3 Hz to 300 kHz (or periods from 333 ms to 3.33  $\mu$ s) using the AC voltage ranges (100 mV to 750 V) or AC current ranges (1 A, 3 A, or 10 A).

### WARNING

*Do not apply more than 1000 V (peak; measurement CAT II at maximum 600 V) to the instrument. Applying higher voltage is an electric shock hazard and could result in personal injury or death. It may also damage the instrument.*

### NOTE

Use the following procedure and commands to perform basic measurements. Refer to [Enhancing measurement performance](#) (on page 3-37) for details about setting measurement speed and resolution. It also provides information on using other features and settings to optimize measurement performance.

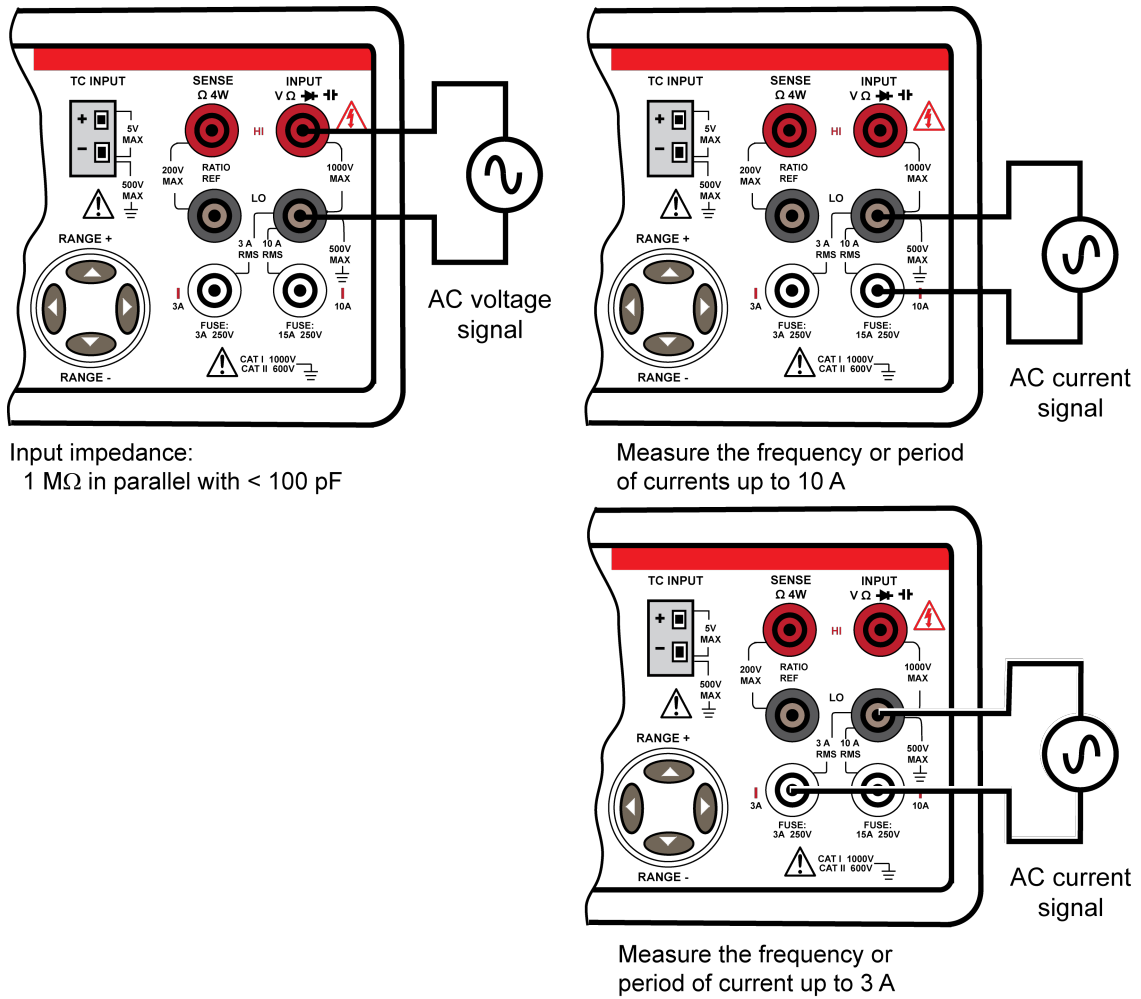
## Front-panel operation

*Perform the following steps to measure frequency or period:*

1. Select the frequency or period measurement function:
  - Frequency: Press the **FREQ** key.
  - Period: Press **FREQ** and **CONFIG**, and with **PERIOD** displayed, press **ENTER**.
2. Select the AC signal (voltage or current) to measure:
  - a. Press **CONFIG**, use the **▶** key to display **INPUT JACK**, and then press **ENTER**.
  - b. Use the **◀** or **▶** key to display **VOLTAGE** or **CURRENT**, and then press **ENTER**.
3. Select a measurement range (auto or manual) for the AC signal to be measured.
  - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press the **SHIFT** key and then **ESC (AUTO)** to select autorange.
  - For manual ranging, press the **RANGE ▲** and **▼** keys to select a measurement range.
4. As shown below, connect the AC signal to the Model 2110 and observe the reading on the display. If the input signal exceeds the selected range, the overflow message **OVL**D is displayed.

### Connections for frequency and period measurements

Figure 20: Connections for FREQ and PERIOD





## Remote operation

### NOTE

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to select the function (frequency or period), set a measure range, set resolution, and perform a measurement:

|                                  |   |
|----------------------------------|---|
| FUNCTION "FREQUency"             | Select frequency function                   |
| FUNCTION "FREQUency[:VOLT]"      | Select frequency function (voltage input)   |
| FUNCTION "FREQUency:CURR"        | Select frequency function (current input)   |
| FUNCTION "PERiod"                | Select period function                      |
| FUNCTION "PERiod[:VOLT]"         | Select period function (voltage input)      |
| FUNCTION "PERiod:CURR"           | Select period function (current input)      |
| FREQUency:VOLTage:RANGe <n>      | Set AC voltage range for frequency function |
| FREQUency:CURRent:RANGe <n>      | Set AC current range for frequency function |
| PERiod:VOLTage:RANGe <n>         | Set AC voltage range for period function    |
| PERiod:CURRent:RANGe <n>         | Set AC current range for period function    |
| <n> = 0 to 750                   | Expected AC voltage level of the signal     |
| <n> = 0 to 10                    | Expected AC current level of the signal     |
| FREQUency:VOLTage:RANGe:AUTO <b> | Frequency autorange for voltage input       |
| FREQUency:CURRent:RANGe:AUTO <b> | Frequency autorange for current input       |
| PERiod:VOLTage:RANGe:AUTO <b>    | Period autorange for voltage input          |
| PERiod:CURRent:RANGe:AUTO <b>    | Period autorange for current input          |
| <b> = 0 or OFF                   | Enable autorange                            |
| = 1 or ON                        | Disable autorange                           |
| READ?                            | Perform measurement and acquire reading     |

Measurement configuration commands can also be used to perform measurements. Use the following commands to select a function (frequency or period), set measure range, set measurement resolution, perform a measurement, and acquire the reading.

MEASure:FREQUency? <range>, <resolution>

MEASure:PERiod? <range>, <resolution>

    <range> = 0 to 750                      Expected AC voltage level of the signal

### NOTE

Resolution is ignored for frequency and period.

## Continuity measurements

The instrument uses the 1 k $\Omega$  range and 5½-digit resolution to measure continuity. The instrument beeps when the test resistance is less than the threshold resistance. The default threshold resistance is 10  $\Omega$ , but can set from 1  $\Omega$  to 1 k $\Omega$ . The resistance value you set is stored in volatile memory and is lost when the instrument is turned off. The source current for continuity measurements is 1 mA.

### WARNING

*Do not apply more than 1000 V (peak; measurement CAT II at maximum 600 V) to the instrument. Applying higher voltage is an electric shock hazard and could result in personal injury or death. It may also damage the instrument.*

## Front-panel operation

*Perform the following steps to measure continuity:*

1. Press the **CONT** key to select the continuity function.
2. Press the **CONFIG** key, and with **CONT RES** displayed, press the **ENTER** key.
3. Use the **◀**, **▶**, **▲**, and **▼** keys to set the threshold resistance (1  $\Omega$  to 1000  $\Omega$ ), and then press the **ENTER** key.
4. As shown in [Connections for resistance measurements](#) (on page 3-10) for 2-wire ohms, connect the resistive device to the Model 2110:
  - If the resistance of the device is more than the threshold resistance, **OPEN** is displayed.
  - If the resistance is less than the threshold resistance, the Model 2110 beeps and displays the resistance of the device.

## Remote operation

Use the following commands to measure continuity:

FUNCTION "CONTInuity"      Select the continuity function.

READ?      Measure continuity and acquire the reading.

A MEASure? command can also be used measure continuity and acquire the reading:

MEASure:CONTInuity?

## Diode measurements

The Model 2110 uses a 1 mA current source for diode measurements. The 1 V DC measurement range and 5½-digit resolution are used to measure a diode.

The default threshold voltage band is between 0.3 V and 0.8 V, and the reading rate is 0.1 PLC. The threshold voltage band can be adjusted from 0.01 V up to 1.2 V. The Model 2110 beeps when the measured diode voltage is within the threshold band.

### NOTE

When connecting a diode, be aware that the source current flows from INPUT HI to INPUT LO.

## Front-panel operation

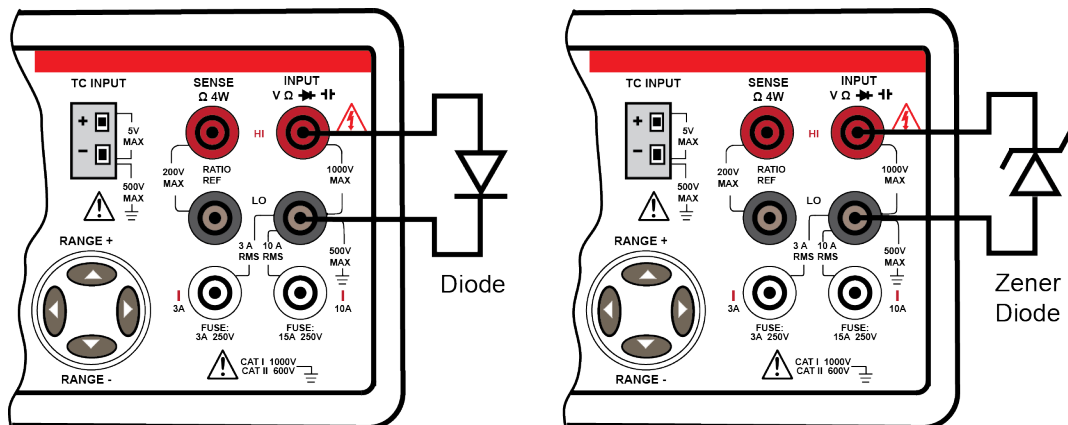
**Perform the following steps to measure the threshold voltage of a diode:**

1. Connect the diode to the instrument, as shown below. These connections forward-bias the diode.
2. Press the **SHIFT** key and then the **CONT** (→←) key to select the diode function.
3. To check or change the threshold voltage band, perform the following steps:
  - a. Press the **CONFIG** key, and with **VF-LOW** displayed, press **ENTER**.
  - b. Use the **◀**, **▶**, **▲**, and **▼** keys to set the low threshold voltage (0.01 V to 1.00 V), and then press **ENTER**.
  - c. With **VF-HI** displayed, press **ENTER**.
  - d. Use the **◀**, **▶**, **▲**, and **▼** keys to set the high threshold voltage (0.01 V to 1.20 V), and then press **ENTER**.
4. Observe the voltage reading on the display. The instrument beeps when the reading is within the threshold voltage band.

## Connections for diode measurements

Source current flows from INPUT HI to INPUT LO as shown in the following figure.

**Figure 21: Connections for diode measurements**



## Remote operation

For remote operation, the default threshold voltage band is used for diode measurements.

Use the following commands to measure the threshold voltage of a diode.

FUNCTION "DIODE"                      Select the diode function.

READ?                                      Measure the diode and acquire the reading.

A MEASURE? command can also be used to perform the measurement and acquire the reading:

MEASURE:DIODE?

## Temperature measurement

For temperature measurements, the instrument supports resistance temperature detector (RTD) probes, NTC thermistors, and thermocouple sensors.

In general, RTDs have a better accuracy and long-term stability than thermocouples. For the instrument, the default RTD sensor type is PT100. The default thermocouple sensor is type K.

### RTD and thermistor measurements

---

The instrument can perform temperature measurements using resistance temperature detectors (RTDs). The supported RTD sensor types are PT100, D100, F100, PT385, PT3916, user definable, and SPRTD. The supported thermistor type is NTCT. The instrument supports 2-wire, 3-wire, and 4-wire RTD probes.

The default RTD sensor type is PT100. The temperature measurement range for the PT100 sensor is -200 °C to 850 °C (-328 °F to 1562 °F).

#### Front-panel operation

*Perform the following steps to measure temperature using an RTD or thermistor:*

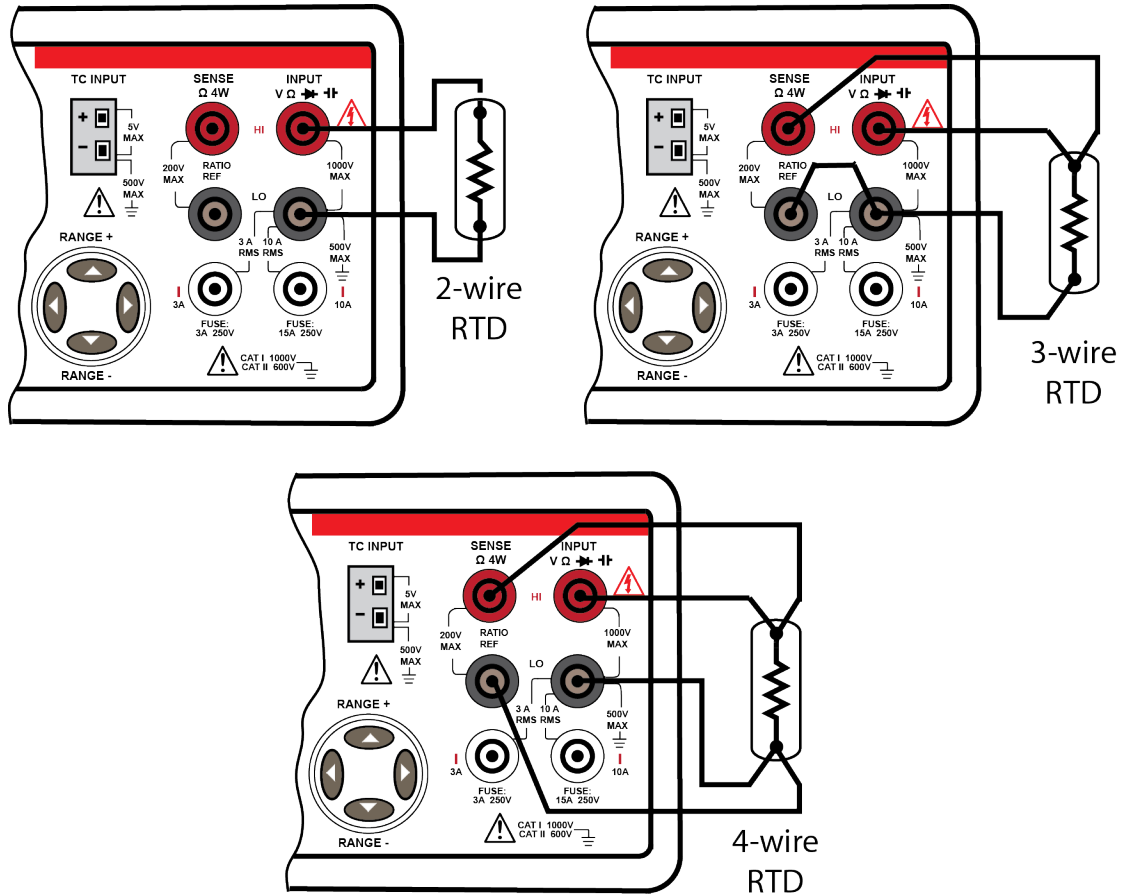
1. Referring to the drawing below, connect the RTD (or thermistor) to the Model 2110.
2. Press the **TEMP** and **CONFIG** keys.
3. Select the sensor:
  - a. Use the ◀ or ▶ key to display **SENSOR** and press **ENTER**.
  - b. Use the ◀ and ▶ keys to display the sensor and press **ENTER**.

Note: If you select the **NTCT**, **SPRTD** or **USER** sensor, you will need to enter coefficient values. See [Entering sensor coefficients](#) (on page 3-20) for details.
4. Select the measurement units:
  - a. Press **CONFIG**, use the ▶ key to display **UNITS**, and then press **ENTER**.
  - b. Use the ◀ or ▶ key to display the units (°C, °F, or K) and press **ENTER**.
5. Select the transducer type (2-wire or 4-wire):
  - a. Press **CONFIG**, use the ▶ key to display **TRANSDUCER**, and then press **ENTER**.
  - b. Use the ◀ or ▶ key to display the transducer type (**2W RTD** or **4W RTD**), and press **ENTER**.
6. Observe the temperature reading on the display.

**Connections to measure temperature using an RTD**

The following figure shows how to connect RTD probes to the instrument. For the 3-wire probe, make sure to connect the SENSE LO terminal to the INPUT LO terminal. Source current flows from INPUT HI to INPUT LO as shown in the following figure.

**Figure 22: Connections for RTD measurements**



### RTD coefficients and temperature calculation

The table below shows the default coefficient values for the PT100, D100, F100, PT385, and PT3916 RTD sensors. For the Model 2110, these values are fixed and cannot be changed. However, if you need to use different coefficient values for these sensors, you can use the USER sensor type. The USER sensor type allows you to enter your own values.

#### Sensor default coefficients

| Sensor type | Alpha ( $\alpha$ ) | Beta ( $\beta$ ) | Delta ( $\delta$ ) | R-Zero       |
|-------------|--------------------|------------------|--------------------|--------------|
| PT100       | 0.003850           | 0.10863          | 1.49990            | 100 $\Omega$ |
| D100        | 0.003920           | 0.10630          | 1.49710            | 100 $\Omega$ |
| F100        | 0.003900           | 0.11000          | 1.49589            | 100 $\Omega$ |
| PT385       | 0.003850           | 0.11100          | 1.50700            | 100 $\Omega$ |
| PT3916      | 0.003916           | 0.11600          | 1.50594            | 100 $\Omega$ |
|             | <b>A</b>           | <b>B</b>         | <b>C</b>           |              |
| NTCT        | 1.129241e-3        | 2.341077e-4      | 8.77546e-8         | n/a          |

The following equations are used to calculate RTD temperature:

When  $t < 0$  °C:

$$R_t = R_0 [1 + At + Bt^2 + Ct^3(t-100)]$$

When  $0$  °C  $\leq t < 630$  °C:

$$R_t = R_0 (1 + At + Bt^2)$$

Where:  $A = \alpha(1 + \delta/100)$

$$B = -\alpha\delta \cdot 10^{-4}$$

$$C = -\alpha\beta \cdot 10^{-8}$$

For the standard platinum RTD (SPRTD) sensor, the ITS-90 (International Temperature Scale) standard provides two reference equations for standard platinum thermometers covering a temperature range from 18.8033 K to 1234.93 K. However, one SPRTD usually cannot cover the entire range, so the temperature range is divided into a few subranges.

These subranges depend on the calibration point of the temperature scale and are based on the melting or triple points of various pure substances. For an exact list of the required elements and details about RTD calibration, refer to NIST Technical Note 1265, "Guidelines for Realizing the International Temperature Scale of 1990." In each subrange, the calibration constants required for that subrange are listed.

### NTCT temperature calculation

For NTCT sensors, the temperature is calculated using the Steinhart-Hart equation:

$$T = \frac{1}{A + B \ln(R) + C (\ln(R))^3}$$

Where R is the resistance measured by the DMM and T is the resulting temperature in Kelvin.

### Entering sensor coefficients

There are three RTD sensor types that allow you to enter coefficient values for sensor parameters. The coefficients are provided with the documentation supplied by the manufacturer of the RTD.

The following sensors allow you to enter coefficient values:

- USER sensor
- NTCT sensor
- SPRTD sensor

#### *Perform the following steps to enter coefficient values:*

1. Press the **TEMP** key.
2. Press **CONFIG**, and with **SENSOR** displayed, press **ENTER**.
3. Use the ◀ or ▶ key to display the sensor type (**NTCT**, **SPRTD**, or **USER**) and press **ENTER**.
4. Use the ◀ and ▶ keys to display an RTD parameter and press **ENTER**.
5. Use the ◀, ▶, ▲, and ▼ keys to enter the coefficient value and press **ENTER**.
6. Repeat steps 4 and 5 to set the coefficients for all the RTD parameters.

### Remote operation

## NOTE

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to select the RTD sensor type and set the measurement units:

|                             |  |
|-----------------------------|--|
| TEMPerature:RTD:TYPE <name> | Select RTD sensor type                                   |
| <name>                      | = PT100, D100, F100, PT385, PT3916, USER, SPRTD, or NTCT |
|                             |  |
| UNIT <name>                 | Set temperature measurement units                        |
| <name>                      | = Cel      Celsius                                       |
|                             | = Far      Fahrenheit                                    |
|                             | = K      Kelvin  |

Use the following commands to enter the parameter coefficients for the USER sensor:

TEMPerature:RTD:RZERo <n>

<n> = R-zero value

TEMPerature:RTD:ALPHa <n>

<n> = Alpha value

TEMPerature:RTD:BETA <n>

<n> = Beta value

TEMPerature:RTD:DELTA <n>

<n> = Delta value

Use the following commands to enter the parameter coefficients for the SPRTD sensor:

TEMPerature:SPRTd:RZERo <n>

<n> = R-zero value

TEMPerature:SPRTd:A4 <n>

<n> = A4 value

TEMPerature:SPRTd:B4 <n>

<n> = B4 value

TEMPerature:SPRTd:AX <n>

<n> = AX value

TEMPerature:SPRTd:BX <n>

<n> = BX value

TEMPerature:SPRTd:CX <n>

<n> = CX value

TEMPerature:SPRTd:DX <n>

<n> = DX value

Use the following commands to enter the parameter coefficients for the NTCT coefficient remote commands.

TEMPerature:NTCT:A <n>

<n> = A value

TEMPerature:NTCT:B <n>

<n> = B value

TEMPerature:NTCT:C <n>

<n> = C value

Use the following command to measure temperature:

MEASure:TEMPerature?



## Thermocouple measurements

The following table lists the temperature range for the supported thermocouple (TC) types:

### Thermocouple temperature measurement ranges

| Thermocouple type | Temperature range (°C) | Temperature range (°F) |
|-------------------|------------------------|------------------------|
| B                 | 600 to 1820            | 1112 to 3308           |
| C                 | 0 to 2316              | 32 to 4200.8           |
| E                 | -250 to 1000           | -418 to 1832           |
| J                 | -210 to 1200           | -346 to 2192           |
| K (default)       | -200 to 1372           | -328 to 2501.6         |
| N                 | -200 to 1300           | 518 to 2372            |
| R                 | 0 to 1767              | 32 to 3212.6           |
| S                 | 0 to 1767              | 32 to 3212.6           |
| T                 | -250 to 400            | -418 to 752            |

Configuration settings for thermocouple temperature measurements:

- Thermocouple type: B, C, E, J, K, N, R, S, T  
Default setting: K
- Measurement units: °C or °F  
Default setting: °C
- Reference junction: Real or simulated  
Default setting: Real

A thermocouple measurement is referenced to a known temperature. The reference junction can be real or simulated.

For a real reference junction, the instrument performs a temperature measurement on a built-in cold junction compensator and uses that reading as the reference point for subsequent thermocouple measurements.

For a simulated reference junction, you enter a temperature reading to use as the reference temperature. An ice bath is typically used in determining a simulated reference junction.

### Front-panel operation

*Perform the following steps to configure the Model 2110 for thermocouple measurements:*

1. Press the **SHIFT** key and then press **TEMP (TCOUPPL)**.
2. Select the sensor type (**B, C, E, J, K, N, R, S, or T**):
  - a. Press **CONFIG**, and with **TYPE** displayed, press **ENTER**.
  - b. Use the ◀ and ▶ keys to display a thermocouple type and press **ENTER**.
3. Select the temperature measurement units (°C, °F, or K).
  - a. Press **CONFIG**, use the ◀ and ▶ keys to display **UNITS**, and press **ENTER**.
  - b. Use the ◀ or ▶ key to display the units and press **ENTER**.
4. Select a reference junction (real or simulated):
  - a. Press **CONFIG**, use the ◀ and ▶ keys to display **RJUNCTION**, and press **ENTER**.
  - b. Use the ◀ or ▶ key to display **REAL** or **SIMULATED** and press **ENTER**.
  - c. If you select **SIMULATED**, use the ◀, ▶, ▲, and ▼ keys to enter the reference temperature, and then press **ENTER**.

*Perform the following steps to measure temperature:*

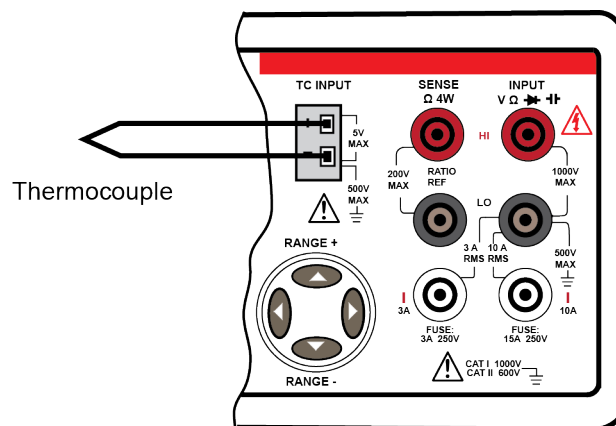
1. Connect the thermocouple to the Model 2110, as shown below.
2. Press **SHIFT** and **TEMP (TCOUPPL)**.
3. Observe the temperature reading on the display.

*Perform the following steps to measure the internal cold-junction temperature:*

1. Press the **SHIFT** key and then press **TEMP (TCOUPPL)**.
2. Press **CONFIG**, use the ◀ and ▶ keys to display **VIEW REAL**, and then press **ENTER**.
3. Observe the temperature reading (°C) on the display.

### Connections to measure temperature using a thermocouple

**Figure 23: Connections for thermocouple temperature measurements**



**Remote operation****NOTE**

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to configure temperature measurements:

|                                       |                                     |
|---------------------------------------|-------------------------------------|
| UNIT <name>                           | Set temperature units               |
| <name> = Cel                          | Celsius                             |
| = Far                                 | Fahrenheit                          |
| = K                                   | Kelvin                              |
| TCouple:TYPE <name>                   | Select the thermocouple type        |
| <name> = B, C, E, J, K, N, R, S, or T |                                     |
| TCouple:RJUNction:RSElect <name>      | Select the reference junction       |
| <name> = REAL                         | Real reference junction             |
| = SIMulated                           | Simulated reference junction        |
| TCouple:RJUNction:SIMulated <n>       | Set simulated reference temperature |
| <n> = -100 to 100                     | Celsius                             |

Use any of the following commands to measure temperature and acquire the reading:

MEASure:TCouple?

READ?

INIT followed by FETCH?

**Capacitance measurements**

The measurement ranges for capacitance measurements are 1 nF, 10 nF, 100 nF, 1 µF, 10 µF, 100 µF, 1 mF, and 10 mF.

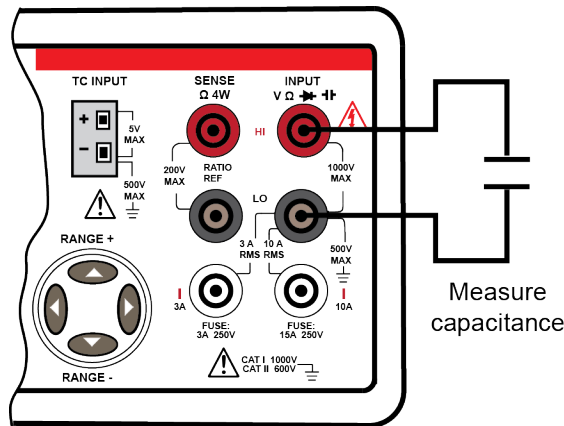
**Front-panel operation**

**Perform the following steps to measure capacitance:**

1. Connect the capacitance to the Model 2110, as shown below.
2. Press the **SHIFT** and **FREQ** (⇄) keys.
3. Select a measurement range (auto or manual):
  - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press **SHIFT** and **ESC** (**AUTO**) to select autorange.
  - For manual ranging, press the **RANGE** ▲ and ▼ keys to select a measurement range.
4. Observe the reading on the display.

### Connections to measure capacitance

Figure 24: Connections for capacitance



### Remote operation

## NOTE

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to select the capacitance function, set a measure range, and perform a measurement:

|  |   |
|--|---|
| <p>FUNCTION "CAPacitance"</p> <p>CAPacitance:RANGE &lt;n&gt;</p> <p style="padding-left: 20px;">&lt;n&gt; = 0 to 10e-3</p> <p>CAPacitance:RANGE:AUTO &lt;b&gt;</p> <p style="padding-left: 20px;">&lt;b&gt; = 0 or OFF</p> <p style="padding-left: 20px;">= 1 or ON</p> <p>READ?</p> | <p>Select capacitance function</p> <p>Set capacitance range</p> <p>Specify expected capacitance reading</p> <p>Enable or disable autorange</p> <p>Perform measurement and acquire reading</p> |
|--|---|

Measurement configuration commands can also be used to perform measurements. Use the following command to select the capacitance function, set the measure range, set display resolution, perform a measurement, and acquire the reading.

|  |                                     |
|--|-------------------------------------|
| <p>MEASure:CAPacitance? &lt;range&gt;, &lt;resolution&gt;</p> <p style="padding-left: 20px;">&lt;range&gt;= 0 to 10e-3</p> | <p>Expected capacitance reading</p> |
|--|-------------------------------------|

## NOTE

Resolution is ignored for capacitance.

## Secondary measurement function

The instrument provides dual measurement capability. When you enable the secondary measurement function, or second function (2ND), you make two measurements at the same time (series measurements). In the following table, the symbol (•) indicates which secondary measurement functions are available for each primary measurement function and the  $\text{⇄}$  symbol indicates capacitance. Diode and continuity testing are not available as a secondary function.

| Primary function    | Secondary function |     |     |     |                     |             |             |               |               |            |            |         |
|---------------------|--------------------|-----|-----|-----|---------------------|-------------|-------------|---------------|---------------|------------|------------|---------|
|                     | DCV                | ACV | DCI | ACI | $\Omega 2/\Omega 4$ | FREQ (VOLT) | FREQ (CURR) | PERIOD (VOLT) | PERIOD (CURR) | $\text{⇄}$ | TEMP (RTD) | TCOUPPL |
| DCV                 |                    | •   | •   |     |                     | •           |             | •             |               |            |            | •       |
| ACV                 | •                  |     | •   |     |                     | •           |             | •             |               |            |            | •       |
| DCI                 | •                  | •   |     | •   |                     | •           | •           | •             | •             |            |            | •       |
| ACI                 |                    |     | •   |     |                     |             | •           |               | •             |            |            | •       |
| $\Omega 2/\Omega 4$ |                    |     |     |     |                     |             |             |               |               |            |            | •       |
| FREQ (VOLT)         | •                  | •   | •   |     |                     |             |             | •             |               |            |            | •       |
| FREQ (CURR)         |                    |     | •   | •   |                     |             |             |               | •             |            |            | •       |
| PERIOD (VOLT)       | •                  | •   | •   |     |                     | •           |             |               |               |            |            | •       |
| PERIOD (CURR)       |                    |     | •   | •   |                     |             | •           |               |               |            |            | •       |
| $\text{⇄}$          |                    |     |     |     |                     |             |             |               |               |            |            | •       |
| TEMP (RTD)          |                    |     |     |     |                     |             |             |               |               |            |            | •       |
| TCOUPPL             | •                  | •   | •   | •   | •                   | •           | •           | •             | •             | •          | •          |         |

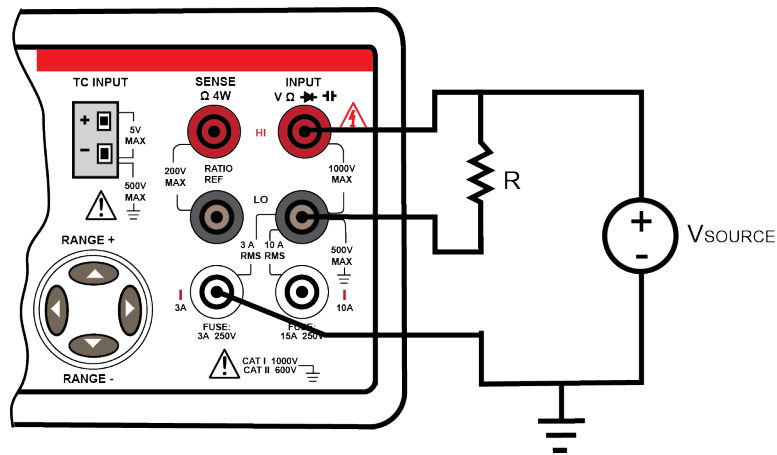
To simultaneously measure DCI and DCV from the same input source, you must use three test leads, as shown in the following figure. The voltage and current measurements share the same common lead at the INPUT LO terminal. However, the resistance of the external LO test lead and the resistance of the internal current measurement LO circuit affect measurement accuracy.

The resistance of the internal current measurement LO circuit is approximately 3 mΩ. If, for example, the LO test lead is 7 mΩ, the total common resistance is 10 mΩ. If 1 A is being measured by the instrument, the voltage is affected as follows:

$$1 \text{ A} \times 10 \text{ m}\Omega = 10 \text{ mV}$$

Therefore, 10 mV of error is introduced into the voltage measurement.

**Figure 25: measure DCI and DCV from the same input source**



## Front-panel operation

**Perform the following steps to perform secondary function measurements:**

1. Select the primary measurement function and connect the device under test or signal to the input of the instrument.
2. Press the **SHIFT** and **ENTER (2ND)** keys.
3. Use the **◀** and **▶** keys to display the second function and press **ENTER**.
4. If prompted, use the **◀**, **▶**, **▲**, and **▼** keys and the **ENTER** key to configure the secondary measurement function.
5. Observe the readings on the display. The primary function reading is shown in the primary display and the secondary function reading is shown in the secondary display.

For example, if you have DCV set as the primary function and want to set a second function of DCI:

1. Verify that the primary function is DCV.
2. Press the **SHIFT** and **ENTER (2ND)** keys.
3. Use the **◀**, **▶**, **▲**, and **▼** keys to display the DCI function.
4. Press the **ENTER** key to select DCI as the secondary function. **CONFIGURE** is displayed.
5. Use the **◀** and **▶** keys to display the options (NPLC and Range in this example).
6. Set the options as needed. Note that for this example, you must return to the **CONFIGURE** menu to set each option.

## Remote operation

---

The following command is used to select a primary or secondary function:

```
FUNction[1|2] "function"
```

When you use the number one (1) or no number, the primary function is selected. When you use the number two (2), the secondary function is selected. Here are some examples:

```
FUNction "VOLTage[:DC]"           Selects DCV as primary function
FUNction1 "VOLTage[:DC]"          Selects DCV as primary function
FUNction2 "VOLTage[:DC]"          Selects DCV as secondary function
```

Use the following commands to select a primary or secondary function:

```
FUNction[1|2] "VOLTage[:DC]"      DCV function
FUNction[1|2] "VOLTage:AC"        ACV function
FUNction[1|2] "CURRent[:DC]"      DCI function
FUNction[1|2] "CURRent:AC"        ACI function
FUNction[1|2] "FREQuency"         FREQ function
FUNction[1|2] "FREQuency[:VOLT]"  FREQ function (voltage input)
FUNction[1|2] "FREQuency:CURR"    FREQ function (current input)
FUNction[1|2] "PERiod"           PERIOD function
FUNction[1|2] "PERiod[:VOLT]"     PERIOD function (voltage input)
FUNction[1|2] "PERiod:CURR"       PERIOD function (current input)
FUNction[1|2] "RESistance"        Ω2 function
FUNction[1|2] "FRESistance"       Ω4 function
FUNction[1|2] "CAPacitance"       Capacitance function
FUNction[1|2] "TEMPerature"       TEMP (RTD) function
FUNction[1|2] "TCouple"          Thermocouple function
FUNction[1|2] "NONE"             Disable second function
FUNction[1|2]?                   Query the selected primary or secondary function
```

## Triggering and data buffer

Triggering is used to initiate one or more measurements by the instrument. Up to 2000 readings can be stored in the data buffer (memory).

You can control instrument trigger operation from the front panel or through a remote interface.

## Front panel triggering

There are two trigger modes for front panel operation: Auto triggering and external triggering.

### Auto triggering

When the instrument is turned on, it goes into the auto triggering to perform continuous measurements. The reading rate depends on the trigger delay setting, integration time setting, and other instrument settings. See [Setting sample count from the front panel](#) (on page 3-33) to set the delay.

Press the **SHIFT** and **TRIGGER (AUTO)** keys to enable or restore auto triggering.

### External triggering

When you use external triggering, the instrument takes one reading (or a specified number of readings) each time you press the **TRIGGER** key or pulse the EXT TRIG input. The reading rate depends on the trigger delay setting, integration rate setting, and other instrument settings. See [Setting trigger delay from the front panel](#) (on page 3-35) to set the delay.

A sample counter determines the number of measurements to perform when the trigger is received. After the specified number of measurements are performed, the instrument waits for the next trigger. See [Setting sample count from the front panel](#) (on page 3-33) to set the sample count. When the TRIG indicator is displayed, the instrument is ready for the next trigger event.

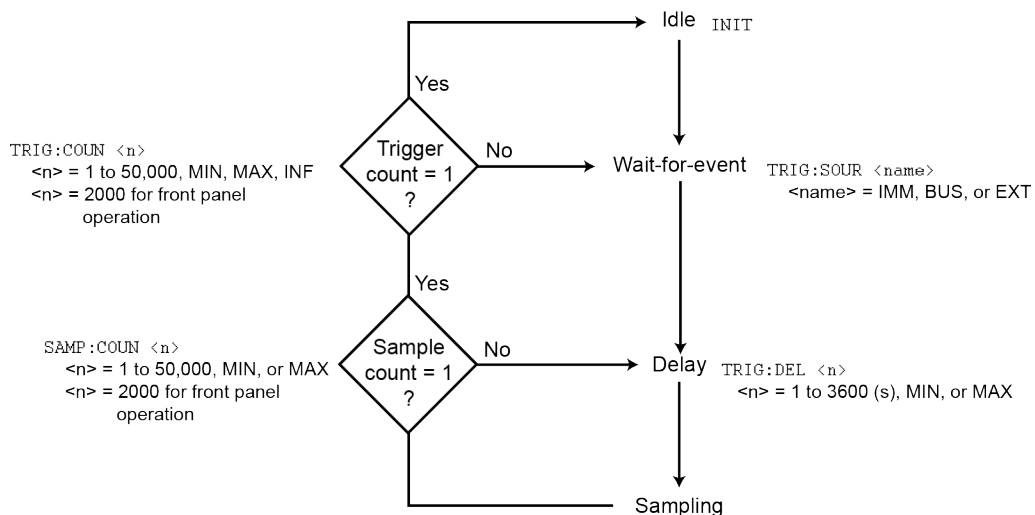
## Trigger model

The trigger model is shown below.

NOTE

When you configure the trigger or sample count from the front panel, a maximum value of 2000 is imposed. This limitation is not present when setting the values using SCPI. However, exceeding 9999 for either value will cause the associated menu item (SAMPLE CNT or TRIG CNT) to read OVLD from the front panel.

Figure 26: Remote trigger model





Measurements begin when the instrument leaves the Idle state and then receives a trigger while in the Wait-for-event state.

The reading rate depends on the trigger delay setting, integration time setting, and other instrument settings. See [Setting trigger delay using remote operation](#) (on page 3-35) to set the trigger delay.

Sample and trigger counters determine the number of measurements that are performed.

- The sample count is the number of measurements to perform for each trigger event.
- The trigger count is the number of trigger events the instrument accepts before entering the Idle state.

The number of measured readings is the product of the trigger count and sample count. For example, if the trigger count is 10 and the sample count is 20, the total number of measurements is 200 (20 x 10).

See [Setting sample count using remote operation](#) (on page 3-33) and [Setting trigger count using remote operation](#) (on page 3-33) to set the counters.

Triggering example:

Assume the sample count is 10 and the trigger count is two (2). The instrument will accept two trigger events. Upon receiving the first trigger, 10 measurements are performed. When the second trigger is received, 10 more measurements are performed. The instrument then returns to the idle state.

## Trigger sources

---

There are three trigger sources for remote operation: Immediate, software (or bus), and external.

### Immediate triggering

When the instrument is in the immediate trigger mode, a trigger is internally generated immediately after it goes into the "wait-for-event" state.

The internal immediate trigger mode is only available using remote operation, and is the default setting for the remote interface.

Use the following command to select internal immediate triggering:

```
TRIGger:SOURce IMMEDIATE
```

### Software triggering

Software triggering is similar to external triggering. Instead of using the **TRIGGER** key on the front panel, a command generates a trigger event.

Use the following command to select the software trigger source:

```
TRIGger:SOURce BUS
```

Use the following command to take the instrument out of the idle state and into the "wait-for-event" state:

```
INITiate
```

Use the following command to generate a trigger event:

```
*TRG
```

**External triggering**

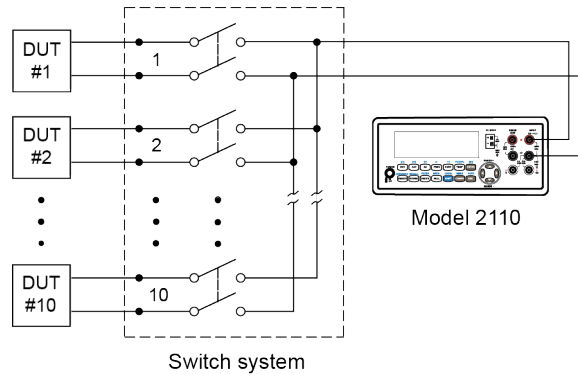
The instrument is triggered by the TRIGGER key or a pulse received from an external source.

After each measurement, the instrument provides an output pulse on the VM COMP (voltmeter complete) terminal. This output pulse can be used to trigger another instrument to perform additional operations.

A typical application for external triggering is to use the instrument with a switch system that also has external triggering capability. The drawing below shows an automated test system to measure 10 DUTs.

The instrument is externally triggered to perform a measurement when a channel closes in the switch system. The switch system then receives the voltmeter complete (VM COMP) pulse when the measurement is complete which then closes the next channel. This handshake sequence between the instrument and switch system continues until all the 10 DUTs are measured.

**Figure 27: DUT test system using external triggering**



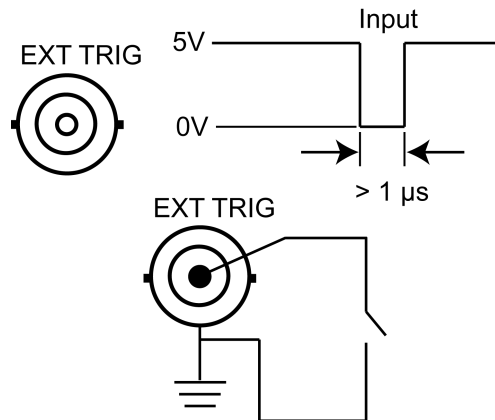
Use the following command to enable external triggering:

```
TRIGger:SOURce EXTernal
```

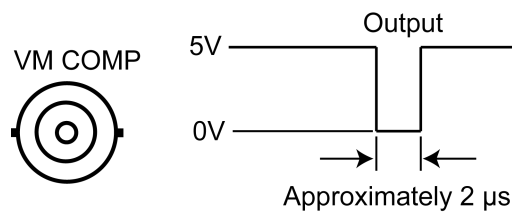
**EXT TRIG terminal**

The **EXT TRIG** (external trigger) terminal is located on the instrument's rear panel. Use this terminal to trigger the instrument by sending it a low-true pulse.

In addition, you can trigger the instrument by connecting a simple switch to the **EXT TRIG** terminal.

**Figure 28: EXT TRIG terminal****VM COMP terminal**

The **VM COMP** (voltmeter complete) BNC terminal located on the rear panel outputs a low-true pulse after finishing each measurement.

**Figure 29: VM COMP terminal****Trigger settings**

The following settings are used to configure triggering:

- Sample count
- Trigger count
- Trigger delay
- Reading hold

Sample count, trigger count, trigger delay, and reading hold can be set from the front panel.

Sample count, trigger count, and trigger delay can be set using remote operation.

**NOTE**

See [Data buffer](#) (on page 3-36) for information about storing measured readings in the buffer.

## Sample count

---

The sample count is the number of measurements (up to 2000) to perform each time the instrument is triggered.

The sample count is stored in volatile memory. It defaults to one (1) when instrument power is turned off and then turned on again.

### Setting sample count from the front panel

*Perform the following steps to set the sample count:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the ◀ and ▶ keys to display **TRIG SYS** and press **ENTER**.
3. Use the ◀ and ▶ keys to display **SAMPLE CNT** and press **ENTER**.
4. Use the ◀, ▶, ▲, and ▼ keys to specify the sample count (1 to 2000) and press **ENTER**.

### Setting sample count using remote operation

#### NOTE

Commands that use the <n> parameter can use the **MINimum** and **MAXimum** name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following command to set the sample count:

```
SAMPlE:COUNT <n>
```

<n> = 1 to 2000                      Sample count

## Trigger count

---

For remote operation, the trigger count (up to 2000) specifies how many times the sample count measurements can be performed. Trigger count is ignored for front-panel operation.

The trigger count is stored in volatile memory. It defaults to one (1) when instrument power is turned off and then turned on again.

### Setting trigger count using remote operation

#### NOTE

Commands that use the <n> parameter can use the **MINimum** and **MAXimum** name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

#### NOTE

You can change the trigger count using the front panel, but the setting only applies during remote operation.

Use the following command to set the trigger count:

```
TRIGger:COUNT <n>
```

<n> = 1 to 2000                      Trigger count

## Trigger delay

A trigger delay is normally used to allow an input signal time to settle before making the measurement. Settling time is affected by the measurement range, test cable properties, and the signal source.

The power-on default setting is auto delay. The auto delay period is determined by the selected combination of measurement function, range, integration time, and AC filter speed.

When not using auto trigger delay, you can manually set the delay time from 0 to 3600 seconds. Your trigger delay time is stored in volatile memory; automatic trigger delay will be used when instrument power is turned off and then turned on again.

The following table lists the auto delay times for each measurement function if you do not specify a delay.

### Auto trigger delay times

| Measurement  | Setting                               | Trigger delay |
|--|---------------------------------------|---------------|
| DCV / DCI  | PLC $\geq$ 1                          | 1.5 ms        |
|  | PLC < 1                               | 1 ms          |
| ACV / ACI<br>(Remote interface/external trigger)     | 3 Hz                                  | 7.0 s         |
|  | 20 Hz                                 | 1.0 s         |
|  | 200 Hz                                | 600 ms        |
| ACV / ACI<br>(Front panel with auto trigger enabled) | 3 Hz                                  | 1.5 s         |
|  | 20 Hz                                 | 200 ms        |
|  | 200 Hz                                | 100 ms        |
| $\Omega$ 2 and $\Omega$ 4<br>(PLC $\geq$ 1)          | 100 $\Omega$ to 100 k $\Omega$        | 1.5 ms        |
|  | 1 M $\Omega$                          | 15 ms         |
|  | 10 M $\Omega$ to 100 M $\Omega$       | 100 ms        |
| $\Omega$ 2 and $\Omega$ 4<br>(PLC > 1)               | 100 $\Omega$ to 100 k $\Omega$        | 1.0 ms        |
|  | 1 M $\Omega$                          | 10 ms         |
|  | 10 M $\Omega$ to 100 M $\Omega$       | 100 ms        |
| Frequency / Period                                   | Remote interface / external           | 1.0 s         |
|  | Front panel with auto trigger enabled | 0 s           |
| Capacitance  | 1 nF to 10 mF                         | 0 s           |

### Setting trigger delay from the front panel

When not using auto trigger delay, you can manually set the delay time from 0 to 3600 seconds (100  $\mu$ s resolution). Your trigger delay time is stored in volatile memory; automatic trigger delay will be used when instrument power is turned off and then turned on again.

#### To set trigger delay (auto or manual) from the front panel:

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the **MENU** options.
2. Use the **◀** and **▶** keys to display **TRIG SYS** and press **ENTER**.
3. Use the **◀** and **▶** keys to display **DELAY** and press **ENTER**.
4. Use the **◀** or **▶** key to display **AUTO** or **MANUAL** and press **ENTER**. If you select **AUTO**, you will exit from the menu structure with auto delay enabled.
5. For a manual delay, use the **◀**, **▶**, **▲**, and **▼** keys to specify the trigger delay (0 to 3600 seconds) and press the **ENTER** key.

### Setting trigger delay using remote operation

#### NOTE

Commands that use the <n> parameter can use the **MINimum** and **MAXimum** name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to set trigger delay (auto or manual):

TRIGger:DElay <n>

|     |             |   |
|-----|-------------|---|
| <n> | = 0 to 3600 | Trigger delay in seconds (100 $\mu$ s resolution) |
|-----|-------------|---|

TRIGger:DElay:AUTO <b>

|     |            |                    |
|-----|------------|--------------------|
| <b> | = 0 or OFF | Disable auto delay |
|     | = 1 or ON  | Enable auto delay  |

### Reading hold

For front panel operation, the reading hold feature captures and holds a stable reading on the display. Reading hold is not available for remote operation.

A reading is considered stable when three consecutive measurements are within a sensitivity band. When a reading falls outside of the sensitivity band, the instrument issues an audible beep and displays the new stable reading.

This sensitivity band is expressed as a percent of reading on the selected range, and can be set by the user from the front panel. The sensitivity band can be set to 0.01 percent, 0.1 percent, 1.0 percent, or 10.0 percent. The 0.1 percent setting is the power-on default.

### Setting reading hold from the front panel

Reading hold is enabled by pressing **SHIFT** and then **TRIGGER** until the HOLD indicator turns on. To disable reading hold, press **SHIFT** again and then press **TRIGGER** (HOLD indicator turns off).

*Perform the following steps to change the sensitivity band for reading hold:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the **MENU** options.
2. Use the ◀ and ▶ keys to display **TRIG** and press **ENTER**.
3. Use the ◀ and ▶ keys to display **READ HOLD** and press **ENTER**,
4. Use the ◀ and ▶ keys to display the desired band setting (**0.01 %**, **0.1 %**, **1.0 %**, or **10.0 %**) and press **ENTER**.

## Data buffer

The instrument can store up to 2000 readings in its volatile memory. The readings are stored in a first-in-first-out (FIFO) order. All the readings are lost when power is turned off.

You can store readings from all measurement functions, math operations, and reading hold. The MEM indicator on the display turns on when the data store is enabled from the front panel.

### Front-panel operation

---

Before using the data store, select and configure a measurement function.

*Perform the following steps to store and recall readings:*

1. Set the number of readings to store:
  - a. Press the **SHIFT** and **CONFIG (MENU)** keys to display the **MENU** options.
  - b. Use the ◀ and ▶ keys to display **TRIG SYS** and press **ENTER**.
  - c. Use the ◀ and ▶ keys to display **STORE RDGS** and press **ENTER**.
  - d. Use the ◀, ▶, ▲, and ▼ keys to specify the number of readings to store (1 to 2000) and press **ENTER**.
2. Press **STORE** to start the storage process. The MEM display indicator turns on while readings are being stored; wait for the storage process to finish (MEM indicator turns off) before recalling stored readings.
3. Press **SHIFT** and **STORE (RECALL)** to display the first stored reading:
  - To scroll through the stored readings, use the ◀ and ▶ keys.
  - To specify the reading to display, press the ▼ key and use the ◀, ▶, ▲, and ▼ keys to select the reading number, and then press **ENTER**.
4. When finished, press **ESC**.

When using auto triggering, readings are stored into the data buffer immediately after the **STORE** key is pressed. The MEM indicator turns off when the specified number of readings are stored. See [Auto triggering](#) (on page 3-29) for details.

When using external triggering, pressing the **TRIGGER** key after the **STORE** key is pressed allows the first reading to be stored in the data buffer. Each subsequent **TRIGGER** key-press stores another reading until the specified number of readings are stored (MEM indicator turns off). See [External triggering](#) (on page 3-29) for details.

## Remote operation

---

When the instrument is triggered to start performing measurements, it stores a specified number of measurement readings in the data buffer (memory).

The total number of measurements the instrument takes is the product of the trigger count and sample count. See [Sample count](#) (on page 3-33) and [Trigger count](#) (on page 3-33) for details.

Use the following command to place the instrument in the wait-for-trigger state:

```
INITiate
```

Use the following command to retrieve the stored readings:

```
FETCh?
```

Use the following command to query the number of stored readings:

```
DATA:POINTs?
```

## Enhancing measurement performance

The following features and settings can be used to optimize measurement performance:

- [Autozero](#) (on page 3-38)
- [Range selection](#) (on page 3-39)
- [Resolution and integration time](#) (on page 3-41)
- [Digital filter](#) (on page 3-47)
- [Math operations](#) (on page 3-48)



## Autozero

The instrument can correct for drifting by comparing the input signal to zero periodically. You can set this up to occur automatically or when requested.

To set the instrument to compare to zero automatically, set autozero on. To only compare when requested, set autozero off.

When the instrument zeroes the input signal, the input signal is measured and then zero is measured. For the zero measurement, the input signal is internally disconnected and the zero offset is measured. The instrument then subtracts the zero offset from the signal measurement and displays the reading:

$$\text{Displayed reading} = \text{Input signal measurement} - \text{Zero offset measurement}$$

Zeroing the input signal results in accurate measured readings by canceling out the zero offset.

Autozero is enabled when the instrument is turned on. When it is on, the instrument takes a zero measurement approximately every two seconds.

Autozero can decrease measurement speed. To increase speed, you can turn autozero off. While this can increase measurement speed, it will also decrease accuracy over time. If you turn autozero off, you should use the ZERO:AUTO ONCE command periodically to maintain accuracy.

The instrument takes a single zero measurement in the following situations:

- When you select a different measurement function.
- Any time the instrument processes a ZERO:AUTO command (ON, OFF, or ONCE).

Autozero can be disabled or enabled from the front panel or by using remote operation.

## Front-panel operation

*Perform the following steps to control autozero:*

1. Press the **SHIFT** and **CONFIG (MENU)** keys.
2. Use the **◀** and **▶** keys to display **SET ADC** and press **ENTER**.
3. With **AUTO ZERO** displayed, press **ENTER**.
4. Use the **◀** or **▶** key to display **ON** or **OFF** and press **ENTER**.

## Remote operation

Use the following command to use autozero:

|                        |        |                       |
|------------------------|--------|-----------------------|
| SENSE:ZERO:AUTO <name> |        | Control autozero      |
| <name>                 | = ON   | Enable autozero       |
|                        | = OFF  | Disable autozero      |
|                        | = ONCE | Perform autozero once |

## Range selection

For best accuracy and resolution, always use an appropriate range to perform the measurement. With autorange enabled, the instrument will automatically select the optimum measurement range. Autorange is the power-on default setting.

You can select a measurement range (or autorange) in a couple of ways:

- Use the front-panel keys to select a range or control autorange.
- Use a configuration menu to select a range or control autorange.

The difference between autoranging and manual ranging is the settling time. Autorange is convenient, but a manually selected range can usually speed up the process.

If the input signal exceeds the allowable range, the **OVL**D message is displayed. The threshold for readings is 120 percent of the range for maximum and 10 percent of the range for minimum.

### NOTE

The measurement range for temperature, continuity, and diode testing is fixed and cannot be changed.

## Front-panel operation

*Perform the following steps to set measurement range using the front panel keys:*

1. Select a measurement function.
2. Select a measurement range or use autorange:
  - Use the **RANGE ▲** and **▼** keys to select a range. The **MAN** indicator turns on to indicate that manual ranging is being used.
  - Pressing **SHIFT** and then **ESC (AUTO)** toggles the instrument between manual ranging and autorange. When autorange is selected, the **MAN** indicator is off.

## Remote operation

### NOTE

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to set a measurement range:

| <function>:RANGe <n>      |                     | Specify expected reading    |  |
|---------------------------|---------------------|-----------------------------|--|
| <function>                | = VOLTage[:DC]      | <n>                         | = -1000 to 1000      Volts DC                  |
|                           | = VOLTage:AC        |                             | = 0 to 750              Volts AC               |
|                           | = CURRent[:DC]      |                             | = -10 to 10            Amps DC                 |
|                           | = CURRent:AC        |                             | = 0 to 10              Amps AC                 |
|                           | = RESistance        |                             | = 0 to 100e6          Ohms (2-wire)            |
|                           | = FRESistance       |                             | = 0 to 100e6          Ohms (4-wire)            |
|                           | = FREQuency[:VOLT]  |                             | = 0 to 750            Volts AC (voltage input) |
|                           | = FREQuency:CURRent |                             | = 0 to 10             Amps AC (current input)  |
|                           | = PERiod[:VOLT]     |                             | = 0 to 750            Volts AC (voltage input) |
|                           | = PERiod:CURRent    |                             | = 0 to 10             Amps AC (current input)  |
|                           | = CAPacitance       |                             | = 0 to 10e-3          Farads                   |
| <function>:RANGe:AUTO <b> |                     | Enable or disable autorange |  |
| <function>                | = VOLTage[:DC]      | <b>                         | = 0 or OFF      Disable autorange              |
|                           | = VOLTage:AC        |                             | = 1 or ON        Enable autorange              |
|                           | = CURRent[:DC]      |                             |  |
|                           | = CURRent:AC        |                             |  |
|                           | = RESistance        |                             |  |
|                           | = FRESistance       |                             |  |
|                           | = FREQuency[:VOLT]  |                             |  |
|                           | = FREQuency:CURRent |                             |  |
|                           | = PERiod[:VOLT]     |                             |  |
|                           | = PERiod:CURRent    |                             |  |
|                           | = CAPacitance       |                             |  |

## Resolution and integration time

Integration time can be set for the following measurement functions:

- Number of power line cycles (NPLC) can be set for the DCV, DCI,  $\Omega 2$ , and  $\Omega 4$  functions.
- Bandwidth can be set for the ACV and ACI functions.
- Aperture can be set for the FREQ and PERIOD functions.

Model 2110 has both 5½-digit and 4½-digit display resolution on the front panel for the following measurement functions: DCV, DCI, ACV, ACI,  $\Omega 2$ ,  $\Omega 4$ , FREQ, PERIOD, TEMP (RTD), and TCOUPL. The actual reading resolution acquired using remote operation can only be set for DCV, DCI, ACV, ACI,  $\Omega 2$ , and  $\Omega 4$ .

### Integration time and resolution for DC and resistance measurements

---

Integration time for DCV, DCI,  $\Omega 2$ , and  $\Omega 4$  measurements is expressed as the number of power line cycles (NPLC).

For 50 Hz line power:

$$1 \text{ PLC} = 1/50 = 0.02 \text{ s (per measurement conversion)}$$

For 60 Hz line power:

$$1 \text{ PLC} = 1/60 = 0.0167 \text{ s (per measurement conversion)}$$

The relationship among display resolution, integration time, and reading resolution is shown in the table below. When you set the integration time, the instrument automatically updates the reading resolution. For example, if the 100 VDC range is selected and you set the integration time to 0.006 PLC, the display resolution is set to 4½ digits and the reading resolution is automatically set to 0.02 (0.0002 x 100 V).

When you change the display resolution, the integration time is also changed. If you change the digits to 4½, the integration time is set to 0.02 PLCs. If digits are set to 5½, the integration time is set to 1 PLC.

The default integration time setting is 1 PLC.

**Integration time and resolution settings for DCV**

| Display resolution | Integration time | Measurement resolution (remote operation) |
|--------------------|------------------|---|
| 4½ digits          | 0.001 PLC        | 0.0003 x full scale range                 |
| 4½ digits          | 0.006 PLC        | 0.0002 x full scale range                 |
| 4½ digits          | 0.02 PLC         | 0.0001 x full scale range                 |
| 4½ digits          | 0.06 PLC         | 0.00005 x full scale range                |
| 5½ digits          | 0.2 PLC          | 0.00001 x full scale range                |
| 5½ digits          | 0.6 PLC          | 0.000005 x full scale range               |
| 5½ digits          | 1 PLC            | 0.000003 x full scale range               |
| 5½ digits          | 2 PLC            | 0.000002 x full scale range               |
| 5½ digits          | 10 PLC           | 0.000001 x full scale range               |
| 5½ digits          | 100 PLC          | 0.0000003 x full scale range              |

**NOTE**

When you enable math operations and your integration rate is faster than 0.6 PLC, the maximum reading rate is affected significantly. For example, the maximum rate at 0.001 PLC with a math function enabled is 6000 readings per second. For more detail, see [Math operations](#) (on page 3-48).

**Front-panel operation****Perform the following steps to set display resolution:**

1. Select the DCV, DCI,  $\Omega 2$ , or  $\Omega 4$  measurement function.
2. Use the **DIGITS** key to set display resolution. Each key-press toggles the display between 4½ and 5½ digits.

**Perform the following steps to set the integration time (speed):**

1. Select the DCV, DCI,  $\Omega 2$ , or  $\Omega 4$  measurement function.
2. Press the **CONFIG** key, use the ◀ and ▶ keys to display NPLC, and press **ENTER**.
3. Use the ◀ and ▶ keys to display a PLC value and press **ENTER**.

**Remote operation****NOTE**

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to set the integration time:

|                            |                                     |
|----------------------------|-------------------------------------|
| VOLTage[:DC]:NPLCycles <n> | Set integration time for DCV        |
| CURRent[:DC]:NPLCycles <n> | Set integration time for DCI        |
| RESistance:NPLCycles <n>   | Set integration time for $\Omega 2$ |
| FRESistance:NPLCycles <n>  | Set integration time for $\Omega 4$ |
|                            | Number of power line cycles (NPLC)  |
| <n> = 0.001 to 100         |                                     |

Use the following commands to set resolution:

|                             |                               |
|-----------------------------|-------------------------------|
| VOLTage[:DC]:RESolution <n> | Set resolution for DCV        |
| CURRent[:DC]:RESolution <n> | Set resolution for DCI        |
| RESistance:RESolution <n>   | Set resolution for $\Omega 2$ |
| FRESistance:RESolution <n>  | Set resolution for $\Omega 4$ |
|                             | Measurement resolution        |
| <n> = (See note)            |                               |

**NOTE**

The resolution setting range for <resolution> depends on the selected function and range. The maximum value for DC measurement is  $3.00e-04 \times$  full-scale range, and the minimum value is  $3.00e-07 \times$  full-scale range. For example, for DCV 1000 V range, the minimum value is  $(3.00e-07 \times 1000 \text{ V} = 3.00e-04)$ . The maximum value is  $(3.00e-04 \times 1000 \text{ V} = 3.00e-01)$ . Therefore, <resolution> =  $3.00e-04$  to  $3.00e-01$  for the DCV 1000 V range.

For example, for DCI 10 A range, the minimum value is  $(3.00e-07 \times 10 \text{ A} = 3.00e-06)$ . The maximum value is  $(3.00e-04 \times 10 \text{ A} = 3.00e-03)$ . Therefore, <resolution> =  $3.00e-06$  to  $3.00e-03$  for the DCI 10 A range.

For example, for  $\Omega 2$  and  $\Omega 4$   $1.00e+08 \Omega$  range, the minimum value is  $(3e-07 \times 1.00e+08 \Omega = 30)$ . The maximum value is  $(3.00e-04 \times 1.00e+08 \Omega = 3.00e+04)$ . Therefore, <resolution> = 30 to  $3.00e+04$  for the  $\Omega 2$  and  $\Omega 4$   $1.00e+08 \Omega$  range.

## Bandwidth and resolution for AC measurements

An AC filter is used for ACV and ACI measurements. The AC filter affects measurement speed. As shown in the table below, there are three bandwidth settings for the AC filter: Slow, medium, and fast. The slow filter allows you to measure lower frequency inputs (down to 3Hz). The fast filter trades low frequency sensitivity for greater measurement speed. The medium filter is a compromise between sensitivity and speed.

The default bandwidth setting is 20 Hz (medium). Bandwidth and resolution can be set from the front panel or by using remote programming. The AC bandwidth setting is stored in volatile memory. When power to the instrument is cycled, the medium setting is restored.

### AC filter bandwidth

| Bandwidth         | AC filter | Time (remote)     | Time (local)      |
|-------------------|-----------|-------------------|-------------------|
| 3 Hz to 300 kHz   | Slow      | 7 s per reading   | 1.5 s per reading |
| 20 Hz to 300 kHz  | Medium    | 1 s per reading   | 0.2 s per reading |
| 200 Hz to 300 kHz | Fast      | 0.1 s per reading | 0.1 s per reading |

## NOTE

The bandwidth times only apply when the trigger delay is set to AUTO. If trigger delay is set to MANUAL, the manual delay is applied instead of the delay specified in the bandwidth table. In MANUAL trigger delay mode, the instrument uses the same delay for local and remote modes.

You can set the AC filter from the front panel or through remote operation.

### Front-panel operation

#### *Perform the following steps to set the AC filter:*

1. Press the **ACV** and **CONFIG** keys.
2. Use the ◀ or ▶ key to display **BAND WIDTH** and press **ENTER**.
3. Use the ◀ or ▶ key to display the bandwidth setting (**3 Hz**, **20 Hz**, or **200 Hz**) and press **ENTER**.

#### *Perform the following steps to set display resolution:*

1. Select the **ACV** or **ACI** measurement function.
2. Use the **DIGITS** key to set display resolution. Each key-press toggles the display between 4½ and 5½ digits.

**Remote operation****NOTE**

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following command to set AC bandwidth:

DETEctor:BA NDwidth <n>

|     |       |                |
|-----|-------|----------------|
| <n> | = 3   | 3 Hz setting   |
|     | = 20  | 20 Hz setting  |
|     | = 200 | 200 Hz setting |

Use the following commands to set resolution:

|                           |                        |
|---------------------------|------------------------|
| VOLTage:AC:RESolution <n> | Set resolution for ACV |
| CURRent:AC:RESolution <n> | Set resolution for ACI |
| <n> = (See Note)          | Measurement resolution |

**NOTE**

The resolution setting range for <resolution> depends on the selected function and range. The maximum value for AC measurement is  $1.00e-04 \times$  full-scale range, and the minimum value is  $1.00e-06 \times$  full-scale range.

For example, for ACV 750 V range, the minimum value is  $(1.00e-06 \times 750 \text{ V} = 7.50e-04)$ . The maximum value is  $(1.00e-04 \times 750 \text{ V} = 7.50e-02)$ . Therefore, <resolution> =  $7.50e-04$  to  $7.50e-02$  for the ACV 750 V range.

For example, for ACI 10 A range, the minimum value is  $(1.00e-06 \times 10 \text{ A} = 1.00e-05)$ . The maximum value is  $(1.00e-04 \times 10 \text{ A} = 1.00e-03)$ . Therefore, <resolution> =  $1.00e-05$  to  $1.00e-03$  for the ACI 10A range.

**Aperture and resolution for frequency and period measurements**

For frequency and period measurements, aperture is analogous to integration time. The aperture settings are 0.01 second (4½-digit resolution), 0.1 second (5½-digit resolution), or 1 second (5½-digit resolution). The default aperture is 0.1 second (5½-digit resolution).

You can set display resolution for 4½-digit or 5½-digit resolution. Changing the display resolution may change the aperture. Selecting 4½-digit resolution will set the aperture to 0.01 second. Selecting 5½-digit resolution will set the aperture to 0.1 second.

Resolution cannot be set using remote programming.



### Front-panel operation

#### *Perform the following steps to set the aperture (integration time):*

1. Select the frequency or period measurement function:
  - To select frequency, press the **FREQ** key.
  - To select period, press **FREQ** and then **CONFIG**. With **PERIOD** displayed, press **ENTER**.
1. Select the **FREQ** or **PERIOD** measurement function.
2. Press the **CONFIG** key, use the ◀ and ▶ keys to display **APERTURE**, and then press **ENTER**.
3. Use the ◀ and ▶ keys to display a aperture time and press **ENTER**.

#### *Perform the following steps to set display resolution:*

1. Select the frequency or period measurement function:
  - To select frequency, press the **FREQ** key.
  - To select period, press **FREQ** and then **CONFIG**. With **PERIOD** displayed, press **ENTER**.
1. Use the **DIGITS** key to set display resolution. Each key-press toggles the display between 4½ and 5½ digits.

### Remote operation

## NOTE

Commands that use the <n> parameter can use the **MINimum** and **MAXimum** name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to set the aperture time:

|                                |                                     |
|--------------------------------|-------------------------------------|
| <b>FREQ</b> uency:APERTure <n> | Set aperture time for <b>FREQ</b>   |
| <b>PER</b> iod:APERTure <n>    | Set aperture time for <b>PERIOD</b> |
| <n> = 0.01                     | 0.01 s aperture                     |
| = 0.1                          | 0.1 s aperture                      |
| = 1                            | 1 s aperture                        |

## Digital filter

The digital filter lets you set the filter response to stabilize noisy measurements. The instrument uses a digital filter, which is based on reading conversions. The displayed, stored, or transmitted reading is an average of a number of reading conversions (from 2 to 100).

Filtered readings are stored in stack memory. There are two types of digital filter: Moving average and repeating average.

- The moving average filter places the specified number of reading conversions in a first-in, first-out (FIFO) order. The first measured reading fills up the stack. The filter averages the readings in the stack to yield a single reading.

Each subsequent measurement conversion replaces the oldest reading in the stack. The readings in the stack are again averaged to yield a single reading.

- The repeating average filter waits for the stack to fill with measurement conversions. It then averages the readings in the stack to yield a single reading. For each subsequent measurement, the filter flushes the stack, waits for the stack to fill again, and then averages the readings to yield another single reading.

The digital filter is not available for diode, continuity, frequency, or period measurements.

The digital filter setting is stored in volatile memory. On power-up, the digital filter is disabled.

---

## Front-panel operation

*Perform the following steps to set and enable the digital filter for the selected function:*

1. Select a measurement function. For example, press the **DCV** key to select the DC volts function.
2. Press the **SHIFT** and **DIGITS (FILTER)** keys.
3. Use the ◀ and ▶ keys to display the filter type (**MOVING AVG** or **REPEAT AVG**) and press **ENTER**.
4. Press the ▶ key to display **READINGS** and press **ENTER**.
5. Use the ◀, ▶, ▲, and ▼ keys to specify the number of readings to average and press **ENTER**.
6. With **RUN** displayed, press **ENTER** to enable the filter. The **FILT** indicator turns on when the digital filter is enabled.

*Perform the following steps to disable the digital filter for the selected function:*

1. Press the **SHIFT** and **DIGITS (FILTER)** keys.
2. Use the ◀ key to display **OFF** and press **ENTER**. The **FILT** indicator turns off.

## Remote operation

### NOTE

Commands that use the <n> parameter can use the MINimum and MAXimum name parameters. MIN selects the minimum value and MAX selects the maximum value.

Use the following commands to configure and enable the digital filter:

|                         |            |                                   |
|-------------------------|------------|-----------------------------------|
| AVERage:TCONtrol <name> |            | Select filter type                |
| <name>                  | = MOVing   | Moving average filter             |
|                         | = REPeat   | Repeating average filter          |
| AVERage:COUNT <n>       |            | Set number of readings to average |
| <n>                     | = 2 to 100 | Number of readings to average     |
| AVERge:STATe <b>        |            | Enable or disable digital filter  |
| <b>                     | = 0 or OFF | Disable digital filter            |
|                         | = 1 or ON  | Enable digital filter             |

## Math operations

The instrument can perform the following math operations:

- PERCENT
- AVERAGE
- NULL
- LIMITS
- mX+b
- dB
- dBm

You can apply these math operations to the measurement functions as shown in the following table. The MATH indicator for the display turns on when a math operation is enabled.

| Math function | Measurement Function |           |     |   |              |
|---------------|----------------------|-----------|-----|---|--------------|
|               | DCV                  | DCV RATIO | ACV | DCI, ACI, Ω2/Ω4, FREQ, PERIOD, HF, TEMP (RTD), TCOUPL | DIODE / CONT |
| PERCENT       | •                    |           | •   | •   |              |
| AVERAGE       | •                    | •         | •   | •   |              |
| NULL          | •                    |           | •   | •   |              |
| LIMITS        | •                    | •         | •   | •   |              |
| mX+b          | •                    | •         | •   | •   |              |
| dB            | •                    |           | •   |   |              |
| dBm           | •                    |           | •   |   |              |

When you enable math operations and your integration rate is faster than 0.6 PLC, the maximum reading rate is affected significantly. The maximum rates when math operations are enabled are as follows:

- The 0.001 PLC rate is 6000 readings/s
- The 0.006 PLC rate is 4000 readings/s
- The 0.02 PLC rate is 2000 readings/s
- The 0.06 PLC rate is 800 readings/s
- The 0.2 PLC rate is 280 readings/s

## Percent

---

This mathematical function calculates the ratio of a measured reading to a specified target value in the form of a percentage. The equation to calculate percent is shown as follows:

$$\text{Percent} = \frac{\text{Input reading}}{\text{Target value}} \cdot 100$$

The set target value is stored in volatile memory and is cleared after the instrument has been turned off or a remote interface reset occurs.

### Front-panel operation

*Perform the following steps to use the percent math function:*

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the ◀ and ▶ keys to display **PERCENT** and press **ENTER**.
3. Use the ◀ and ▶ keys to display **TARGET** and press **ENTER**.  
Note that if you select the **RUN** menu option instead, the percent function will enable using the current target value.
4. Use the ◀, ▶, ▲, and ▼ keys to enter the target value. Note that the polarity sign can be toggled between plus and minus.
5. Press the **ENTER** key. The MATH indicator turns on.

You can disable the math operation by pressing a different function key. You can also disable it from the math menu as follows:

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the ◀ and ▶ keys to display **OFF** and press **ENTER**.

**Remote operation****NOTE**

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to configure and control the percent math function:

|   |                                       |
|---|---------------------------------------|
| <code>CALCulate:FUNCTION PERCent</code>         | Select the percent math function      |
| <code>CALCulate:PERCent:TARGet &lt;n&gt;</code> | Set target value                      |
| <n> = (see Note)                                | Set target value (1 $\mu$ resolution) |

**NOTE**

The target value setting range depends on the selected function. For example, for DCV, the target value can be set from -1200 to 1200.

|  |                                   |
|--|-----------------------------------|
| <code>CALCulate:STATe &lt;b&gt;</code> | Enable or disable math operations |
| <b> = 0 or OFF                         | Disable math                      |
| = 1 or ON                              | Enable math                       |

**Average**

When the average math function is enabled, the instrument performs measurements and displays the average reading in the secondary display. It can also display the minimum and maximum readings, as well as the reading count.

The data acquired by the average math function is stored in volatile memory. It is lost when power to the instrument is cycled or when the remote interface is reset.

The average math function can be used from the front panel or by using remote operation.

**Front-panel operation**

**Perform the following steps to use the average math function:**

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the **◀** and **▶** keys to display **AVERAGE** and press **ENTER**.
3. With **RUN** displayed, press **ENTER**. The MATH indicator turns on.  
The primary (top) display shows the measured readings, and the secondary (bottom) display shows the average (**AVG**) reading of the measurements that have already been performed.
4. Use the **◀** and **▶** keys to change the secondary display to show the maximum (**MAX**) minimum (**MIN**) readings, and the reading count (**COUNT**).

You can disable the math operation by pressing a different function key. You can also disable it from the math menu as follows:

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the **◀** and **▶** keys to display **OFF** and press **ENTER**.

### Remote operation

Use the following commands to configure and control the average math function:

|                            |                                   |
|----------------------------|-----------------------------------|
| CALCulate:FUNCTION AVERAge | Select the average math function  |
| CALCulate:STATE <b>        | Enable or disable math operations |
| <b> = 0 or OFF             | Disable math                      |
| = 1 or ON                  | Enable math                       |

Use the following commands to acquire the count, minimum, maximum, and average readings:

```
CALCulate:AVERAge:MINimum?
CALCulate:AVERAge:MAXimum?
CALCulate:AVERAge:AVERAge?
CALCulate:AVERAge:COUNT?
```

### Null

---

When the null feature is enabled, the displayed reading is the difference between the measured input signal and the stored null (also called relative) value:

$$\text{Displayed reading} = \text{Measured input reading} - \text{Null value}$$

You can acquire the null (relative) value by measurement or by specifying the value. The null value is stored in volatile memory, which will be cleared when power to the instrument is cycled.

Typical uses of the null feature:

- Cancel out test-lead resistance that can result in inaccurate low-level resistance Measurements. The subsequent resistance measurement reading will exclude the test lead resistance.
- Establish a baseline level (such as a voltage) that will shift the measured reading. For example, if a 5 V null level is set, the measurement of a 5 V input signal is displayed as 0 V.

The null feature is available for all functions except continuity, diode, and ratio.

The null feature and other math functions may not be used at the same time.

The null feature can be used from the front panel or by using remote operation.

### Front-panel operation

#### *Perform the following steps to use a measured value as the null value:*

1. Select and configure a measurement function.
2. Connect the null signal or device to the input of the instrument.  
To null out test-lead resistance, connect the test leads to the input and short them together.
3. Press the **NULL** key. The MATH indicator turns on and display reads zero (or near zero).
4. Disconnect the null signal or device and connect the signal or device to be measured. Each reading on the display is the result of the measured reading minus the null value.

#### *Perform the following steps to enter a null value:*

1. Select and configure a measurement function. For example, press the **DCV** key to select the DC volts function.
2. Press the **SHIFT** and **NULL (MATH)** keys.
3. Use the ◀ and ▶ keys to display **NULL** and press **ENTER**.
4. Use the ◀ and ▶ keys to display **NULL VALUE** and press **ENTER**.  
Note that if you select the **RUN** menu option instead, the null feature will enable using the present null value.
5. Use the ◀, ▶, ▲, and ▼ keys to set the null value. Note that the polarity sign can be toggled between plus and minus.
6. Press the **ENTER** key. The MATH indicator turns on.

You can disable the math operation by pressing the NULL key. You can also disable it from the math menu as follows:

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the ◀ and ▶ keys to display **OFF** and press **ENTER**.

### Remote operation

#### NOTE

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to configure and control the null feature:

|  |                            |
|--|----------------------------|
| <code>CALCulate:FUNCTION NULL</code>         | Select the null feature    |
| <code>CALCulate:NULL:OFFSet &lt;n&gt;</code> | Set the null value         |
| <code>&lt;n&gt; = (see Note)</code>          | Set value (1 μ resolution) |

#### NOTE

The null value setting range depends on the selected function. For example, for DCV, the null value can be set from -1200 to 1200.

|  |                                   |
|--|-----------------------------------|
| <code>CALCulate:STATe &lt;b&gt;</code> | Enable or disable math operations |
| <code>&lt;b&gt; = 0 or OFF</code>      | Disable math                      |
| <code>= 1 or ON</code>                 | Enable math                       |

## Limits

---

Limit testing allows you to set high and low limit values. When the reading falls outside these limits, the instrument beeps and displays the "HI" or "LO" message.

The limit values are stored in volatile memory. The values are reset to zero when the instrument is turned off. Limits can be used with all measurements (except continuity and diode measurements).

For information on using the USB port as a status indicator for limit testing, see [Pass/fail output from USB connector](#) (on page C-5).

### Front-panel operation

*Perform the following steps to use the limits feature:*

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the ◀ and ▶ keys to display **LIMITS** and press **ENTER**.
3. Set the high and low limits:
  - a. Use the ◀ and ▶ keys to display **HIGH LIMIT** and press **ENTER**.  
Note that if you select the **RUN** menu option instead, the limits feature will enable using the present limit values.
  - b. Use the ◀, ▶, ▲, and ▼ keys to set the high limit. Note that the polarity sign can be toggled between plus and minus. Press the **ENTER** key.
  - c. Use the ◀ and ▶ keys to display **LOW LIMIT** and press **ENTER**.
  - d. Use the ◀, ▶, ▲, and ▼ keys to set the low limit and press **ENTER**.
4. With **RUN** displayed, press **ENTER**. The MATH indicator turns on and limit testing starts.

You can disable the math operation by pressing a different function key. You can also disable it from the math menu as follows:

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the ◀ and ▶ keys to display **OFF** and press **ENTER**.



**Remote operation****NOTE**

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to configure and control limit testing:

|  |                            |
|--|----------------------------|
| <code>CALCulate:FUNCTION LIMit</code>        | Select the limits feature  |
| <code>CALCulate:LIMit:LOWer &lt;n&gt;</code> | Set the lower limit        |
| <code>CALCulate:LIMit:UPPer &lt;n&gt;</code> | Set the upper limit        |
| <code>&lt;n&gt; = (see Note)</code>          | Set value (1 μ resolution) |

**NOTE**

The limit value setting range depends on the selected function. For example, for DCV, the limit value can be set from -1200 to 1200.

|  |                                   |
|--|-----------------------------------|
| <code>CALCulate:STATe &lt;b&gt;</code> | Enable or disable math operations |
| <code>&lt;b&gt; = 0 or OFF</code>      | Disable math                      |
| <code>= 1 or ON</code>                 | Enable math                       |

**mX+b**

This math function multiplies a scale factor (m) to the measured reading (X), and then adds an offset (b). The result of the calculation (y) is displayed on the instrument:

$$y = mX + b$$

You can enable this math function and set the values of m and b from the front panel or by using remote operation. These values are stored in volatile memory and are lost when the instrument is turned off.

**Front-panel operation**

*Perform the following steps to use the mX+b function:*

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the **◀** and **▶** keys to display **MX+B** and press **ENTER**.
3. Set the m and b values:
  - a. Use the **◀** and **▶** keys to display **SET M** and press **ENTER**.  
 Note that if you select the RUN menu option, mX+b is enabled with the present m and b values.
  - b. Use the **◀**, **▶**, **▲**, and **▼** keys to set the m value. Note that the polarity sign can be toggled between plus and minus.
  - c. Press the **ENTER** key.
  - d. Use the **◀** and **▶** keys to display **SET B** and press **ENTER**.
  - e. Use the **◀**, **▶**, **▲**, and **▼** keys to set the b value and press **ENTER**.
4. With **RUN** displayed, press **ENTER**. The MATH indicator turns on.

You can disable the math operation by pressing a different function key. You can also disable it from the math menu as follows:

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the **◀** and **▶** keys to display **OFF** and press **ENTER**.

**Remote operation**

**NOTE**

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to configure the mX+b math function:

|                                     |                        |                                |
|-------------------------------------|------------------------|--------------------------------|
| <code>CALCulate:FUNCTION</code>     | <code>MXB</code>       | Select the mX+b math function  |
| <code>CALCulate:MXB:MMFactor</code> | <code>&lt;n&gt;</code> | Set the m value                |
| <code>CALCulate:MXB:MBFactor</code> |                        | Set the b value                |
| <code>&lt;n&gt;</code>              | = (see Note)           | Set the value (1 μ resolution) |

**NOTE**

The range of the mX+b value setting depends on the selected function. For example, for DCV, the value can be set from -1200 to 1200.

|                              |                        |                                   |
|------------------------------|------------------------|-----------------------------------|
| <code>CALCulate:STATE</code> | <code>&lt;b&gt;</code> | Enable or disable math operations |
|                              | = 0 or OFF             | Disable math                      |
|                              | = 1 or ON              | Enable math                       |

## dBm

---

The dBm math function is defined as decibels above or below a 1 mW reference. With a user-programmable reference impedance, the instrument reads 0 dBm when the voltage needed to dissipate 1 mW through the reference impedance is applied. The relationship between dBm, a reference impedance, and the voltage is defined by the following equation:

$$10 \log \left[ \frac{\left( \frac{V_{IN}^2}{R_{REF}} \right)}{1mW} \right]$$

Where:  $V_{IN}$  is the input signal voltage

$Z_{REF}$  is the reference impedance

The reference resistance ( $Z_{REF}$ ) can be set from 50  $\Omega$  to 8000  $\Omega$  and can be set from the front panel or by using remote programming. Changing the reference resistance does not affect a stored null (relative) value.

The reference resistance value is stored in volatile memory. The reference resistance defaults to 600  $\Omega$  when power to the instrument is cycled.

This feature is available for DCV and ACV only.

### Front-panel operation

*Perform the following steps to use the dBm function:*

1. Select the **DCV** or **ACV** function.
2. Press the **SHIFT** and **NULL (MATH)** keys.
3. Use the **◀** and **▶** keys to display **dBm** and press **ENTER**.
4. Use the **◀** and **▶** keys to display **REF RES** and press **ENTER**.

Note that if you select the **RUN** menu option instead, the percent function will enable using the current target value.

5. Use the **◀**, **▶**, **▲**, and **▼** keys to enter the reference resistance and press **ENTER**.
6. With **RUN** displayed, press **ENTER**. The MATH indicator turns on.

You can disable the math operation by pressing a different function key. You can also disable it from the math menu as follows:

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the **◀** and **▶** keys to display **OFF** and press **ENTER**.

**Remote operation****NOTE**

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to configure and control the dBm math function:

|  |                                   |
|--|-----------------------------------|
| <code>CALCulate:FUNCTION DBM</code>            | Select the dBm math function      |
| <code>CALCulate:DBM:REFerence &lt;n&gt;</code> | Set reference resistance value    |
| <n> = 50 to 8000                               | Set reference (in ohms)           |
| <code>CALCulate:STATe &lt;b&gt;</code>         | Enable or disable math operations |
| <b> = 0 or OFF                                 | Disable math                      |
| = 1 or ON                                      | Enable math                       |

**dB**

The instrument expresses dB in terms of the dBm function as follows:

$$\text{dB} = (\text{input signal in dBm}) - (\text{relative value in dBm})$$

The dB relative value can be set from -200 to 200 dBm and can be set from the front panel or by using remote programming.

The dB relative value is stored in volatile memory and defaults to 0 dBm when power to the instrument is cycled.

This feature is available for DCV and ACV only.

**NOTE**

Since dB is calculated in terms of the dBm function, the dBm REF RES value has an effect on the dB result.

**Front-panel operation**

*Perform the following steps to use the dBm function:*

1. Select the **DCV** or **ACV** function.
2. Press the **SHIFT** and **NULL (MATH)** keys.
3. Use the ◀ and ▶ keys to display **dB** and press **ENTER**.
4. Use the ◀ and ▶ keys to display **dB REL** and press **ENTER**.  
Note that if you select the **RUN** menu option instead, the dB function will enable using the present relative value.
5. Use the ◀, ▶, ▲, and ▼ keys to enter the reference resistance and press **ENTER**. The MATH indicator turns on.

You can disable the math operation by pressing a different function key. You can also disable it from the math menu as follows:

1. Press the **SHIFT** and **NULL (MATH)** keys.
2. Use the ◀ and ▶ keys to display **OFF** and press **ENTER**.

**Remote operation****NOTE**

Commands that use the <n> parameter can use the **MIN**imum and **MAX**imum name parameters. **MIN** selects the minimum value and **MAX** selects the maximum value.

Use the following commands to configure and control the dB math function:

|   |                                   |
|---|-----------------------------------|
| <code>CALCulate:FUNCTION DB</code>            | Select the dB math function       |
| <code>CALCulate:DB:REFerence &lt;n&gt;</code> | Set the relative value            |
| <n> = 0 to 200.00                             | Set value (in dBm)                |
| <code>CALCulate:STATe &lt;b&gt;</code>        | Enable or disable math operations |
| <b> = 0 or OFF                                | Disable math                      |
| = 1 or ON                                     | Enable math                       |

# Theory of operation

**In this section:**

AC voltage measurements and crest factor ..... 4-1  
 DMM resistance measurement methods..... 4-3  
 Reference junctions ..... 4-4  
 Accuracy calculations..... 4-5

## AC voltage measurements and crest factor

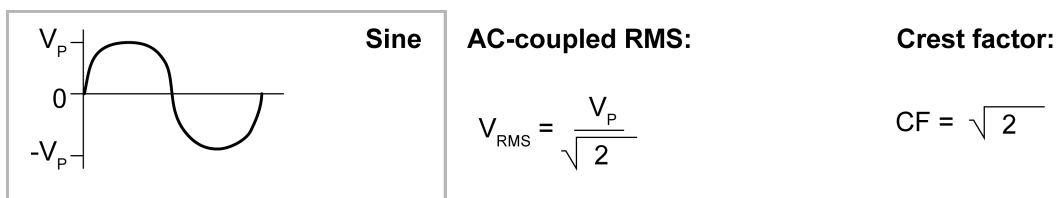
The root-mean-square (RMS) value of any periodic voltage or current is equal to the value of the DC voltage or current which delivers the same power to a resistance as the periodic waveform does. Crest factor is the ratio of the peak value to the RMS value of a particular waveform. This is represented by the following equations:

**Equation 1: AC voltage measurements and crest factor (1)**

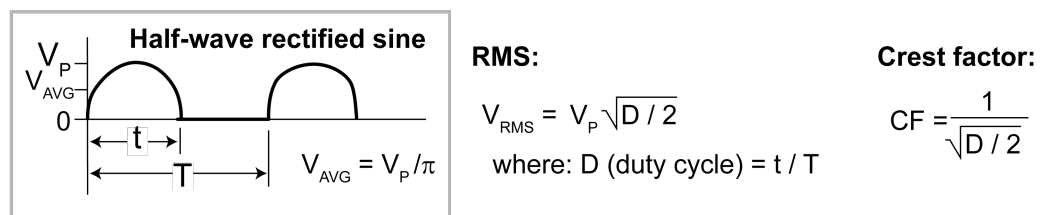
$$CF = \frac{V_P}{V_{RMS}} \quad \text{or} \quad CF = \frac{I_P}{I_{RMS}}$$

The crest factor of various waveforms is different, because the peak-to-RMS ratios are variable. For example, the crest factor for a pulse waveform is related to the duty cycle; as the duty cycle decreases, the crest factor increases. The RMS calculations and crest factor (CF) for various waveforms are shown in the following figures.

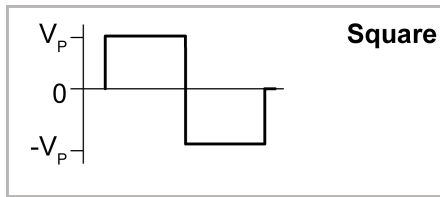
**Figure 30: RMS calculations and crest factor — sine**



**Figure 31: RMS calculations and crest factor — half-wave rectified sine**



**Figure 32: RMS calculations and crest factor — square**



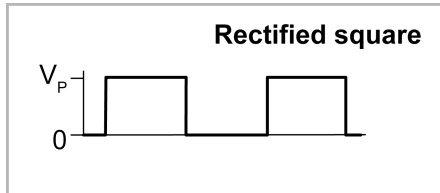
**AC-coupled RMS:**

$$V_{RMS} = V_P$$

**Crest factor:**

$$CF = 1$$

**Figure 33: RMS calculations and crest factor — rectified square**



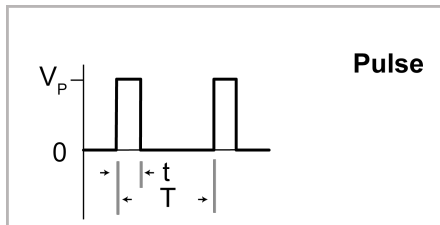
**AC-coupled RMS:**

$$V_{RMS} = \frac{V_P}{2}$$

**Crest factor:**

$$CF = 2$$

**Figure 34: RMS calculations and crest factor — pulse**



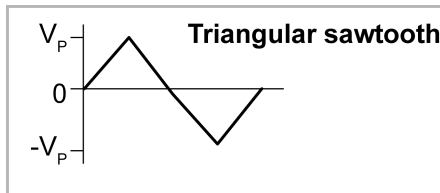
**AC-coupled RMS:**

$$\frac{V}{CF} \times \sqrt{1 - \frac{1}{CF^2}}$$

**Crest factor:**

$$\sqrt{\frac{T}{t}}$$

**Figure 35: RMS calculations and crest factor - triangular sawtooth**



**AC-coupled RMS:**

$$V_{RMS} = 0.577 V_P$$

**Crest factor:**

$$CF = 1.732$$

The Model 2110 is an AC-coupled RMS instrument. For an AC waveform with DC content, the DC component is removed before the RMS is calculated.

Crest factor is a relative measurement of the harmonic content of a particular waveform and reflects the accuracy of the measurement. For a rectangular pulse train, the higher the crest factor, the higher the harmonic content of the waveform. This is not always true when making spectral comparisons between different types of waveforms. A sine wave, for example, has a crest factor of 1.414, and a square wave has a crest factor of 1. The sine wave has a single spectral component and the square wave has components at all odd harmonics of the fundamental.

Additional error uncertainties are also specified for non-sinusoidal waveforms of specific crest factors and frequencies.

## DMM resistance measurement methods

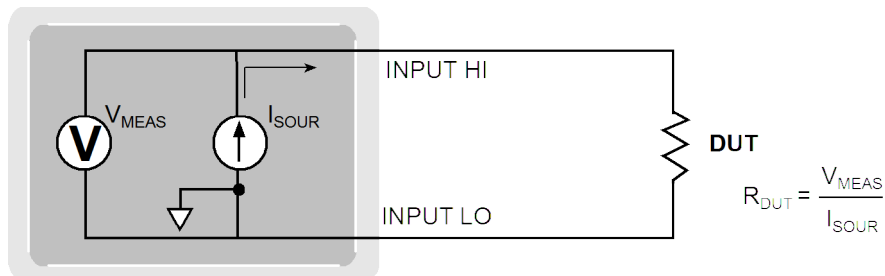
The Model 2110 uses the constant-current method to measure resistance. The constant-current method sources a constant current ( $I_{SOUR}$ ) to the device under test (DUT) and measures the voltage ( $V_{MEAS}$ ). Resistance ( $R_{DUT}$ ) is then calculated and displayed using the known current and measured voltage ( $R_{DUT} = V_{MEAS}/I_{SOUR}$ ).

The constant-current method is shown below. The test current sourced to the DUT depends on the selected measurement range. For example, for the 100 Ω range, the test current is 1 mA. Because the voltmeter of the Model 2110 has very high input impedance, virtually all the test current (1 mA) flows through the DUT. For  $DUT \leq 1\text{ k}\Omega$ , 4-wire ohms measurements should be used as shown. Because the voltage is measured at the DUT, voltage drop in the test leads is eliminated (this voltage could be significant when measuring low-ohm DUT).

| Resistance measurement range | Test current |
|------------------------------|--------------|
| 100 Ω                        | 1 mA         |
| 1 KΩ                         | 1 mA         |
| 10 KΩ                        | 100 μA       |
| 100 KΩ                       | 10 μA        |
| 1 MΩ                         | 1 μA         |
| 10 MΩ                        | 0.1 μA       |
| 100 MΩ                       | 0.1 μA       |

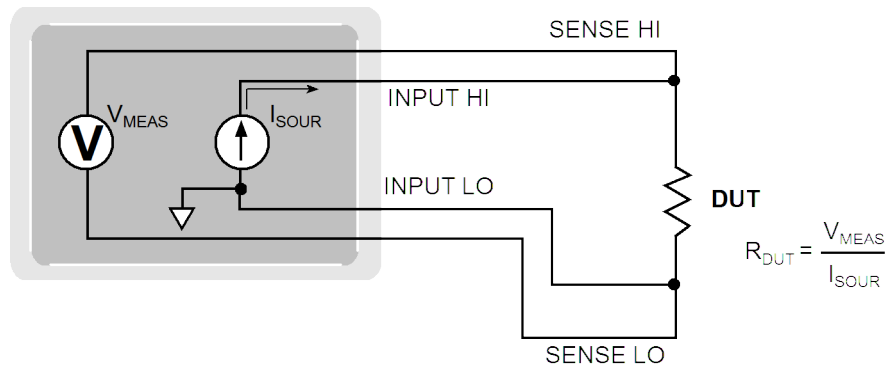
The 2-wire constant-current method is shown below.

**Figure 36: Two-wire constant-current source method**



The 4-wire constant-current method is shown below.



**Figure 37: Four-wire constant-current source method**

## Reference junctions

A reference junction is the cold junction in a thermocouple circuit that is held at a stable, known temperature. The cold junction is where dissimilar wire connections must be made. As long as the temperature of the cold junction is known, the Model 2110 can factor in the reference temperature to calculate the actual temperature reading at the thermocouple.

The standard reference temperature is the ice point (0° C). The ice point can be precisely controlled, and the National Institute of Standards and Technology (NIST) uses it as the fundamental reference for its voltage-to-temperature conversion tables. However, other known temperatures can be used.

There are two ways for the Model 2110 to acquire the cold junction temperature:

- The instrument can measure the cold junction using internal transducers.
- The user can enter the known temperature value.

These two references are known as:

- Real (internal) reference junction
- Simulated reference junction

These reference junctions are explained in the following paragraphs.

### Real (internal) reference junction

Real implies that temperature transducers are used to measure the cold junction. This value is influenced and changed by different climate conditions and environments. The Model 2110 measures the temperature of the cold junction, measures the input voltage, and then calculates the temperature reading at the thermocouple.

### Simulated reference junction

An example of a simulated reference junction is an ice bath. The copper wire to thermocouple wire connections are immersed (but electrically isolated) in the ice bath, known to be 0 °C. The temperature measured becomes an offset to the simulated reference temperature. The simulated reference temperature for the Model 2110 can be set from -100 °C to 100 °C. The Model 2110 measures the input voltage and factors in the simulated reference temperature to calculate the temperature reading at the thermocouple.

## Accuracy calculations

The following information discusses how to calculate accuracy for both DC and AC characteristics.

### Calculating DC and AC characteristics accuracy

DC characteristics accuracy is calculated as follows:

$$\text{Accuracy} = \quad \% \text{ of reading} + \% \text{ of range}$$

As an example of how to calculate the actual reading limits, assume that you are measuring 5V on the 10V range. You can compute the reading limit range from one-year DCV accuracy specifications as follows:

$$\begin{aligned} \text{Accuracy} &= 0.012\% \text{ of reading} + 0.004\% \text{ of range} \\ &0.012\% * 5 \text{ V} + 0.004\% * 10 \text{ V} \\ &0.0006 \text{ V} + 0.0004 \text{ V} \\ &0.0010 \text{ V} \end{aligned}$$

Thus, the actual reading range is 5 V ± 1 mV or from 4.999 V to 5.001 V.

DC current, AC voltage, AC current, and resistance calculations are performed in exactly the same manner using the pertinent specifications, ranges, and input signal values.



---

## Remote commands

### In this section:

---

|  |      |
|--|------|
| Programming syntax .....                       | 5-1  |
| Common commands .....                          | 5-4  |
| Introduction to SCPI language .....            | 5-9  |
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## Programming syntax

The information in this section describes syntax for both common commands and Standard Commands for Programmable Instruments (SCPI). For information that is not described here, see the IEEE-488.2 and SCPI standards.

### Command format used in this manual

The format used to show commands in this manual is described in the following topics.

#### Command syntax

---

The command syntax shows most commands (and some parameters) as a mixture of upper and lowercase letters. The uppercase letters indicate the abbreviated spelling for the command. For shorter program lines, send the abbreviated form. For better program readability, send the long form.

For example, in the following syntax statement:

```
VOLTage[:DC]:RANGe {<range>|MINimum|MAXimum}
```

VOLT and VOLTAGE are both acceptable forms. You can use upper or lowercase letters. Therefore, VOLTAGE, volt, and Volt are all acceptable. Other forms, such as VOL and VOLTAG, will generate an error.

### Long-form and short-form versions

A SCPI command word can be sent in its long-form or short-form version. For example, this manual lists commands in the [SCPI command subsystem reference](#) (on page 5-19) topic using the long-form version. However, the short-form version is indicated by upper case characters.

#### Examples:

```
:SYSTem:REMOte    long-form
:SYST:REM         short-form
:SYSTem:REM      long-form and short-form combination
```

Each command word must be in long-form or short-form, and not something in between. For example, :SYSTe:REMO will generate an error. The command will not be executed.

### Short-form rules

Use the following rules to determine the short-form version of any SCPI command:

- If the length of the command word is four letters or less, no short form version exists. For example, :AUTO = AUTO
- The following rules apply to command words that exceed four letters:
  - If the fourth letter of the command word is a vowel, delete it and all the letters after it. For example :immediate = :imm
  - Rule exception: The short form version of the following command uses only the first two letters of the word :TCouple = :tc
  - If the fourth letter of the command word is a consonant, retain it but drop all the letters after it. For example, :format = :form
  - If the command contains a question mark (; query) or a non-optional number included in the command word, you must include it in the short-form version. Example: :delay? = :del?
- Command words or characters that are enclosed in brackets ([ ]) are optional and need not be included in the program message

### Angle brackets

Angle brackets (< >) are used to denote a parameter type. Do not include the brackets in the program message. For example:

```
:HOLD:STATe <b>
```

The <b> indicates that a Boolean-type parameter is required. Thus, to enable the Hold feature, you must send the command with the ON or 1 parameter as follows:

```
:HOLD:STATe ON or 1
```

### Brackets [ ]

Some command words are enclosed in brackets ([ ]). These brackets are used to denote an optional command word that does not need to be included in the program message. For example:

```
:INITiate[:IMMEDIATE]
```

These brackets indicate that :IMMEDIATE is implied (optional) and does not have to be used. Thus, the above command can be sent in one of two ways:

```
:INITiate or :INITiate:IMMEDIATE
```

Notice that the optional command is used without the brackets. When using optional command words in your program, do not include the brackets.

---

## Braces

---

Braces ( { } ) enclose the parameter choices for a given command string. The braces are not sent with the command string.

---

## Vertical bar

---

A vertical bar ( | ) separates multiple parameter choices for a given command string.

---

## Using the MIN and MAX parameters

---

You can substitute **MIN**imum or **MAX**imum in place of a parameter for many commands. For example, consider the following command:

```
VOLTage[:DC]:RANGe MINimum
```

Instead of specifying a specific voltage range, you can substitute **MIN** to set the range to its minimum value or **MAX** to set the range to its maximum value.

---

## IEEE-488.2 common commands

---

The IEEE-488.2 standard defines a set of common commands that perform functions like reset, self-test, and status operations. Common commands always begin with an asterisk ( \* ), are four to five characters in length, and may include one or more parameters. The command keyword is separated from the first parameter by a blank space.

Use a semicolon ( ; ) to separate multiple commands, as shown below:

```
*RST; *CLS; *ESE 32; *OPC?
```

Refer to [Common commands](#) (on page 5-4) for more information about common commands.

---

## Querying parameter settings

---

You can query the current value of most parameters by adding a question mark ( ? ) to the command. The following command sets the sample count to 10 readings:

```
SAMP:COUN 10
```

Then you can query the sample count by executing:

```
SAMP:COUN?
```

You can also query the minimum or maximum count allowed using the following commands:

```
SAMP:COUN? MIN  
SAMP:COUN? MAX
```

## NOTE

If you send two query commands without reading the response from the first, and then attempt to read the second response, you may receive some data from the first response followed by the complete second response. To avoid this, do not send a query command without reading the response. When you cannot avoid this situation, send a device clear before sending the second query command.

## SCPI command terminators

A command string sent to the instrument must terminate with a <new line> character. The IEEE-488.2 EOI (end-or-identify) message is interpreted as a <new line> character and can be used to terminate a command string in place of a <new line> character. A <carriage return> followed by a <new line> is also accepted. Command string termination will always reset the current SCPI command path to the root level.

## Common commands

Common commands (summarized in [Common command summary](#) (on page 5-4)) are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard. Most of these commands are described in detail in this section.

### Common command summary

The following table lists the IEEE-488.2 common commands used by the instrument.

| Mnemonic   | Name                           | Description  |
|------------|--------------------------------|--|
| *CLS       | Clear status                   | Clear the Status Byte Summary Register and all event registers.  |
| *ESE <Nrf> | Event enable command           | Enable bits in the Standard Event Enable Register. The selected bits are then reported to the Status Byte.   |
| *ESE?      | Event enable query             | Query the Standard Event Enable Register. The instrument returns a decimal value that corresponds to the binary-weighted sum of all bits set in the register.  |
| *ESR?      | Event status register query    | Query the Standard Event Status Register. The instrument returns a decimal value that corresponds to the binary-weighted sum of all bits set in the register.  |
| *IDN?      | Identification query           | Returns the manufacturer, model number, serial number, and firmware revision levels of the instrument.   |
| *OPC       | Operation complete command     | This command sets the OPC bit.   |
| *OPC?      | Operation complete query       | Returns "1" to the output buffer after the command is executed.  |
| *PSC <b>   | Power-on status clear          | Clear the Status Byte and Standard Event Register enable masks when power is turned on (*PSC 1). When *PSC 0 is in effect, the Status Byte and Standard Event Register enable masks are not cleared when power is turned on. [Stored in nonvolatile memory]. |
| *PSC?      | Power-on status clear query    | Query the power-on status clear setting. Returns "0" (*PSC 0) or "1" (*PSC 1).   |
| *RST       | Reset command                  | Reset the instrument to the power-on configuration.  |
| *SRE <NRf> | Service request enable command | Enable bits in the Status Byte Enable Register.  |
| *SRE?      | Service request enable query   | Query the Status Byte Enable Register.   |
| *STB?      | Status byte query              | Query the Status Byte Summary Register.  |
| *TRG       | Trigger command                | Sends a bus trigger to the instrument.   |

## Common command reference

This topic provides a detailed reference for all common commands.

---

### \*CLS — clear status

This command clears the Status Byte Summary Register and all event registers.

---

### \*ESE <NRf> — event enable command

This command enables bits in the Standard Event Enable Register. The selected bits are then reported to the Status Byte.

#### Usage

```
*ESE 1
*SRE 32
```

#### Details

Use the \*ESE command and the appropriate decimal value for each bit to set the enable register mask. Refer to [Standard Event Register](#) (on page B-8) for information about values. For example, enable “operation complete” by using the \*ESE 1 command.

---

### \*ESE? — event enable query

This query command queries the Standard Event Enable Register.

#### Usage

```
*ESE?
```

#### Details

The instrument returns a decimal value that corresponds to the binary-weighted sum of all bits set in the register. Refer to [Standard Event Register](#) (on page B-8) for information about values.

---

### \*ESR? — event status register query

This query command queries the value of the Standard Event Status Register. This query command clears the Standard Event Register.

#### Usage

```
*ESR?
```

#### Details

The instrument returns a decimal value that corresponds to the binary-weighted sum of all bits set in the register. Refer to [Standard Event Register](#) (on page B-8) for information about values.



---



---

## \*IDN? — identification query

This query command reads the instrument's identification code.

### Usage

---

\*IDN?

### Details

---

The identification code includes the manufacturer, model number, serial number, and firmware revision level and is sent in a format consisting of four fields delimited by commas as follows:

```

manufacturer
model
serial number
firmware revision level
Format: x.xx-yy-zz

```

#### Where:

x.xx - indicates the firmware revision number for the measurement processor  
yy - indicates the I/O processor  
zz - indicates the front-panel processor

For example,

```
KEITHLEY INSTRUMENTS INC.,MODEL 2110,1311126,01.00-01-01
```

You can use the `SYSTEM:IDNStr` command to modify the manufacturer and model information for compatibility purposes.

---



---

## \*OPC — operation complete command

Set the Operation Complete bit (bit 0) in the Standard Event Register after all pending commands have been executed.

---



---

## \*OPC? — operation complete query

This query command places a "1" in the output queue.

### Usage

---

\*OPC?

### Details

---

When \*OPC is sent, the OPC bit in the Standard Event Register will set after all pending command operations are complete. When \*OPC? is sent, an ASCII "1" is placed in the Output Queue after all pending command operations are complete.

Typically, either one of these commands is sent after the INITiate command. The INITiate command is used to take the instrument out of idle in order to perform measurements.

After all programmed operations are completed, the instrument returns to the idle state, at which time all pending commands (including \*OPC and/or \*OPC?) are executed. After the last pending command is executed, the OPC bit and/or an ASCII "1" is placed in the Output Queue.

---

---

## **\*PSC <b> — power-on status clear**

This command enables or disables the power-on status clear function.

### **Usage**

---

\*PSC 0  
\*PSC 1

### **Details**

---

When \*PSC 1 is in effect, the Status Byte and Standard Event Register enable masks are cleared when power is turned on. \*PSC 1 is the default.

When \*PSC 0 is in effect, the Status Byte and Standard Event Register enable masks are not cleared when power is turned on.

The command is stored in nonvolatile memory.

---

---

## **\*PSC? — power-on status clear query**

This query command returns the power-on status clear setting.

### **Usage**

---

\*PSC?

### **Details**

---

Query the power-on status clear setting. Returns "0" (\*PSC 0) or "1" (\*PSC 1).

---

---

## **\*RST — reset command**

This command resets the instrument to the power-on configuration.

### **Usage**

---

\*RST

### **Details**

---

Reset the instrument to the power-on configuration. This command does not clear the error queue. Refer to [Power-on settings](#) (on page 1-6) for information about power-on configuration.

---

---

## **\*SRE <NRf> — service request enable command**

This command sets or clears the individual bits of the Service Request Enable Register.

---

### **Usage**

\*SRE 1  
\*SRE 32

---

### **Details**

The individual bits of the Service Request Enable Register can be set or cleared by using the \*SRE common command. To read the Service Request Enable Register, use the \*SRE? query command. The Service Request Enable Register clears when power is cycled or a parameter value of 0 is sent with the \*SRE command (for example, \*SRE 0).

Set the instrument for an SRQ interrupt by using \*SRE 32.

---

---

## **\*SRE? — service request enable command query**

This command queries the Status Byte Enable Register.

---

### **Usage**

\*SRE?

---

### **Details**

The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.

---

---

## **\*STB? — status byte query**

The \*STB? command is similar to a serial poll, but it is processed like any other instrument command.

---

### **Usage**

\*STB?

---

### **Details**

The \*STB? command returns the same result as a serial poll, but the “request service” bit (bit 6) is not cleared if a serial poll has occurred.

---

---

## **\*TRG — trigger command**

Use the \*TRG command to issue a trigger to the instrument. It has the same effect as a group execute trigger (GET).

---

### **Usage**

\*TRG

---

### **Details**

Use the \*TRG command as an event to control operation. The instrument reacts to this trigger if BUS is the programmed arm control source. The control source is programmed from the TRIGger subsystem.

## Introduction to SCPI language

### Topic overview

This section contains reference information on programming the Model 2110 with the SCPI commands. It is organized as follows:

### SCPI parameter types

The SCPI language defines several different data formats to be used in program messages and response messages:

#### Numeric parameters <n>

Commands that require numeric parameters will accept all commonly used decimal representations of numbers, including optional signs, decimal points, and scientific notation.

Special values for numeric parameters like **MINimum**, **MAXimum**, and **DEFault** are also accepted. You can also include unit prefixes and units with numeric parameters (for example, 10MΩ, 1kV, or 50μA). If only specific numeric values are accepted, the instrument will automatically round the input numeric parameters. The following command uses a numeric parameter:

```
VOLTage[:DC]:RANGe <range> |MINimum|MAXimum
```

#### NOTE

Unit prefixes must be used in combination with a unit. For example, the following command is valid:

```
CONF:RES 10KOhm
```

However, this command is not valid:

```
CONF:RES 10K
```

#### Discrete parameters <name>

Discrete parameters are used to program settings that have a limited number of values (for example, BUS, IMMEDIATE, EXTERNAL). They have a short form and a long form just like command keywords. You can mix upper- and lowercase letters. Query responses will always return the short form in all uppercase letters. The following command uses discrete parameters:

```
TRIGger:SOURce BUS|IMMEDIATE|EXTERNAL
```

#### Numeric representation format parameters <NRf>

Numeric representation format parameters are numbers that can be expressed as an integer (e.g., 8), a real number (e.g., 23.6), or an exponent (2.3E6). The following command uses a numeric parameter:

```
CALCulate:PERCent:TARGET 100e6
```

#### Boolean parameters <b>

Boolean parameters are used to enable or disable an instrument operation. 0 or OFF disables the operation, and 1 or ON enables the operation. For example, use the ON parameter to enable auto ranging. When you query a Boolean setting, the instrument will always return 0 or 1.

```
:CURRent:AC:RANGe:AUTO ON
```

## String parameters <string>

String parameters can contain virtually any set of ASCII characters. A string must begin and end with matching quotes; either with a single quote or with a double quote. You can include the quote delimiter as part of the string by typing it twice without any characters in between. The following command uses a string parameter:

```
DISPlay:TEXT <a quoted string>
```

## Commands and command parameters

Common commands and SCPI commands may or may not use a parameter. The following are some examples:

|                      |                          |
|----------------------|--------------------------|
| *SAV <NRf>           | Parameter (NRf) required |
| *RST                 | No parameter used        |
| :CALCulate:STATe <b> | Parameter <b> required   |
| :SYSTem:PRESet       | No parameter used.       |

Put at least one space between the command word and the parameter. Refer to [SCPI parameter types](#) (on page 5-9) for information about SCPI parameters.

## Query commands

This type of command requests (queries) the currently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form, for example:

|              |                           |
|--------------|---------------------------|
| :SAMP:COUNT? | Queries the sample count. |
|--------------|---------------------------|

## Program messages

A program message is made up of one or more command words sent by the computer to the instrument. The command words can be common commands, as described in the common command reference, or they can be SCPI commands, as described in the SCPI command subsystem reference. The SCPI commands for the instrument are organized by functionality. If you understand the organization, it will help you to write efficient program messages. As an example, the structure of the STATus subsystem is listed below.

|               |                       |
|---------------|-----------------------|
| :STATus       | Path (Root)           |
| :QUEStionable | Path                  |
| :ENABle <n>   | Command and parameter |
| :ENABle?      | Query command         |
| :EVENT?       | Query command         |
| :PRESet       | Command               |

## Single command messages

---

The above command structure has three levels. The first level is made up of the root command (:STATus) and serves as a path. The second level is made up of another path (:QUESTionable) and a command (:PRESet). The third level of the structure is occupied by the ENABLE and EVENT commands. The commands in this structure can be executed by sending four separate program messages as follows:

```
:stat:ques:enab <NRf>
:stat:ques:enab?
:stat:ques:even?
:stat:pres
```

In each of the above program messages, the path pointer starts at the root command (:stat) and moves down the command levels until the command is executed.

## Multiple command messages

---

You can send multiple command messages in the same program message as long as they are separated by semicolons (;). The following example shows two commands in one program message:

```
:stat:pres; :stat:ques:enab <NRf>
```

When the above message is sent, the first command word is recognized as the root command (:stat). When the next colon is detected, the path pointer moves down to the next command level and executes the command. When the path pointer sees the colon after the semicolon (;), it resets back to the root level and starts over.

Commands that are on the same command level can be executed without having to retype the entire command path. For example:

```
:stat:ques:enab <n>; enab?
```

After the first command (:enab) is executed, the path pointer is at the third command level in the structure. Since :enab? is also on the third level, it can be typed in without repeating the entire path name. Notice that the leading colon for :enab? is not included in the program message. If a colon were included, the path pointer would reset to the root level and expect a root command. Since :enab? is not a root command, an error would occur.

## Command path rules

---

- Each new program message must begin with the root command, unless it is optional (for example, [:SENSe]). If the root is optional, simply treat a command word on the next level as the root.
- The colon (:) at the beginning of a program message is optional and need not be used. For example, the following two lines of code are equivalent:

```
:stat:pres
stat:pres
```

- When the path pointer detects a colon (:) it moves down to the next command level. An exception is when the path pointer detects a semicolon (;), which is used to separate commands within the program message (see next rule).
- When the path pointer detects a colon (:) that immediately follows a semicolon (;), it resets back to the root level.
- The path pointer can only move down. It cannot be moved up a level. Executing a command at a higher level requires that you start over at the root command.

---

## Using common commands and SCPI commands in the same message

---

Both common commands and SCPI commands can be used in the same message as long as they are separated by semicolons (;). A common command can be executed at any command level and will not affect the path pointer. For example:

```
:stat:ques:enab <n>; *ESE <n>
```

---

## Program message terminator (PMT)

---

Each program message must be terminated with a LF (line feed), EOI (end or identify), or an LF+EOI. The bus will hang if your computer does not provide this termination. The following example shows how a multiple command program message must be terminated:

```
*rst;*cls <PMT>
```

---

## Command execution rules

---

Command execution rules are as follows:

- Commands execute in the order that they are presented in the program message.
- An invalid command generates an error and is not executed.
- Valid commands that precede an invalid command in a multiple command program message are executed.
- Valid commands that follow an invalid command in a multiple command program message are ignored.

## Output Data

---

### Type

---

The instrument provides the following types of output data:

- Non-reading queries
- Single reading (IEEE-488.2)
- Multiple readings (IEEE-488.2)
- Single reading (USB)
- Multiple readings (USB)

### Format

Output data will be in one of the following formats.

- < 80 ASCII character string
- SD.DDDDDDDDESDD<nl>
- SD.DDDDDDDDESDD,.....,<nl>
- SD.DDDDDDDDESDD<cr><nl>
- SD.DDDDDDDDESDD,.....,<cr><nl>
- S Negative sign or positive sign
- D Numeric digits
- E Exponent
- <nl> newline character
- <cr> carriage return character

## SCPI signal-oriented measurement commands

The signal-oriented measurement commands configure the instrument for measurement and acquire measurement readings. You can use these high-level instructions to control the measurement process. These commands are summarized in the following table.

### Signal oriented measurement command summary

| Command   | Description   |
|---|---|
| :CONFigure:<function> <range> ,<br><resolution> | Configures instrument for measurements on the specified function. |
| :CONFigure?                                     | Returns active function.  |
| :FETCh?   | Requests latest readings.   |
| :INITiate                                       | Changes the state of the triggering system to wait-for-trigger.   |
| :READ?  | Performs a measurement.   |
| :MEASure:<function> <range> , <resolution>      | Performs a :CONFigure: <function>, and a :READ?.                  |



## **:CONFigure:<function> [<range>|MIN|MAX|DEF,<resolution>|MIN|MAX|DEF]**

This command configures the instrument to a specific setup for a specified measurement function. This command does not initiate the measurement. The :READ? command can be used to trigger a measurement. You can also use the INIT::FETC? command.

### Parameters

#### NOTE

All <range> and <resolution> parameters also include MIN, MAX, and DEF. N/A indicates that the <range> and/or <resolution> parameters are not applicable for the <function>.

| <b>&lt;function&gt;</b> | <b>&lt;range&gt;</b> | <b>&lt;resolution&gt; (see note 1)</b> | <b>Description (see note 2)</b> |
|-------------------------|----------------------|--|---------------------------------|
| CURRent[:DC]            | -10 to 10            | 3.00e-07 to 3.00e-04                   | Amperes                         |
| CURRent:AC              | 0 to 10              | 1.00e-06 to 1.00e-04                   | Amperes                         |
| VOLTage[:DC]            | -1000 to 1000        | 3.00e-07 to 3.00e-04                   | Voltage                         |
| VOLTage:AC              | 0 to 750             | 1.00e-06 to 1.00e-04                   | Voltage                         |
| CAPacitance             | 0 to 10e-3           | N/A                                    | Farads                          |
| VOLTage[:DC]:RATio      | -1000 to 1000        | 3.00e-07 to 3.00e-04                   | Voltage                         |
| RESistance              | 0 to 100e6           | 3.00e-07 to 3.00e-04                   | Ohms                            |
| FRESistance             | 0 to 100e6           | 3.00e-07 to 3.00e-04                   | Ohms                            |
| FREQuency[:VOLTage]     | 0 to 750             | N/A                                    | Voltage                         |
| FREQuency:CURRent       | 0 to 10              | N/A                                    | Amperes                         |
| PERiod[:VOLTage]        | 0 to 750             | N/A                                    | Voltage                         |
| PERiod:CURRent          | 0 to 10              | N/A                                    | Amperes                         |
| CONTinuity              | N/A                  | N/A                                    | N/A                             |
| DIODE                   | N/A                  | N/A                                    | N/A                             |
| TCOuple                 | N/A                  | N/A                                    | N/A                             |
| TEMPerature             | N/A                  | N/A                                    | N/A                             |

#### NOTE

1. Do not use the number of digits to specify a resolution; instead, use the same units as the measurement function. For example, specify the resolution in volts and the frequency in hertz. You must multiply the resolutions in the table by the needed range before using them as resolution arguments. Refer to [Bandwidth and resolution for AC measurements](#) (on page 3-44) for more information about AC measurements. Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) for information about DC measurements.

2. Information listed in the description column is for reference only. This column lists the measurement unit for the <function>. Do not include units in commands.

---

**Query**

---

| Command    | Description                  |
|------------|------------------------------|
| CONFigure? | Query the selected function. |

---

**Details**

---

The CONFigure command offers a little more flexibility than the MEASure? command. The multimeter sets the parameters for the requested function, range and resolution. You have an option to change the configuration. The CONFigure command does not initiate the measurement. To initiate the measurement, use INITiate or READ? command.

When this command is sent, the instrument will be configured as follows:

- The function specified by this command is selected.
- The range and resolution are selected as specified.
- All other controls related to the selected function are defaulted to the \*RST values.

This command is automatically asserted when the :MEASure? command is sent.

---

**Example**

---

|                         |   |
|-------------------------|---|
| CONF:VOLT[:DC] 10,0.001 | Configure 1 mV resolution digits on the 10 VDC range. |
| CONF:FREQ 1KHz,0.1Hz    | Configure 1000 Hz input, 0.1 Hz resolution.           |

---

**Also see**

---

[:INITiate](#) (on page 5-16)

[:READ\[1|2\]?](#) (on page 5-17)

[:FETCh\[1|2\]?](#) (on page 5-16)

---



---

## :FETCh[1|2]?

The FETCh? command transfers readings to the instrument's output buffer. The INITiate command is used to store readings in the instrument's internal memory.

### Variations

|         |   |
|---------|---|
| FETCh1? | Stored readings from the primary measurement function are transferred to the output buffer.   |
| FETCh2? | Stored readings from the secondary measurement function are transferred to the output buffer. |

### Details

The FETCh? and INITiate commands provide the lowest level of control for measurement triggering and reading retrieval, but offer the most flexibility.

After you have configured the instrument, use INITiate command to change the state of the triggering system from the "idle" state to the "wait-for-trigger" state. The instrument will start the measurements when the specified trigger condition requirements are met after it receives the INITiate command. The results are sent to the internal memory and stored until you are ready to read them.

The FETCh? command sends the data in the instrument's internal memory to the output buffer where you can read it into your bus controller.

The FETCh? command does not affect the instrument setup.

The FETCh? command does not trigger measure operations; it simply requests the last available readings. Note that this command can repeatedly return the same readings. Until there are new readings, this command continues to return the old readings.

### Example

|        |  |
|--------|--|
| INIT   | Change state of triggering system to wait for trigger state.             |
| FETCh? | Sends the data in the instrument's internal memory to the output buffer. |

### Also see

[:INITiate](#) (on page 5-16)

[:DATA:POINTS?](#) (on page 5-65)

---



---

## :INITiate

Change the state of the triggering system from the "idle" state to "wait-for-trigger" state. The meter will start to make measurements when a required triggering condition is met after the INITiate command is received. Readings are stored in memory until you are ready to read them. Use FETCh? command to retrieve your measurements results.

---

---

## :READ[1|2]?

The READ? command changes the state of the trigger system from the idle state to the wait-for-trigger state. When the specified trigger condition requirements are met after the instrument receives the READ? command, the measurement is initiated. The result is sent to the output buffer immediately. You must enter the reading data into your bus controller or the instrument will stop making measurements when the output buffer fills. Readings are not stored in the instrument's internal memory when using the READ? command.

To take many samples quickly, use INIT;:FETC?.

### Variations

---

|        |  |
|--------|--|
| READ1? | Initiates the trigger model and transfers the readings from the primary measurement function to the output buffer.   |
| READ2? | Initiates the trigger model and transfers the readings from the secondary measurement function to the output buffer. |

### Example

---

```
:READ2?
```

### Also see

---

[:INITiate](#) (on page 5-16)

[:FETCh\[1|2\]?](#) (on page 5-16)

## :MEASure[:<function>]? <range>|MIN|MAX|DEF,<resolution>|MIN|MAX|DEF

This command configures the specified function, range, and resolution, and then returns a single measurement.

### Parameters

#### NOTE

All <range> and <resolution> parameters also include MIN, MAX, and DEF. N/A indicates that the <range> and/or <resolution> parameters are not applicable for the <function>.

| <function>          | <range>       | <resolution> (see note 1) | Description (see note 2) |
|---------------------|---------------|---------------------------|--------------------------|
| CURRent[:DC]        | -10 to 10     | 3.00e-07 to 3.00e-04      | Amperes                  |
| CURRent:AC          | 0 to 10       | 1.00e-06 to 1.00e-04      | Amperes                  |
| VOLTage[:DC]        | -1000 to 1000 | 3.00e-07 to 3.00e-04      | Voltage                  |
| VOLTage:AC          | 0 to 750      | 1.00e-06 to 1.00e-04      | Voltage                  |
| CAPacitance         | 0 to 10e-3    | N/A                       | Farads                   |
| VOLTage[:DC]:RATio  | -1000 to 1000 | 3.00e-07 to 3.00e-04      | Voltage                  |
| RESistance          | 0 to 100e6    | 3.00e-07 to 3.00e-04      | Ohms                     |
| FRESistance         | 0 to 100e6    | 3.00e-07 to 3.00e-04      | Ohms                     |
| FREQuency[:VOLTage] | 0 to 750      | N/A                       | Voltage                  |
| FREQuency:CURRent   | 0 to 10       | N/A                       | Amperes                  |
| PERiod[:VOLTage]    | 0 to 750      | N/A                       | Voltage                  |
| PERiod:CURRent      | 0 to 10       | N/A                       | Amperes                  |
| CONTinuity          | N/A           | N/A                       | N/A                      |
| DIODE               | N/A           | N/A                       | N/A                      |
| TCCouple            | N/A           | N/A                       | N/A                      |
| TEMPerature         | N/A           | N/A                       | N/A                      |

#### NOTE

1. Do not use the number of digits to specify a resolution; instead, use the same units as the measurement function. For example, specify the resolution in volts and the frequency in hertz. You must multiply the resolutions in the table by the needed range before using them as resolution arguments. Refer to [Bandwidth and resolution for AC measurements](#) (on page 3-44) for more information about AC measurements. Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) for information about DC measurements.

2. Information listed in the description column is for reference only. This column lists the measurement unit for the <function>. Do not include units in commands.

### Details

This command combines all of the other signal oriented measurement commands to perform a single measurement and acquire the reading.

Although it does not offer much flexibility, using the MEASure? command is the simplest way to program the instrument for measurements. You specify the measurement function, range and resolution, the instrument automatically sets the other parameters for you, make the measurement and send the result to the output buffer.

**Example**

|                             |   |
|-----------------------------|---|
| MEASure:VOLT[:DC]? 10,0.001 | Measure 4 ½ digits on the 10 Vdc range. |
| MEAS:Curr:AC? 1,1E-5        | Measure 5 ½ digits on the 1 A range.    |

**Also see**

[:INITiate](#) (on page 5-16)  
[:READ\[1|2\]?](#) (on page 5-17)  
[:FETCh\[1|2\]?](#) (on page 5-16)  
[:CONFigure:<function> \[<range>|MIN|MAX|DEF,<resolution>|MIN|MAX|DEF\]](#) (on page 5-14)

## SCPI command subsystem reference

The following SCPI subsystems are available on the Model 2110. The subsystem commands are summarized in the following tables.

- CALCulate subsystem (Refer to [CALCulate subsystem summary](#) (on page 5-20))
- DISPlay subsystem (Refer to [DISPlay subsystem summary](#) (on page 5-21))
- SENSE subsystem (Refer to [SENSe subsystem summary](#) (on page 5-21))
- STATus subsystem summary (Refer to [STATus subsystem summary](#) (on page 5-25))
- SYSTem subsystem (Refer to [SYSTem subsystem summary](#) (on page 5-25))
- TRIGger subsystem (Refer to [TRIGger subsystem summary](#) (on page 5-26))

This section includes commands that are device-specific to the Model 2110. Although not included in the 1999.0 version of the SCPI standard, these commands are compliant to the SCPI format and they follow the syntax rules of the standard. Device specific commands are indicated in the command description.

Many of the required SCPI commands are accepted by the instrument, but are not described in this manual for simplicity or clarity. Most of these non-documented commands duplicate the functionality of a command already described in this section.

## CALCulate subsystem summary

| Command                                | Description   |
|--|---|
| <b>:CALCulate</b>                      | Path to configure math calculations.  |
| :FUNction <name>                       | Specify math function: PERCent, AVERage, NULL, LIMit, MXB, DB, or DBM.  |
| :FUNction?                             | Query the present math function. Returns PERC, AVER, NULL, LIM, MXB, DB or DBM.   |
| :STATe <b>                             | Enable or disable calculation for the specified math function. Where: 0 = off and 1 = on.   |
| :STATe?                                | Query state of math function. Returns 0 (off) or 1 (on).  |
| :PERCent                               | Path to configure percent calculations.   |
| :TARGet <n> MIN MAX                    | Specify target value, MIN, or MAX for PERCent calculation.  |
| :TARGet? [MIN MAX]                     | Query the target value for percent math function.   |
| :AVERage                               | Path to query reading values.   |
| :MINimum?                              | Query the minimum value found during the averaging operation.   |
| :MAXimum?                              | Query the maximum value found during the averaging operation.   |
| :AVERage?                              | Query the average value of all readings taken since the averaging operation was enabled.  |
| :COUNT?                                | Query the number of readings taken since averaging was enabled.   |
| :NULL                                  | Path to configure the Null register.  |
| :OFFset <n> MIN MAX                    | Store a null value, MIN or MAX in the instrument's Null Register.   |
| :OFFset? [MIN MAX]                     | Query the null value.   |
| :LIMit                                 | Path to configure limit testing.  |
| :LOWer <n> MIN MAX                     | Specify the lower limit for limit testing. You can set the value to any number from 0 to ± 120% of the highest range, for the present function. |
| :LOWer? [MIN MAX]                      | Query the lower limit for the limit testing.  |
| :UPPer <n> MIN MAX                     | Specify the upper limit for limit testing. You can set the value to any number from 0 to ± 120% of the highest range, for the present function. |
| :UPPer? [MIN MAX]                      | Query the upper limit for the limit testing.  |
| :MXB                                   | Path to configure mX+b.   |
| :MMFactor <n> MIN MAX                  | Specify the m factor for mX+b (-1e6 to 1e6) or MINimum MAXimum.   |
| :MMFactor? [MIN MAX]                   | Query the value of m.   |
| :MBFactor <n> MIN MAX                  | Specify the b factor for mX+b (-1e6 to 1e6) or MINimum MAXimum.   |
| :MBFactor? [MIN MAX]                   | Query the value of b.   |
| :DB                                    | Path to configure the dB Relative Register.   |
| :REFerence <n> MIN MAX                 | Store a relative value in the dB Relative Register (any number between -200 dBm and +200 dBm) or MINimum MAXimum.                               |
| :REFerence? [MIN MAX]                  | Query the dB relative value.  |
| :DBM                                   | Path to configure the dBm reference value.  |
| :REFerence <n> MIN MAX                 | Specify the dBm reference value. Choose from: 50 ~ 8000 Ω or MINimum MAXimum.   |
| :REFerence? [MIN MAX]                  | Query the dBm reference value.  |
| :DATA:FEED RDG_STORE, [ 'CALC'   ' ' ] | Specifies whether readings taken using the INITiate command are stored in the multimeter's internal memory (default) or not stored at all.      |
| :DATA:FEED?                            | Query the reading memory state. Return "CALC" or "".  |

## DISPlay subsystem summary

| Command             | Description  |
|---------------------|--|
| :DISPlay <b>        | Turn on or off front panel display. Where: 0 = off and 1 = on.   |
| :DISPlay:TEXT <a>   | Define ASCII message "a" (up to 16 characters in length). The message will display on the secondary display. |
| :DISPlay:TEXT:CLEAr | Clear the message shown on the front panel display.  |
| :DISPlay?           | Query the display setting. Returns 0 (off) or 1 (on).  |

## SENSE subsystem summary

See the following table for the SENSE command summary. Refer to [Power-on settings](#) (on page 1-6) for information about default values for SENSE commands.

| Command                 | Description   |
|-------------------------|---|
| [ :SENSe]               | Path to sense commands.   |
| :FUNction[1 2]          | Path to FUNction, FUNCTION1, and FUNction2. FUNction1 displays the selected function on the primary display. FUNction2 displays the selected function on the secondary display.   |
| <a>                     | Specify one of the following functions to measure (enclosed function in quotation marks):<br>"VOLTage:AC"<br>"VOLTage[:DC]"<br>"VOLTage[:DC]:RATio"<br>"CURRent:AC"<br>"CURRent[:DC]"<br>"FREQuency[:VOLT]"<br>"FREQuency:CURR"<br>"RESistance"<br>"PERiod[:VOLT]"<br>"PERiod:CURR"<br>"RESistance"<br>"DIODE"<br>"TCouple"<br>"TEMPerature"<br>"CONTInuity"<br>Note: DIODE and CONTInuity are not SCPI compliant parameters. |
| :FUNction[1 2]?         | Query function. Returns function name.  |
| :VOLTage[:DC]           | Path to configure DC voltage.   |
| :RANGe <n> MIN MAX      | Specify the range: 100 mV, 1 V, 10 V, 100 V, 1000 V, MIN, or MAX.   |
| ? [MIN MAX]             | Query the range.  |
| :AUTO <b>               | Enable or disable auto range. Where: 0 = OFF and 1 = ON.  |
| :AUTO?                  | Query auto range.   |
| :RESolution <n> MIN MAX | Specify resolution: <n> = 3.00e-07 to 3.00e-04 of range, MIN, or MAX. Refer to <a href="#">Integration time and resolution for DC and resistance measurements</a> (on page 3-41) for more information about valid values for n.   |
| :RESolution? [MIN MAX]  | Query the resolution.   |



| Command                 | Description  |
|-------------------------|--|
| :NPLCycles <n> MIN MAX  | Specify the integration time in number of power line cycles for the selected function: 0.001, 0.006, 0.02, 0.06, 1, 2, 10, 100, MIN, or MAX. Refer to <a href="#">Integration time and resolution for DC and resistance measurements</a> (on page 3-41) for more information about valid values for n. |
| :NPLCycles?[MIN MAX]    | Query NPLCycles.   |
| :VOLTage:AC             | Path to configure AC voltage.  |
| :RANGe <n> MIN MAX      | Specify range: 100 mV, 1 V, 10 V, 100 V, 750 V, MIN, or MAX.   |
| ? [MIN MAX]             | Query the range.   |
| :AUTO <b>               | Enable or disable auto range. Where: 0 = OFF and 1 = ON.   |
| :AUTO?                  | Query auto range.  |
| :RESolution <n> MIN MAX | Specify resolution. Where <n> = 1.00e-06 to 1.00e-04 of range, MIN, or MAX. Refer to <a href="#">Bandwidth and resolution for AC measurements</a> (on page 3-44) for more information about valid values for n.  |
| :RESolution?            | Query the resolution.  |
| :CURRENT:AC             | Path to configure AC current.  |
| :RANGe <n> MIN MAX      | Specify range:0 to 10, MIN, or MAX.  |
| ? [MIN MAX]             | Query the range for AC voltage.  |
| :AUTO <b>               | Enable or disable auto range. Where: 0 = OFF and 1 = ON.   |
| :AUTO?                  | Query auto range.  |
| :RESolution <n> MIN MAX | Specify resolution. Where <n> = 1.00e-06 to 1.00e-04 of range, MIN, or MAX. Refer to <a href="#">Bandwidth and resolution for AC measurements</a> (on page 3-44) for more information about valid values for n.  |
| :RESolution? [MIN MAX]  | Query the resolution.  |
| :CURRENT[:DC]           | Path to configure DC current.  |
| :RANGe <n> MIN MAX      | Specify range: 10 mA, 100 mA, 1 A, 3 A, 10 A, MIN, or MAX.   |
| ? [MIN MAX]             | Query the range for DC voltage.  |
| :AUTO <b>               | Enable or disable auto range. Where: 0 = off and 1 = on.   |
| :AUTO?                  | Query auto range.  |
| :RESolution <n> MIN MAX | Specify resolution: <n> = 3.00e-07 to 3.00e-04 of range, MIN, or MAX. Refer to <a href="#">Integration time and resolution for DC and resistance measurements</a> (on page 3-41) for more information about valid values for n.  |
| :RESolution ?           | Query the resolution.  |
| :NPLCycles <n> MIN MAX  | Specify the integration time in number of power line cycles for the selected function: 0.001, 0.006, 0.02, 0.06, 1, 2, 10, 100, MIN, or MAX. Refer to <a href="#">Integration time and resolution for DC and resistance measurements</a> (on page 3-41) for more information about valid values for n. |
| :NPLCycles? [MIN MAX]   | Query NPLCycles.   |
| :RESistance             | Path to configure resistance (2-wire $\Omega$ ).   |
| :RANGe <n> MIN MAX      | Specify range: 0 to 100e6, MIN, or MAX.  |
| ? [MIN MAX]             | Query resistance range.  |
| :AUTO <b>               | Enable or disable auto range. Where: 0 = OFF and 1 = ON.   |
| :AUTO?                  | Query auto range.  |
| :RESolution <n> MIN MAX | Specify resolution: <n> = 3.00e-07 to 3.00e-04 of range, MIN, or MAX. Refer to <a href="#">Integration time and resolution for DC and resistance measurements</a> (on page 3-41) for more information about valid values for n.  |
| :RESolution? [MIN MAX]  | Query the resistance resolution.   |

| Command                 | Description  |
|-------------------------|--|
| :NPLCycles <n> MIN MAX  | Specify the integration time in number of power line cycles for the selected function: 0.001, 0.006, 0.02, 0.06, 1, 2, 10, 100, MIN, or MAX. Refer to <a href="#">Integration time and resolution for DC and resistance measurements</a> (on page 3-41) for more information about valid values for n. |
| :NPLCycles?             | Query NPLCycles.   |
| :FRESistance            | Path to configure fresistance (4-wire $\Omega$ ).  |
| :RANGe <n> MIN MAX      | Specify range: 0 to 100e6, MIN, or MAX.  |
| ? [MIN MAX]             | Query the fresistance range.   |
| :AUTO <b>               | Enable or disable auto range. Where, 0 = OFF and 1 = ON.   |
| :AUTO?                  | Query auto range.  |
| :RESolution <n> MIN MAX | Specify resolution: <n> = 3.00e-07 to 3.00e-04 of range, MIN, or MAX. Refer to <a href="#">Integration time and resolution for DC and resistance measurements</a> (on page 3-41) for more information about valid values for n.  |
| :RESolution? [MIN MAX]  | Query the fresistance resolution.  |
| :NPLCycles <n> MIN MAX  | Specify the integration time in number of power line cycles for the selected function: 0.001, 0.006, 0.02, 0.1, 1, 2, 10, 100, MIN, or MAX.  |
| :NPLCycles? [MIN MAX]   | Query NPLCycles.   |
| :FREquency              | Path to configure frequency.   |
| :VOLTagE                | Path to configure voltage.   |
| :RANGe <n> MIN MAX      | Specify range: 0 to 750, MIN, or MAX.  |
| ? [MIN MAX]             | Query range.   |
| :AUTO <b>               | Enable or disable auto range. Where: 0 = OFF and 1 = ON.   |
| :AUTO?                  | Query auto range setting.  |
| :CURRent                | Path to configure current.   |
| :RANGe <n> MIN MAX      | Specify range.   |
| ? [MIN MAX]             | Query range.   |
| :APERTure <n> MIN MAX   | Specify the aperture time for the selected function: 0.01, 0.1, 1, MIN, or MAX.  |
| :APERTure? [MIN MAX]    | Query the aperture time for frequency function.  |
| :PERiod                 | Path to configure period.  |
| :VOLTagE                | Path to period voltage.  |
| :RANGe <n> MIN MAX      | Specify range: 0 to 750, MIN, or MAX.  |
| ? [MIN MAX]             | Query the period range setting.  |
| :AUTO <b>               | Enable or disable auto range. Where: 0 = OFF and 1 = ON.   |
| :AUTO?                  | Query auto range setting.  |
| :CURRent                | Path to configure current.   |
| :RANGe <n> MIN MAX      | Specify range.   |
| ? [MIN MAX]             | Query the range.   |
| :APERTure <n> MIN MAX   | Specify the aperture time for the selected function: 0.01, 0.1, 1, MIN, or MAX. Default = 100 ms.  |
| :APERTure? [MIN MAX]    | Query the aperture time for period function.   |
| :UNIT <name>            | Specify units for temperature measurement (C, F, or K)   |
| :UNIT?                  | Query units for temperature measurement.   |
| :TCouple                | Path to configure thermocouple.  |
| :TYPE <name>            | Specify thermocouple sensor type (B, C, E, J, K, N, R, S, or T).   |
| ?                       | Query thermocouple sensor type.  |
| :RJUNction              | Path to thermocouple reference junction.   |
| :RSElect <name>         | Specify reference junction type, real or simulated. (REAL or SIMulated).   |

| Command                | Description  |
|------------------------|--|
| :RSElect?              | Query the reference junction type.   |
| :SIMulated <n> MIN MAX | Specify the default temperature of the simulated reference junction.                                       |
| :SIMulated? [MIN MAX]  | Query the default temperature of the simulated reference junction.   |
| :REAL <n> MIN MAX      | Path to offset voltage of the real reference junction.   |
| :REAL? [MIN MAX]       | Query the temperature of the internal reference junction.  |
| :TEMPerature           | Path to temperature measurements.  |
| :RTD                   | Path to resistance temperature detector (RTD).   |
| :TYPE <name>           | Specify temperature type: PT100, D100, F100, P385, PT3916, USER, SPRTD, or NTCT.                           |
| :TYPE?                 | Query the RTD temperature type.  |
| :RZERo <n> MIN MAX     | Specify the R-Zero coefficient for the user-defined RTD type (value).                                      |
| :RZERo?                | Query the R-Zero coefficient for the user-defined RTD type.  |
| :ALPHa <n> MIN MAX     | Specify the alpha coefficient for the user-defined RTD type (value).                                       |
| :ALPHa?                | Query the alpha coefficient for the user-defined RTD type.   |
| :BETA <n> MIN MAX      | Specify the beta coefficient for the user-defined RTD type.  |
| :BETA?                 | Query the beta coefficient for the user-defined RTD type.  |
| :DELTA <n> MIN MAX     | Set the delta coefficient for the user-defined RTD type (value).   |
| :DELTA?                | Query the delta coefficient for the user-defined RTD type.   |
| :SPRTD                 | Path to the sensor R value at 0 degree Celsius.  |
| :RZERo <n> MIN MAX     | Specify the sensor R value at 0 degree Celsius (value).  |
| :RZERo?                | Query the sensor R value at 0 degree Celsius.  |
| :A4 <n> MIN MAX        | Specify the A4 coefficient (value).  |
| :A4? [MIN MAX]         | Query the A4 coefficient.  |
| :B4 <n> MIN MAX        | Specify the B4 coefficient (value).  |
| :B4? [MIN MAX]         | Query the B4 coefficient.  |
| :AX <n> MIN MAX        | Specify the AX coefficient (value).  |
| :AX? [MIN MAX]         | Query the AX coefficient.  |
| :BX <n> MIN MAX        | Specify the BX coefficient (value).  |
| :BX? [MIN MAX]         | Query the BX coefficient.  |
| :CX <n> MIN MAX        | Specify the CX coefficient (value).  |
| :CX? [MIN MAX]         | Query the CX coefficient.  |
| :DX <n> MIN MAX        | Specify the DX coefficient (value).  |
| :DX? [MIN MAX]         | Query the DX coefficient.  |
| :TRANsducer <name>     | Configure transducer. Where: FRTD = 4-wire as the RTD measurement and RTD = 2-wire as the RTD measurement. |
| :NTCT                  | Path to the settings for sensor type NTCT.   |
| :A <n> MIN MAX         | Specify the A value.   |
| :A? [MIN MAX]          | Query the A value.   |
| :B <n> MIN MAX         | Specify the B value.   |
| :B? [MIN MAX]          | Query the B value.   |
| :C <n> MIN MAX         | Specify the C value.   |
| :C? [MIN MAX]          | Query the C value.   |
| :DETEctor              | Path to configure detector.  |
| :BANDwidth <n> MIN MAX | Specify bandwidth range (3, 20, 200).  |
| :BANDwidth? [MIN MAX]  | Query bandwidth range.   |
| :ZERO                  | Path to configure auto zero.   |
| :AUTO <name>           | Specify auto zero configuration: OFF, ONCE, or ON.   |

| Command             | Description   |
|---------------------|---|
| :AUTO?              | Query auto zero. Returns 0 (off) or 1 (on). ONCE returns 0 (off). |
| :AVERage            | Path to configure average.  |
| :TCONtrol <name>    | Specify MOVing or REPeat.   |
| :TCONtrol?          | Query average type.   |
| :COUNT <n>  MIN MAX | Specify count (value).  |
| :COUNT? [MIN MAX]   | Query count.  |
| :STATE <b>          | Specify ON or OFF.  |
| :STATE?             | Query state. Returns 0 (off) or 1 (on).                           |

### STATus subsystem summary

See the following table for the STATus command summary. Refer to the following topics for additional information on status commands.

- [Common commands](#) (on page 5-4)
- [Status model](#) (on page B-1)

| Command       | Description  |
|---------------|--|
| STATus:       |  |
| :QUESTionable | Path to configure the Questionable Data Enable Register.   |
| :ENABle <NRF> | Enable bits in the Questionable Data Enable Register. The selected bits are then reported to the Status Byte.<br>A 0 value clears the Questionable Data Enable Register. |
| :ENABle?      | Query the Questionable Data Enable Register. The instrument returns a binary-weighted decimal representing the bits set in the Questionable Data Enable Register.        |
| :EVENT?       | Query the Questionable Data Event Register. The instrument returns a decimal value which corresponds to the binary-weighted sum of all bits set in the register.         |
|               | Clear the Questionable Data Event Register.  |
| :PRESet       | Clear all bits in the Questionable Data Enable Register.   |

### SYSTEM subsystem summary

| Command       | Description   |
|---------------|---|
| :SYSTEM       | Path to system commands.  |
| :BEEPer       | Issue a single beeping tone.  |
| :STATE <b>    | Turn the beeper on or off. Where: 0 = off and 1 = on.   |
| :STATE?       | Query state of beeper. Returns 0 (off) 1 (on).  |
| :ERRor?       | Query the instrument's error queue. Up to 20 errors can be stored in the queue. Errors are retrieved in first-in-first-out (FIFO) order. Each error string may contain up to 80 characters. |
| :LOCal        | Place the instrument in the local mode. All keys on the front panel are fully functional.   |
| :REMote       | Place the instrument in the remote mode. All keys on the front panel, except the <b>LOCAL</b> key, are disabled.  |
| :VERSion?     | Query the present SCPI version.   |
| :DATA:POINTs? | Query the number of readings stored in the instrument's internal memory.  |

## TRIGger subsystem summary

| Command                    | Description   |
|----------------------------|---|
| TRIGger                    |   |
| :SOURce <name>             | Specify a trigger source. The instrument will accept a software (BUS) trigger, an immediate internal trigger (IMMediate), or a hardware trigger from the rear-panel (EXT TRIG) terminal.                        |
| :SOURce?                   | Query the trigger source.   |
| :COUNT <n> MIN MAX DEF INF | Specify the number of triggers the instrument will accept before returning to the "idle" state. (1 to 50,000, MIN, MAX, or INF). The INFinite parameter instructs the instrument to take triggers continuously. |
| :COUNT?                    | Query measure count. Returns the number of triggers the instrument will accept before returning to the "idle" state.  |
| :DElay <n> MIN MAX DEF     | Set delay time (0 to 3600 sec., MIN or MAX).  |
| :DElay? [MIN MAX DEF]      | Query the trigger delay time  |
| :AUTO <b>                  | Enable or disable auto delay. Where: 0 = off and 1 = on.  |
| :AUTO?                     | Query state of delay. Returns 0 (off) or 1 (on).  |
| :SAMPle                    | Path to trigger sample.   |
| :COUNT <n> MIN MAX DEF     | Set the number of readings (samples) the instrument takes per trigger (1 to 50,000, MIN or MAX)   |
| :COUNT? [MIN MAX DEF]      | Query the sample count.   |

## CALCulate subsystem

The commands in this subsystem configure and control the Calculate subsystems and are summarized in [CALCulate subsystem summary](#) (on page 5-20).

There are seven math operations. Only one of them can be enabled at a time. They either store data for later use or perform mathematical operations on the readings. See [Math operations](#) (on page 3-48) for more details.

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### CALCulate:AVERage:AVERage?

This command reads the average value of all readings taken since the averaging operation was enabled. The instrument clears the value when averaging is turned on, when the power is turned off, or a remote interface reset occurs.

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### CALCulate:AVERage:COUNT?

This command reads the average value of all readings taken since averaging was enabled. The instrument clears the value when averaging is turned on, when the power is turned off, or a remote interface reset occurs.

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### CALCulate:AVERage:MINimum?

This command reads the minimum value found during the averaging operation. The instrument clears the value when averaging is turned on, when the power is turned off, or a remote interface reset occurs.

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### CALCulate:AVERage:MAXimum?

This command reads the maximum value found during the averaging operation. The instrument clears the value when averaging is turned on, when the power is turned off, or a remote interface reset occurs.

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## CALCulate:DB:REference <n>|MIN|MAX

This command stores a relative value in the dB Relative Register. You must turn on the math operation before writing to the math register.

### Parameters

| parameters | description   |
|------------|---|
| <n>        | Set the dB value to any value between -200 and 200. |
| MINimum    | Set value to the minimum.                           |
| MAXimum    | Set value to the maximum.                           |

### Query

| command                     | description                  |
|-----------------------------|------------------------------|
| CALCulate:DB:REference?     | Query the dB relative value. |
| CALCulate:DB:REference? MIN | Query the minimum value.     |
| CALCulate:DB:REference? MAX | Query the maximum value.     |

---



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## CALCulate:DBM:REference <n>|MIN|MAX

This command is used to set the dBm reference resistance value in ohms.

### Parameters

| parameter | description   |
|-----------|---|
| <n>       | You can set the relative value to any number between 50 ~ 8000 Ω. |
| MINimum   | Set value to the minimum.   |
| MAXimum   | Set value to the maximum.   |

### Query

| command                      | description                    |
|------------------------------|--------------------------------|
| CALCulate:DBM:REference?     | Query the dBm reference value. |
| CALCulate:DBM:REference? MIN | Query the minimum value.       |
| CALCulate:DBM:REference? MAX | Query the maximum value.       |

## CALCulate:FUNction <name>

This command configures the math function for the calculate commands. You can only select one function at a time.

### Parameters

| <name>  | Description  |
|---------|--|
| PERCent | Select percent math calculation.                                   |
| AVERage | Select average math calculation.                                   |
| NULL    | Select the null feature.   |
| LIMit   | Select the limits feature to configure and control limits testing. |
| MXB     | Select mX+b polynomial math calculation.                           |
| DB      | Select the mX+b calculations.                                      |
| DBM     | Select the dBm reference resistance value.                         |

### Query

| command   | description                     |
|-----------|---------------------------------|
| FUNCTion? | Query the measurement function. |

### Details

Refer to [Math operations](#) (on page 3-48) for detail about the math operations.

## CALCulate:LIMit:LOWer <n>|MIN|MAX

This command is used to specify the lower limit for limit testing.

A limit value of 1 is 1 V for the voltage functions (DCV or ACV), 1 A for the current functions (DCI or ACI), 1  $\Omega$  on the resistance functions (2 or 4), and 1 (C, F, or K) for the temperature function. A limit value is not range sensitive. For example, a limit of 1 for DCV is 1 V on all measurement ranges.

### Parameter

| <n>                                  | description   |
|--------------------------------------|---|
| 0 to $\pm$ 120% of the highest range | Set the lower limit for limit testing. You can set the value to any number from 0 to $\pm$ 120% of the highest range, for the present function. |
| MINimum                              | Set specified limit to 0.   |
| MAXimum                              | Set specified limit to $\pm$ 120% of the highest range.   |

### Query

| command                | description                                  |
|------------------------|--|
| CALCulate:LIMit:LOWer? | Query the lower limit for the limit testing. |
| CALCulate:LIMit? MIN   | Query the minimum value.                     |
| CALCulate:LIMit? MAX   | Query the maximum value.                     |



## CALCulate:LIMit:UPPer <n>|MIN|MAX

This command is used to specify the upper limit for limit testing. The actual limit depends on which measurement function is currently selected.

For example, a limit value of 1 is 1 V for the volts functions (DCV or ACV), 1 A for the current functions (DCI or ACI), 1  $\Omega$  on the ohms functions (2-wire or 4-wire), and 1 (C, F, or K) for the temperature function. A limit value is not range sensitive. A limit of 1 for DCV is 1 V on all measurement ranges.

### Parameters

| <n>                                   | description  |
|---------------------------------------|--|
| 0 to $\pm 120\%$ of the highest range | Set the upper limit for limit testing. You can set the value to any number from 0 to $\pm 120\%$ of the highest range, for the present function. |
| MINimum                               | Set value to the minimum.  |
| MAXimum                               | Set value to the maximum.  |

### Query

| command                    | description                                  |
|----------------------------|--|
| CALCulate:LIMit:UPPer?     | Query the upper limit for the limit testing. |
| CALCulate:LIMit:UPPer? MIN | Query the minimum upper limit.               |
| CALCulate:LIMit:UPPer? MAX | Query the maximum upper limit.               |

## CALCulate:MXB:MBFactor <n>|MIN|MAX

This command defines the b factor for the  $mX+b$  calculation.

### Parameters

| <n>         | description               |
|-------------|---------------------------|
| -1e6 to 1e6 | Set a value for b.        |
| MINimum     | Set value to the minimum. |
| MAXimum     | Set value to the maximum. |

### Query

| command                     | description                   |
|-----------------------------|-------------------------------|
| CALCulate:MXB:MBFactor?     | Query the value of b.         |
| CALCulate:MXB:MBFactor? MIN | Query the minimum value of b. |
| CALCulate:MXB:MBFactor? MAX | Query the maximum value of b. |

## CALCulate:MXB:MMFactor <n>|MIN|MAX

This command defines the m factor for the  $mX+b$  calculation.

### Parameters

| <n>         | description               |
|-------------|---------------------------|
| -1e6 to 1e6 | Set a value for m.        |
| MINimum     | Set value to the minimum. |
| MAXimum     | Set value to the maximum. |

### Query

| command                     | description                   |
|-----------------------------|-------------------------------|
| CALCulate:MXB:MMFactor?     | Query the value of m.         |
| CALCulate:MXB:MMFactor? MIN | Query the minimum value of m. |
| CALCulate:MXB:MMFactor? MAX | Query the maximum value of m. |

## CALCulate:NULL:OFFSet <n>|MIN|MAX

This command stores a null value in the instrument's Null Register. You must turn on the math operation before writing to the math register.

### Parameters

| <n>                                   | description   |
|---------------------------------------|---|
| 0 to $\pm 120\%$ of the highest range | Select the null (relative) value. You can set the null value to any number between -120 % and 120 % of the highest range. |
| MINimum                               | Set value to the minimum.   |
| MAXimum                               | Set value to the maximum.   |

### Query

| command                  | description  |
|--------------------------|--|
| CALCulate:NULL:OFFSet?   | Query the null value.                                |
| CALCulate:NULL:OFFS? MIN | Query the null minimum value for null math function. |
| CALCulate:NULL:OFFS? MAX | Query the null maximum value for null math function. |

## CALCulate:PERCent:TARGet <n>|MIN|MAX

This command specifies the target value for percent math function.

### Parameters

| <n> | description  |
|-----|--|
|     | Specify the measurement function dependent target value. |

|         |                       |
|---------|-----------------------|
| MINimum | Set to minimum value. |
| MAXimum | Set to maximum value. |

### Query

| command                       | description   |
|-------------------------------|---|
| CALCulate:PERCent:TARGet?     | Query the target value for percent math function.         |
| CALCulate:PERCent:TARGet? MIN | Query the target minimum value for percent math function. |
| CALCulate:PERCent:TARGet? MAX | Query the target maximum value for percent math function. |

## CALCulate:STATe <b>

Turn the selected math function on or off.

### Parameters

| <b>      | description                      |
|----------|----------------------------------|
| 0 or OFF | Turn selected math function on.  |
| 1 or ON  | Turn selected math function off. |

### Query

| command          | description   |
|------------------|---|
| CALCulate:STATe? | Query the state of the selected math function. Returns 0 (off) or 1 (on). |

## DATA:FEED RDG\_STORE,'CALCulate'|"

This command selects whether readings taken using the INITiate command are stored in the multimeter's internal memory (default) or not stored at all. In the default state (DATA:FEED RDG\_STORE,'CALC'), up to 2000 readings are stored in memory when INITiate is executed. The MEASure? And CONFigure commands automatically select 'CALC'. With memory disabled (DATA:FEED RDG\_STORE,""), readings taken using INITiate are not stored. This may be useful with the averaging operation since it allows you to determine an average of the readings without storing the individual values. An error will be generated if you attempt to transfer readings to the output buffer using the FETCh? command.

| parameter | description   |
|-----------|---|
| 'CALC'    | Stores up to 2000 readings in memory when INITiate is executed. |
| ' '       | Readings taken using INITiate are not stored.                   |

### Query

| command    | description   |
|------------|---|
| DATA:FEED? | Query the reading memory state. Returns "CALC" or "". |

## DISPlay subsystem

The display subsystem controls the display of the instrument and is summarized in [DISPlay subsystem summary](#) (on page 5-21).

---

### DISPlay <b>

This command enables or disables the display.

#### Parameters

| <b>      | description                   |
|----------|-------------------------------|
| 0 or OFF | Turn measurement display off. |
| 1 or ON  | Turn measurement display on.  |

#### Query

| command  | description  |
|----------|--|
| DISPlay? | Query state of measurement display. Returns 0 (off) or 1 (on). |

#### Details

This command is used to enable and disable the front panel display circuitry. In the OFF mode an OFF indicator is shown on the display. Refer to [Turning off measurement display](#) (on page 2-21) for information about how this command controls the display.

#### Example

|            |                       |
|------------|-----------------------|
| DISPlay ON | Turns on the display. |
|------------|-----------------------|

---

### DISPlay:TEXT <a>

This command displays text on the secondary display (second line of the front panel display).

#### Parameters

| <a>                                   | description   |
|---------------------------------------|---|
| A maximum of any 16 ASCII characters. | String parameters can contain virtually any set of ASCII characters. A string must begin and end with matching quotes; either with a single quote or with a double quote. You can include the quote delimiter as part of the string by typing it twice without any characters in between. |

#### Query

| command       | description  |
|---------------|--|
| DISPlay:TEXT? | Query the message sent to the front panel display. |

#### Details

The message can be up to 16 characters; any additional characters will be truncated.

#### Example

|                                 |                                  |
|---------------------------------|----------------------------------|
| DISPlay:TEXT "Hello World 1234" | Displays the string you type in. |
|---------------------------------|----------------------------------|

---

## DISPlay:TEXT:CLEAr

This command clears text messages from the secondary display.

### Parameters

| command            | description         |
|--------------------|---------------------|
| DISPlay:Text:CLEAr | Clears the message. |

### Example

|                    |                     |
|--------------------|---------------------|
| DISPlay:TEXT:CLEAr | Clears the message. |
|--------------------|---------------------|

## SENSe subsystem

The sense subsystem controls measurement configuration and is summarized in [SENSe subsystem summary](#) (on page 5-21).

---

## [SENSe:]AVERAge:COUNT <n>|MIN|MAX

Use this command to set the number of readings the digital filter stores before calculating the average of the stored readings. The digital filter averages the readings to yield a single reading.

### Parameters

| <n>      | description   |
|----------|---|
| 2 to 100 | Select the number of readings the digital filter stores before calculating the average. |
| MINimum  | Select the minimum value.   |
| MAXimum  | Select the maximum value.   |

### Query

| command                    | description                                      |
|----------------------------|--|
| [SENSe:]AVERAge:COUNT?     | Query the number of readings to average.         |
| [SENSe:]AVERAge:COUNT? MIN | Query the minimum number of readings to average. |
| [SENSe:]AVERAge:COUNT? MAX | Query the maximum number of readings to average. |

### Details

Refer to [Digital filter](#) (on page 3-47) for more information about using this command.

**[SENSe:]AVERAge:STATe <b>**

Use this command to turn the digital filter on or off.

**Parameters**

| <b>&lt;b&gt;</b> | <b>description</b>           |
|------------------|------------------------------|
| 0 or OFF         | Turn the digital filter off. |
| 1 or ON          | Turn the digital filter on.  |

**Query**

| <b>command</b>         | <b>description</b>  |
|------------------------|---|
| [SENSe:]AVERAge:STATe? | Query the state of the digital filter. Returns 0 (off) or 1 (on). |

**Details**

Refer to [Digital filter](#) (on page 3-47) for more information about using this command.

**[SENSe:]AVERAge:TCONtrol <name>**

Use this command to select the digital filter type.

**Parameters**

| <b>&lt;name&gt;</b> | <b>description</b>                |
|---------------------|-----------------------------------|
| <b>MOVing</b>       | Select the moving average filter. |
| <b>REPeat</b>       | Select the moving average filter. |

**Query**

| <b>command</b>            | <b>description</b>   |
|---------------------------|--|
| [SENSe:]AVERAge:TCONtrol? | Query the type of digital filter. Returns 0 (off) or 1 (on). |

**Details**

Refer to [Digital filter](#) (on page 3-47) for more information about using this command.

---



---

## [SENSe:]CAPacitance:RANGe <n>|MIN|MAX

Use this command to select the capacitance range.

### Parameters

| <n>        | description  |
|------------|--|
| 0 to 10e-3 | Specify the value of the expected capacitance reading. |
| MINimum    | Select the minimum value.                              |
| MAXimum    | Select the maximum value.                              |

### Query

| command                        | description                          |
|--------------------------------|--------------------------------------|
| [SENSe:]CAPacitance:RANGe      | Query the capacitance range.         |
| [SENSe:]CAPacitance:RANGe? MIN | Query the minimum capacitance range. |
| [SENSe:]CAPacitance:RANGe? MAX | Query the maximum capacitance range. |

### Details

The measurement ranges for capacitance measurements are 1 nF, 10 nF, 100 nF, 1 µF, 10 µF, 100 µF, 1 mF, and 10 mF.

Resolution is ignored for capacitance. Refer to [Capacitance measurements](#) (on page 3-24) for more information about this command.

---



---

## [SENSe:]CAPacitance:RANGe:AUTO <b>

This command turns capacitance autorange on or off.

### Parameters

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

### Query

| command                         | description            |
|---------------------------------|------------------------|
| [SENSe:]CAPacitance:RANGe:AUTO? | Query autorange state. |

---

## [SENSe:]CURRent:AC:RANGe <n>|MIN|MAX

Use this command to select the function (ACI) and set a measurement range.

### Parameters

| <n>     | description                           |
|---------|---------------------------------------|
| 0 to 10 | Select the measurement range in amps. |
| MINimum | Select the minimum value.             |
| MAXimum | Select the maximum value.             |

### Query

| command                       | description                  |
|-------------------------------|------------------------------|
| [SENSe:]CURRent:AC:RANGe?     | Query the measurement range. |
| [SENSe:]CURRent:AC:RANGe? MIN | Query the minimum range.     |
| [SENSe:]CURRent:AC:RANGe? MAX | Query the maximum range.     |

---

## [SENSe:]CURRent:AC:RESolution <n>|MIN|MAX

Use this command to select the resolution for AC current measurements (ACI).

### Parameters

| <n>                                | description                               |
|------------------------------------|---|
| (1.00e-06 to 1.00e-04) * ACI range | Select the resolution of the measurement. |
| MINimum                            | Select the minimum value.                 |
| MAXimum                            | Select the maximum value.                 |

### Query

| command                            | description                       |
|------------------------------------|-----------------------------------|
| [SENSe:]CURRent:AC:RESolution?     | Query the measurement resolution. |
| [SENSe:]CURRent:AC:RESolution? MIN | Query the minimum resolution.     |
| [SENSe:]CURRent:AC:RESolution? MAX | Query the maximum resolution.     |

### Details

Refer to [Bandwidth and resolution for AC measurements](#) (on page 3-44) for more information about resolution.



## [SENSe:]CURRent[:DC]:NPLCycles <n>|MIN|MAX

Use this command to select the integration time for DC current measurements. Integration time for DCI measurements is expressed as the number of power line cycles (NPLC).

### Parameters

| <n>     | description               |
|---------|---------------------------|
| 0.001   | Select 0.001 NPLC.        |
| 0.006   | Select 0.006 NPLC.        |
| 0.02    | Select 0.02 NPLC.         |
| 0.06    | Select 0.06 NPLC.         |
| 0.2     | Select 0.2 NPLC.          |
| 0.6     | Select 0.6 NPLC.          |
| 1       | Select 1 NPLC.            |
| 2       | Select 2 NPLC.            |
| 10      | Select 10 NPLC.           |
| 100     | Select 100 NPLC.          |
| MINimum | Select the minimum value. |
| MAXimum | Select the maximum value. |

### Query

| command                             | description              |
|-------------------------------------|--------------------------|
| [SENSe:]CURRent[:DC]:NPLCycles?     | Query the NPLCycles.     |
| [SENSe:]CURRent[:DC]:NPLCycles? MIN | Query the minimum value. |
| [SENSe:]CURRent[:DC]:NPLCycles? MAX | Query the maximum value. |

### Details

Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) for more information about NPLC.

## [SENSe:]CURRent[:DC]:RANGe <n>|MIN|MAX

Use this command to select the function (DCI) and set a measure range.

### Parameters

| <n>       | description                           |
|-----------|---------------------------------------|
| -10 to 10 | Select the measurement range in amps. |
| MINimum   | Select the minimum value.             |
| MAXimum   | Select the maximum value.             |

### Query

| command                         | description                  |
|---------------------------------|------------------------------|
| [SENSe:]CURRent[:DC]:RANGe?     | Query the measurement range. |
| [SENSe:]CURRent[:DC]:RANGe? MIN | Query the minimum range.     |
| [SENSe:]CURRent[:DC]:RANGe? MAX | Query the maximum range.     |

## [SENSe:]CURREnt[:DC]:RESolution <n>|MIN|MAX

Use this command to select the resolution for DC current measurements (DCI).

### NOTE

When you set the resolution, the instrument automatically updates the integration time.

#### Parameters

| <n>                                | description                               |
|------------------------------------|---|
| (3.00e-07 to 3.00e-04) * DCI range | Select the resolution of the measurement. |
| MINimum                            | Select the minimum value.                 |
| MAXimum                            | Select the maximum value.                 |

#### Query

| command                              | description                           |
|--------------------------------------|---------------------------------------|
| [SENSe:]CURREnt[:DC]:RESolution?     | Query the resolution setting.         |
| [SENSe:]CURREnt[:DC]:RESolution? MIN | Query the minimum resolution setting. |
| [SENSe:]CURREnt[:DC]:RESolution? MAX | Query the maximum resolution setting. |

#### Details

Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) more information about resolution.

## [SENSe:]CURREnt:AC:RANGe:AUTO <b>

This command turns AC current autorange on or off.

#### Parameters

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

#### Query

| command                | description            |
|------------------------|------------------------|
| CURREnt:AC:RANGe:AUTO? | Query autorange state. |

## [SENSe:]CURRent[:DC]:RANGe:AUTO <b>

This command turns DC current autorange on or off.

### Parameters

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

### Query

| command                       | description            |
|-------------------------------|------------------------|
| CURRent [ :DC ] :RANGe :AUTO? | Query autorange state. |

## [SENSe:]DETEctor:BANDwidth <n>|MIN|MAX

Use this command to specify the lowest frequency expected in the input signal. The instrument selects the slow, medium or fast AC filter based on the frequency you specify.

### Parameters

| <n>     | description   |
|---------|---|
| 3       | Slow AC filter. 3 Hz. A value less than 3 will error. A floor calculation is performed. |
| 20      | Medium AC filter. 20 Hz.  |
| 200     | Fast AC filter. 200 Hz. This is the default value.                                      |
| MINimum | Select the minimum value.   |
| MAXimum | Select the maximum value.   |

### Query

| command                         | description                  |
|---------------------------------|------------------------------|
| [SENSe:]DETEctor:BANDwidth?     | Query the bandwidth.         |
| [SENSe:]DETEctor:BANDwidth? MIN | Query the minimum bandwidth. |
| [SENSe:]DETEctor:BANDwidth? MAX | Query the maximum bandwidth. |

### Details

Refer to [Bandwidth and resolution for AC measurements](#) (on page 3-44) more information about bandwidth.

## [SENSe:]FRESistance:NPLCycles <n>|MIN|MAX

Use this command to select the integration time for 4-wire measurements. Integration time for 4-wire measurements is expressed as the number of power line cycles (NPLC).

### Parameters

| <n>     | description               |
|---------|---------------------------|
| 0.001   | Select 0.001 NPLC.        |
| 0.006   | Select 0.006 NPLC.        |
| 0.02    | Select 0.02 NPLC.         |
| 0.06    | Select 0.06 NPLC.         |
| 0.2     | Select 0.2 NPLC.          |
| 0.6     | Select 0.6 NPLC.          |
| 1       | Select 1 NPLC.            |
| 2       | Select 2 NPLC.            |
| 10      | Select 10 NPLC.           |
| 100     | Select 100 NPLC.          |
| MINimum | Select the minimum value. |
| MAXimum | Select the maximum value. |

### Query

| command                            | description              |
|------------------------------------|--------------------------|
| [SENSe:]FRESistance:NPLCycles?     | Query the NPLCycles.     |
| [SENSe:]FRESistance:NPLCycles? MIN | Query the minimum value. |
| [SENSe:]FRESistance:NPLCycles? MAX | Query the maximum value. |

### Details

Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) more information about NPLC.

## [SENSe:]FRESistance:RANGe <n>|MIN|MAX

Use this command to set a measure range for 4-wire ( $\Omega$ ) measurements.

### Parameters

| <n>        | description                           |
|------------|---------------------------------------|
| 0 to 100e6 | Select the measurement range in ohms. |
| MINimum    | Select the minimum value.             |
| MAXimum    | Select the maximum value.             |

### Query

| command                        | description                  |
|--------------------------------|------------------------------|
| [SENSe:]FRESistance:RANGe      | Query the measurement range. |
| [SENSe:]FRESistance:RANGe? MIN | Query the minimum range.     |
| [SENSe:]FRESistance:RANGe? MAX | Query the maximum range.     |

## [SENSe:]FRESistance:RANGe:AUTO <b>

This command turns autorange on or off for  $\Omega$ 4.

### Parameters

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

### Query

| command                         | description                       |
|---------------------------------|-----------------------------------|
| [SENSe:]FRESistance:RANGe:AUTO? | Query $\Omega$ 4 autorange state. |

## [SENSe:]FRESistance:RESolution <n>|MIN|MAX

Use this command to set a measured resolution for 4-wire ( $\Omega$ 4) measurements.

### NOTE

When you set the resolution, the instrument automatically updates the integration time.

### Parameters

| <n>                                       | description                               |
|---|---|
| (3.00e-07 to 3.00e-04) * $\Omega$ 4 range | Select the resolution of the measurement. |
| MINimum                                   | Select the minimum value.                 |
| MAXimum                                   | Select the maximum value.                 |

### Query

| command                             | description                           |
|-------------------------------------|---------------------------------------|
| [SENSe:]FRESistance:RESolution?     | Query the resolution setting.         |
| [SENSe:]FRESistance:RESolution? MIN | Query the minimum resolution setting. |
| [SENSe:]FRESistance:RESolution? MAX | Query the maximum resolution setting. |

### Details

Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) more information about resolution.

## [SENSe:]FREQUency:APERture <n>|MIN|MAX

Use this command to select the aperture time for frequency function. For frequency and period measurements, aperture time is analogous to integration time.

### Parameters

| <n>         | description               |
|-------------|---------------------------|
| 0.01 second | 4½-digit resolution.      |
| 0.1 second  | 5½-digit resolution.      |
| 1 second    | 5½-digit resolution.      |
| MINimum     | Select the minimum value. |
| MAXimum     | Select the maximum value. |

### Query

| command                         | description                      |
|---------------------------------|----------------------------------|
| [SENSe:]FREQUency:APERture?     | Query the aperture time.         |
| [SENSe:]FREQUency:APERture? MIN | Query the minimum aperture time. |
| [SENSe:]FREQUency:APERture? MAX | Query the maximum aperture time. |

### Details

Refer to [Aperture and resolution for frequency and period measurements](#) (on page 3-45) for more information about aperture time.

## [SENSe:]FREQUency:CURRent:RANGe <n>|MIN|MAX

Use this command to select the current range for the frequency function.

### Parameters

| <n>     | description                                      |
|---------|--|
| 0 to 10 | Set AC current range for the frequency function. |
| MINimum | Select the minimum value.                        |
| MAXimum | Select the maximum value.                        |

### Query

| command                              | description                  |
|--------------------------------------|------------------------------|
| [SENSe:]FREQUency:CURRent:RANGe?     | Query the measurement range. |
| [SENSe:]FREQUency:CURRent:RANGe? MIN | Query the minimum range.     |
| [SENSe:]FREQUency:CURRent:RANGe? MAX | Query the maximum range.     |

---



---

## [SENSe:]FREQUency:VOLTage:RANGe <n>|MIN|MAX

Use this command to select the voltage range for the frequency function.

### Parameters

| <n>      | description                                  |
|----------|--|
| 0 to 750 | Set AC voltage range for frequency function. |
| MINimum  | Select the minimum value.                    |
| MAXimum  | Select the maximum value.                    |

### Query

| command                              | description                  |
|--------------------------------------|------------------------------|
| [SENSe:]FREQUency:VOLTage:RANGe?     | Query the measurement range. |
| [SENSe:]FREQUency:VOLTage:RANGe? MIN | Query the minimum range.     |
| [SENSe:]FREQUency:VOLTage:RANGe? MAX | Query the maximum range.     |

---



---

## [SENSe:]FREQUency:VOLTage:RANGe:AUTO <b>

This command turns autorange on or off.

### Parameters

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

### Query

| command                               | description            |
|---------------------------------------|------------------------|
| [SENSe:]FREQUency:VOLTage:RANGe:AUTO? | Query autorange state. |

## [SENSe:]FUNcTion [1|2] "<function>"

This command selects the measurement function listed in the function parameter. You can also use this command to turn off the secondary display.

### Parameters

| <function>            | description   |
|-----------------------|---|
| "CURRent[:DC]"        | Select amps function DC.  |
| "CURRent:AC"          | Select amps function AC.  |
| "VOLTage[:DC]"        | Select volts function DC.   |
| "VOLTage:AC"          | Select volts function AC.   |
| "VOLTage[:DC]:RATio"  | Select DC ratio measurements. This parameter is only valid only when used with FUNC1.         |
| "CAPacitance"         | Select capacitance measurements.  |
| "RESistance"          | Select 2- wire ohms function.   |
| "FRESistance"         | Select 4- wire ohms function.   |
| "FREQuency[:VOLTage]" | Select voltage frequency measurement.   |
| "FREQuency:CURRent"   | Select current frequency measurement.   |
| "PERiod[:VOLTage]"    | Select voltage period measurement.  |
| "PERiod:CURRent"      | Select current period measurement.  |
| "CONTinuity"          | Select continuity measurement.  |
| "DIODE"               | Select diode measurement.   |
| "TCouple"             | Select thermocouple temperature measurement.  |
| "TEMPerature"         | Select temperature measurement.   |
| "NONE"                | Select to turn off secondary display. This parameter is only valid only when used with FUNC2. |

### Query

| command   | description  |
|-----------|--|
| FUNCtion? | Query the measurement function and return a quoted string. |

### Details

Refer to [Secondary measurement function](#) (on page 3-26) for information about the instrument's dual measurement capability.

Specify a measurement function and enclose it in quotes in the command string.

Optionally, include one of the following parameter to indicate primary or secondary display:

- 1 for primary display. For example FUNCtion1.
- 2 for secondary display.

If you do not specify a display, the display parameter defaults to a 1 for the primary display.

Include "NONE" to turn off secondary display. This is only valid only when used with FUNCtion2.

### Example

|                         |  |
|-------------------------|--|
| FUNCtion "VOLTage:AC"   | Specifies Voltage AC as the measurement function and primary display as the display.     |
| FUNCtion2 "CAPacitance" | Specifies capacitance as the measurement function and the second display as the display. |
| FUNCtion2 "NONE"        | Turn off secondary display.  |



## [SENSe:]PERiod:APERture <n>|MIN|MAX

Use this command to set the aperture time for period function. For frequency and period measurements, aperture time is analogous to integration time.

### Parameters

| <n>  | description          |
|------|----------------------|
| 0.01 | 4½-digit resolution. |
| 0.1  | 5½-digit resolution. |
| 1    | 5½-digit resolution. |

### Query

| command                      | description                      |
|------------------------------|----------------------------------|
| [SENSe:]PERiod:APERture?     | Query the aperture time.         |
| [SENSe:]PERiod:APERture? MIN | Query the minimum aperture time. |
| [SENSe:]PERiod:APERture? MAX | Query the maximum aperture time. |

### Details

Refer to [Aperture and resolution for frequency and period measurements](#) (on page 3-45) for more information about aperture time.

## [SENSe:]PERiod:VOLTage:RANGe <n>|MIN|MAX

Use this command to select the voltage range for the period function.

### Parameters

| <n>       | description                                   |
|-----------|---|
| 0 to 750. | Set AC voltage range for the period function. |
| MINimum   | Select the minimum value.                     |
| MAXimum   | Select the maximum value.                     |

### Query

| command                           | description                  |
|-----------------------------------|------------------------------|
| [SENSe:]PERiod:VOLTage:RANGe?     | Query the measurement range. |
| [SENSe:]PERiod:VOLTage:RANGe? MIN | Query the minimum range.     |
| [SENSe:]PERiod:VOLTage:RANGe? MAX | Query the maximum range.     |

**[SENSe:]PERiod:VOLTage:RANGe:AUTO <b>**

This command turns autorange on or off for the period voltage function.

**Parameters**

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

**Query**

| command                            | description            |
|------------------------------------|------------------------|
| [SENSe:]PERiod:VOLTage:RANGe:AUTO? | Query autorange state. |

**[SENSe:]RESistance:RANGe <n>|MIN|MAX**

Use this command to select the measure range for the 2-wire resistance function.

**Parameters**

| <n>        | description                           |
|------------|---------------------------------------|
| 0 to 100e6 | Select the measurement range in ohms. |
| MINimum    | Select the minimum value.             |
| MAXimum    | Select the maximum value.             |

**Query**

| command                       | description                  |
|-------------------------------|------------------------------|
| [SENSe:]RESistance:RANGe?     | Query the measurement range. |
| [SENSe:]RESistance:RANGe? MIN | Query the minimum range.     |
| [SENSe:]RESistance:RANGe? MAX | Query the maximum range.     |

**[SENSe:]RESistance:RANGe:AUTO <b>**

This command turns autorange on or off for the 2-wire resistance function.

**Parameters**

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

**Query**

| command                        | description            |
|--------------------------------|------------------------|
| [SENSe:]RESistance:RANGe:AUTO? | Query autorange state. |

---



---

## [SENSe:]RESistance:RESolution <n>|MIN|MAX

Use this command to set a measurement resolution for 2-wire ( $\Omega$ ) resistance measurements.

### NOTE

When you set the resolution, the instrument automatically updates the integration time.

#### Parameters

| <n>                                       | description                               |
|---|---|
| (3.00e-07 to 3.00e-04) * $\Omega$ 2 range | Select the resolution of the measurement. |
| MINimum                                   | Select the minimum value.                 |
| MAXimum                                   | Select the maximum value.                 |

#### Query

| command                            | description                           |
|------------------------------------|---------------------------------------|
| [SENSe:]RESistance:RESolution?     | Query the resolution setting.         |
| [SENSe:]RESistance:RESolution? MIN | Query the minimum resolution setting. |
| [SENSe:]RESistance:RESolution? MAX | Query the maximum resolution setting. |

#### Details

Refer to [Aperture and resolution for frequency and period measurements](#) (on page 3-45) for more information about resolution.

## [SENSe:]RESistance:NPLCycles <n>|MIN|MAX

Use this command to select the integration time for 2-wire resistance measurements. Integration time for 2-wire measurements is expressed as the number of power line cycles (NPLC).

### Parameters

| <n>     | description               |
|---------|---------------------------|
| 0.001   | Select 0.001 NPLC.        |
| 0.006   | Select 0.006 NPLC.        |
| 0.02    | Select 0.02 NPLC.         |
| 0.06    | Select 0.06 NPLC.         |
| 0.2     | Select 0.2 NPLC.          |
| 0.6     | Select 0.6 NPLC.          |
| 1       | Select 1 NPLC.            |
| 2       | Select 2 NPLC.            |
| 10      | Select 10 NPLC.           |
| 100     | Select 100 NPLC.          |
| MINimum | Select the minimum value. |
| MAXimum | Select the maximum value. |

### Query

| command                           | description              |
|-----------------------------------|--------------------------|
| [SENSe:]RESistance:NPLCycles?     | Query the NPLCycles.     |
| [SENSe:]RESistance:NPLCycles? MIN | Query the minimum value. |
| [SENSe:]RESistance:NPLCycles? MAX | Query the maximum value. |

### Details

Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) more information about resolution.

## [SENSe:]TCouple:RJUNction:REAL?

Use this command to query the temperature of the internal reference junction.

### Query

| command                         | description   |
|---------------------------------|---|
| [SENSe:]TCouple:RJUNction:REAL? | Query the temperature of the internal reference junction. |

### Details

The junction temperature is reported in degrees Celsius.

Refer to the [Temperature measurement](#) (on page 3-17) section for more information about offset value.

---

## [SENSe:]TCouple:RJUNction:RSElect <name>

Use this command to select a reference junction type, real or simulated.

### Parameters

| <name>    | description                                 |
|-----------|---|
| REAL      | Select a real reference junction type.      |
| SIMulated | Select a simulated reference junction type. |

### Query

| command                            | description   |
|------------------------------------|---|
| [SENSe:]TCouple:RJUNction:RSElect? | Query the reference junction type, real or simulated. |

### Details

Refer to [Thermocouple measurements](#) (on page 3-22) for more information about sensor type.

---

## [SENSe:]TCouple:RJUNction:SIMulated <n>|MIN|MAX

Use this command to select the default temperature of the simulated reference junction.

### Parameters

| <n>         | description  |
|-------------|--|
| -100 to 100 | Select the default temperature value in degrees Celsius. |
| MINimum     | Select the minimum value.                                |
| MAXimum     | Select the maximum value.                                |

### Query

| command                              | description  |
|--------------------------------------|--|
| [SENSe:]TCouple:RJUNction:SIMulated? | Query the temperature of the simulated reference junction. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about sensor type. [Thermocouple measurements](#) (on page 3-22).

---

## [SENSe:]TCouple:TYPE <name>

Use this command to select thermocouple sensor type.

### Parameters

| <name> | description          |
|--------|----------------------|
| B      | Thermocouple type B. |
| C      | Thermocouple type C. |
| E      | Thermocouple type E. |
| J      | Thermocouple type J. |
| K      | Thermocouple type K. |
| N      | Thermocouple type N. |
| R      | Thermocouple type R. |
| S      | Thermocouple type S. |
| T      | Thermocouple type T. |

### Query

| command               | description   |
|-----------------------|---|
| [SENSe:]TCouple:TYPE? | Query thermocouple sensor type. Returns type parameter. |

### Details

Refer to [Thermocouple measurements](#) (on page 3-22) for information about thermocouple types.

### Example

|                |                |
|----------------|----------------|
| TCouple:TYPE J | Select type J. |
|----------------|----------------|

### Also see

[\[SENSe:\]UNIT <name>](#) (on page 5-60)

[\[SENSe:\]TCouple:RJUNction:RSElect <name>](#) (on page 5-50)

---

## [SENSe:]TEMPerature:NTCT:A <n>|MIN|MAX

Use this command to select the A coefficient for the NTCT type.

### Parameters

| <n>       | description                     |
|-----------|---------------------------------|
| 0 to 0.01 | Select the A coefficient.       |
| MINimum   | Select the minimum coefficient. |
| MAXimum   | Select the maximum coefficient. |

### Query

| command                         | description  |
|---------------------------------|--|
| [SENSe:]TEMPerature:NTCT:A?     | Query the A coefficient for the NTCT type.         |
| [SENSe:]TEMPerature:NTCT:A? MIN | Query the minimum A coefficient for the NTCT type. |
| [SENSe:]TEMPerature:NTCT:A? MAX | Query the maximum A coefficient for the NTCT type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the NTCT type: [NTCT temperature calculation](#) (on page 3-19).

---

## [SENSe:]TEMPerature:NTCT:B <n>|MIN|MAX

Use this command to select the B coefficient for the NTCT type.

### Parameters

| <n>       | description                     |
|-----------|---------------------------------|
| 0 to 0.01 | Select the B coefficient.       |
| MINimum   | Select the minimum coefficient. |
| MAXimum   | Select the maximum coefficient. |

### Query

| command                         | description  |
|---------------------------------|--|
| [SENSe:]TEMPerature:NTCT:B?     | Query the B coefficient for the NTCT type.         |
| [SENSe:]TEMPerature:NTCT:B? MIN | Query the minimum B coefficient for the NTCT type. |
| [SENSe:]TEMPerature:NTCT:B? MAX | Query the maximum B coefficient for the NTCT type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the NTCT type: [NTCT temperature calculation](#) (on page 3-19).

## [SENSe:]TEMPerature:NTCT:C <n>|MIN|MAX

Use this command to select the C coefficient for the NTCT type.

### Parameters

| <n>       | description                     |
|-----------|---------------------------------|
| 0 to 0.01 | Select the C coefficient.       |
| MINimum   | Select the minimum coefficient. |
| MAXimum   | Select the maximum coefficient. |

### Query

| command                         | description  |
|---------------------------------|--|
| [SENSe:]TEMPerature:NTCT:C?     | Query the C coefficient for the NTCT type.         |
| [SENSe:]TEMPerature:NTCT:C? MIN | Query the minimum C coefficient for the NTCT type. |
| [SENSe:]TEMPerature:NTCT:C? MAX | Query the maximum C coefficient for the NTCT type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the NTCT type: [NTCT temperature calculation](#) (on page 3-19).

## [SENSe:]TEMPerature:RTD:ALPHA <n>|MIN|MAX

Use this command to select the alpha coefficient for the user-defined RTD type.

### Parameters

| <n>       | description                     |
|-----------|---------------------------------|
| 0 to 0.01 | Select the alpha coefficient.   |
| MINimum   | Select the minimum coefficient. |
| MAXimum   | Select the maximum coefficient. |

### Query

| command                            | description  |
|------------------------------------|--|
| [SENSe:]TEMPerature:RTD:ALPHA?     | Query the alpha coefficient for the user defined RTD type.         |
| [SENSe:]TEMPerature:RTD:ALPHA? MIN | Query the minimum alpha coefficient for the user defined RTD type. |
| [SENSe:]TEMPerature:RTD:ALPHA? MAX | Query the maximum alpha coefficient for the user defined RTD type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about RTD type: [RTD coefficients and temperature calculation](#) (on page 3-19).



## [SENSe:]TEMPerature:RTD:BETA <n>|MIN|MAX

Use this command to select the beta coefficient for the user-defined RTD type.

### Parameters

| <n>     | description                     |
|---------|---------------------------------|
| 0 to 1  | Select the beta coefficient.    |
| MINimum | Select the minimum coefficient. |
| MAXimum | Select the maximum coefficient. |

### Query

| command                           | description   |
|-----------------------------------|---|
| [SENSe:]TEMPerature:RTD:BETA?     | Query the beta coefficient for the user-defined RTD type.         |
| [SENSe:]TEMPerature:RTD:BETA? MIN | Query the minimum beta coefficient for the user-defined RTD type. |
| [SENSe:]TEMPerature:RTD:BETA? MAX | Query the maximum beta coefficient for the user-defined RTD type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about RTD type: [RTD coefficients and temperature calculation](#) (on page 3-19).

## [SENSe:]TEMPerature:RTD:DELTA <n>|MIN|MAX

Use this command to select the delta coefficient for the user-defined RTD type.

### Parameters

| <n>     | description                     |
|---------|---------------------------------|
| 0 to 5  | Select the delta coefficient.   |
| MINimum | Select the minimum coefficient. |
| MAXimum | Select the maximum coefficient. |

### Query

| command                            | description  |
|------------------------------------|--|
| [SENSe:]TEMPerature:RTD:DELTA?     | Query the delta coefficient for the user-defined RTD type.         |
| [SENSe:]TEMPerature:RTD:DELTA? MIN | Query the minimum delta coefficient for the user-defined RTD type. |
| [SENSe:]TEMPerature:RTD:DELTA? MAX | Query the maximum delta coefficient for the user-defined RTD type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about RTD type: [RTD coefficients and temperature calculation](#) (on page 3-19).

## [SENSe:]TEMPerature:RTD:TYPE <name>

Use this command to select the RTD sensor type for temperature measurement with RTD.

### Parameters

| <name> | description             |
|--------|-------------------------|
| PT100  | Select RTD type PT100.  |
| D100   | Select RTD type D100.   |
| F100   | Select RTD type F100.   |
| PT385  | Select RTD type PT385.  |
| PT3916 | Select RTD type PT3916. |
| USER   | Select RTD type USER.   |
| SPRTD  | Select RTD type SPRTD.  |
| NTCT   | Select RTD type NTCT.   |

### Query

| command                       | description  |
|-------------------------------|--|
| [SENSe:]TEMPerature:RTD:TYPE? | Query the RTD type for temperature measurement with RTD. |

### Details

Refer to [Thermocouple measurements](#) (on page 3-22) and [RTD coefficients and temperature calculation](#) (on page 3-19) for information about RTD coefficients.

## [SENSe:]TEMPerature:RTD:RZERO <n>|MIN|MAX

Use this command to set the R-Zero coefficient at 0 degrees Celsius for the user-defined RTD type.

### Parameters

| <n>        | description   |
|------------|---|
| 10 to 1000 | Select the R-Zero coefficient at 0 degrees Celsius. |
| MINimum    | Select the minimum coefficient.                     |
| MAXimum    | Select the maximum coefficient.                     |

### Query

| command                            | description  |
|------------------------------------|--|
| [SENSe:]TEMPerature:RTD:RZERO?     | Query the R-Zero coefficient at 0 degrees Celsius for the user-defined RTD type.         |
| [SENSe:]TEMPerature:RTD:RZERO? MIN | Query the minimum R-Zero coefficient at 0 degrees Celsius for the user-defined RTD type. |
| [SENSe:]TEMPerature:RTD:RZERO? MAX | Query the maximum R-Zero coefficient at 0 degrees Celsius for the user-defined RTD type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about RTD type: [RTD coefficients and temperature calculation](#) (on page 3-19).

## [SENSe:]TEMPerature:SPRTD:RZERO <n>|MIN|MAX

Use this command to set the sensor R coefficient at 0 degrees Celsius.

### Parameters

| <n>        | description                                       |
|------------|---|
| 10 to 1000 | Select sensor R coefficient at 0 degrees Celsius. |
| MINimum    | Select the minimum value.                         |
| MAXimum    | Select the maximum value.                         |

### Query

| command                              | description  |
|--------------------------------------|--|
| [SENSe:]TEMPerature:SPRTD:RZERO?     | Query the sensor R value at 0 degrees Celsius.         |
| [SENSe:]TEMPerature:SPRTD:RZERO? MIN | Query the minimum sensor R value at 0 degrees Celsius. |
| [SENSe:]TEMPerature:SPRTD:RZERO? MAX | Query the maximum sensor R value at 0 degrees Celsius. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about SPRTD type: [RTD coefficients and temperature calculation](#) (on page 3-19).

## [SENSe:]TEMPerature:SPRTD:A4 <n>|MIN|MAX

Use this command to set the A4 coefficient for the SPRTD sensor.

### Parameters

| <n>          | description                     |
|--------------|---------------------------------|
| -1.1 to +1.1 | A4 coefficient.                 |
| MINimum      | Select the minimum coefficient. |
| MAXimum      | Select the maximum coefficient. |

### Query

| command                           | description                              |
|-----------------------------------|--|
| [SENSe:]TEMPerature:SPRTD:A4?     | Query the sensor A4 coefficient.         |
| [SENSe:]TEMPerature:SPRTD:A4? MIN | Query the minimum sensor A4 coefficient. |
| [SENSe:]TEMPerature:SPRTD:A4? MAX | Query the maximum sensor A4 coefficient. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the A4 coefficient: [RTD coefficients and temperature calculation](#) (on page 3-19).

---

## [SENSe:]TEMPerature:SPRTD:B4 <n>|MIN|MAX

Use this command to set the B4 coefficient for the SPRTD sensor.

### Parameters

| parameter    | description                     |
|--------------|---------------------------------|
| -1.1 to +1.1 | B4 coefficient.                 |
| MINimum      | Select the minimum coefficient. |
| MAXimum      | Select the maximum coefficient. |

### Query

| command                           | description                              |
|-----------------------------------|--|
| [SENSe:]TEMPerature:SPRTD:B4?     | Query the sensor B4 coefficient.         |
| [SENSe:]TEMPerature:SPRTD:B4? MIN | Query the minimum sensor B4 coefficient. |
| [SENSe:]TEMPerature:SPRTD:B4? MAX | Query the maximum sensor B4 coefficient. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the B4 coefficient: [RTD coefficients and temperature calculation](#) (on page 3-19).

---

## [SENSe:]TEMPerature:SPRTD:AX <n>|MIN|MAX

Use this command to set the AX coefficient for the SPRTD sensor.

### Parameters

| <n>          | description                                     |
|--------------|---|
| -1.1 to +1.1 | Select the AX coefficient for the SPRTD sensor. |
| MINimum      | Select the minimum coefficient.                 |
| MAXimum      | Select the maximum coefficient.                 |

### Query

| command                           | description                              |
|-----------------------------------|--|
| [SENSe:]TEMPerature:SPRTD:AX?     | Query the sensor AX coefficient.         |
| [SENSe:]TEMPerature:SPRTD:AX? MIN | Query the minimum sensor AX coefficient. |
| [SENSe:]TEMPerature:SPRTD:AX? MAX | Query the maximum sensor AX coefficient. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the AX coefficient: [RTD coefficients and temperature calculation](#) (on page 3-19).

---

## [SENSe:]TEMPerature:SPRTD:BX <n>|MIN|MAX

Use this command to set the BX coefficient for the SPRTD sensor.

### Parameters

| <n>          | description                                     |
|--------------|---|
| -1.1 to +1.1 | Select the BX coefficient for the SPRTD sensor. |
| MINimum      | Select the minimum coefficient.                 |
| MAXimum      | Select the maximum coefficient.                 |

### Query

| command                           | description                              |
|-----------------------------------|--|
| [SENSe:]TEMPerature:SPRTD:AX?     | Query the sensor BX coefficient.         |
| [SENSe:]TEMPerature:SPRTD:AX? MIN | Query the minimum sensor BX coefficient. |
| [SENSe:]TEMPerature:SPRTD:AX? MAX | Query the maximum sensor BX coefficient. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the BX coefficient: [RTD coefficients and temperature calculation](#) (on page 3-19).

---

## [SENSe:]TEMPerature:SPRTD:CX <n>|MIN|MAX

Use this command to set the CX coefficient for the SPRTD sensor.

### Parameters

| <n>          | description                                     |
|--------------|---|
| -1.1 to +1.1 | Select the CX coefficient for the SPRTD sensor. |
| MINimum      | Select the minimum coefficient.                 |
| MAXimum      | Select the maximum coefficient.                 |

### Query

| command                           | description                              |
|-----------------------------------|--|
| [SENSe:]TEMPerature:SPRTD:CX?     | Query the sensor CX coefficient.         |
| [SENSe:]TEMPerature:SPRTD:CX? MIN | Query the minimum sensor CX coefficient. |
| [SENSe:]TEMPerature:SPRTD:CX? MAX | Query the maximum sensor CX coefficient. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the CX coefficient: [RTD coefficients and temperature calculation](#) (on page 3-19).

---

## [SENSe:]TEMPerature:SPRTD:DX <n>|MIN|MAX

Use this command to set the DX coefficient for the SPRTD sensor.

### Parameters

| <n>          | description                                     |
|--------------|---|
| -1.1 to +1.1 | Select the DX coefficient for the SPRTD sensor. |
| MINimum      | Select the minimum coefficient.                 |
| MAXimum      | Select the maximum coefficient.                 |

### Query

| command                           | description                              |
|-----------------------------------|--|
| [SENSe:]TEMPerature:SPRTD:DX?     | Query the sensor DX coefficient.         |
| [SENSe:]TEMPerature:SPRTD:DX? MIN | Query the minimum sensor DX coefficient. |
| [SENSe:]TEMPerature:SPRTD:DX? MAX | Query the maximum sensor DX coefficient. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about the DX coefficient: [RTD coefficients and temperature calculation](#) (on page 3-19).

---

## [SENSe:]TEMPerature:TRANsducer <name>

Use this command to select the temperature transducer type.

### Parameters

| <name> | description                                     |
|--------|---|
| RTD    | Select 2-wire RTD.                              |
| FRTD   | Select 4-wire RTD (also works with 3-wire RTD). |

### Query

| command                              | description                            |
|--------------------------------------|--|
| [SENSe:]TEMPerature:TRANsducer:TYPE? | Query the temperature transducer type. |

### Details

Refer to the following topic in the [Temperature measurement](#) (on page 3-17) section for more information about RTD measurement: [RTD coefficients and temperature calculation](#) (on page 3-19).

---

## [SENSe:]UNIT <name>

Use this command to select units for temperature measurement.

### Parameters

| <name> | description |
|--------|-------------|
| Cel    | Celsius     |
| Far    | Fahrenheit  |
| K      | Kelvin      |

### Query

| command       | description                           |
|---------------|---------------------------------------|
| [SENSe:]UNIT? | Query unit sensor type. Returns type. |

### Details

Select units for temperature measurement. Refer to the following topics in the [Temperature measurement](#) (on page 3-17) section for more information about units: [RTD coefficients and temperature calculation](#) (on page 3-19) and [Entering sensor coefficients](#) (on page 3-20)

---

## [SENSe:]VOLTage:AC:RANGe <n>|MIN|MAX

Use this command to select the measurement range for the ACV function.

### Parameters

| <n>      | description                            |
|----------|--|
| 0 to 750 | Select the measurement range in volts. |
| MINimum  | Select the minimum value.              |
| MAXimum  | Select the maximum value.              |

### Query

| command                       | description                  |
|-------------------------------|------------------------------|
| [SENSe:]VOLTage:AC:RANGe?     | Query the measurement range. |
| [SENSe:]VOLTage:AC:RANGe? MIN | Query the minimum range.     |
| [SENSe:]VOLTage:AC:RANGe? MAX | Query the maximum range.     |

---

## [SENSe:]VOLTage:AC:RANGe:AUTO <b>

This command turns autorange on or off for AC voltage measurements.

### Parameters

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

### Query

| command                        | description                       |
|--------------------------------|-----------------------------------|
| [SENSe:]VOLTage:AC:RANGe:AUTO? | Query AC voltage autorange state. |

---

## [SENSe:]VOLTage:AC:RESolution <n>|MIN|MAX

Use this command to select resolution for AC voltage measurements (ACV).

### Parameters

| <n>                                | description                               |
|------------------------------------|---|
| (1.00e-06 to 1.00e-04) * ACV range | Select the resolution of the measurement. |
| MINimum                            | Select the minimum value.                 |
| MAXimum                            | Select the maximum value.                 |

### Query

| command                            | description                       |
|------------------------------------|-----------------------------------|
| [SENSe:]VOLTage:AC:RESolution?     | Query the measurement resolution. |
| [SENSe:]VOLTage:AC:RESolution? MIN | Query the minimum resolution.     |
| [SENSe:]VOLTage:AC:RESolution? MAX | Query the maximum resolution.     |

### Details

Refer to [Bandwidth and resolution for AC measurements](#) (on page 3-44) more information about resolution.



---



---

## [SENSe:]VOLTage[:DC]:RANGe <n>MIN|MAX

Use this command to select the measurement range for the DCV function.

### Parameters

| <n>           | description                            |
|---------------|--|
| -1000 to 1000 | Select the measurement range in volts. |
| MINimum       | Select the minimum value.              |
| MAXimum       | Select the maximum value.              |

### Query

| command                         | description                  |
|---------------------------------|------------------------------|
| [SENSe:]VOLTage[:DC]:RANGe?     | Query the measurement range. |
| [SENSe:]VOLTage[:DC]:RANGe? MIN | Query the minimum range.     |
| [SENSe:]VOLTage[:DC]:RANGe? MAX | Query the maximum range.     |

---



---

## [SENSe:]VOLTage[:DC]:RANGe:AUTO <b>

This command turns autorange on or off for DC voltage measurements.

### Parameters

| <b>      | description         |
|----------|---------------------|
| 0 or OFF | Turn autorange off. |
| 1 or ON  | Turn autorange on.  |

### Query

| command                          | description                       |
|----------------------------------|-----------------------------------|
| [SENSe:]VOLTage[:DC]:RANGe:AUTO? | Query DC voltage autorange state. |

---

## [SENSe:]VOLTage[:DC]:NPLCycles <n>|MIN|MAX

Use this command to select the integration time for voltage measurements. Integration time for DCV measurements is expressed as the number of power line cycles (NPLC).

### Parameters

| <n>     | description               |
|---------|---------------------------|
| 0.001   | Select 0.001 NPLC.        |
| 0.006   | Select 0.006 NPLC.        |
| 0.02    | Select 0.02 NPLC.         |
| 0.06    | Select 0.06 NPLC.         |
| 0.2     | Select 0.2 NPLC.          |
| 0.6     | Select 0.6 NPLC.          |
| 1       | Select 1 NPLC.            |
| 2       | Select 2 NPLC.            |
| 10      | Select 10 NPLC.           |
| 100     | Select 100 NPLC.          |
| MINimum | Select the minimum value. |
| MAXimum | Select the maximum value. |

### Query

| command                             | description              |
|-------------------------------------|--------------------------|
| [SENSe:]VOLTage[:DC]:NPLCycles?     | Query the NPLCycles.     |
| [SENSe:]VOLTage[:DC]:NPLCycles? MIN | Query the minimum value. |
| [SENSe:]VOLTage[:DC]:NPLCycles? MAX | Query the maximum value. |

### Details

Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) more information about NPLC.

## [SENSe:]VOLTage[:DC]:RESolution <n>|MIN|MAX

Use this command to select resolution for DC voltage measurements (DCV).

### Parameters

| <n>                                | description                               |
|------------------------------------|---|
| (3.00e-07 to 3.00e-04) * DCV range | Select the resolution of the measurement. |
| MINimum                            | Select the minimum value.                 |
| MAXimum                            | Select the maximum value.                 |

### Query

| command                              | description                  |
|--------------------------------------|------------------------------|
| [SENSe:]VOLTage[:DC]:RESolution?     | Query the measurement range. |
| [SENSe:]VOLTage[:DC]:RESolution? MIN | Query the minimum range.     |
| [SENSe:]VOLTage[:DC]:RESolution? MAX | Query the maximum range.     |

### Details

Refer to [Integration time and resolution for DC and resistance measurements](#) (on page 3-41) more information about resolution.

## NOTE

When you set the resolution, the instrument automatically updates the integration time.

## [SENSe:]ZERO:AUTO <name>

Use this command to turn autozero mode on, on once, or off. The OFF and ONCE parameters have a similar effect. OFF mode takes an immediate zero measurement, but then does not issue a new offset measurement until the multimeter goes to the "WAIT-FOR-TRIGGER" state.

### Parameters

| <name> | description                                |
|--------|--|
| OFF    | Turn autozero off.                         |
| ON     | Turn autozero on.                          |
| ONCE   | ONCE issues an immediate zero measurement. |

### Query

| command            | description  |
|--------------------|--|
| [SENSe:]ZERO:AUTO? | Query the auto zero mode. Returns 1 for on, 0 for off or once. |

### Details

Refer to [Autozero](#) (on page 3-38) for more information about autozero.

## SYSTem subsystem

The SYSTem subsystem contains miscellaneous commands that are summarized in [SYSTem subsystem summary](#) (on page 5-25).

---

### :BEEPer <b>

This command turns the beeper on or off for limit tests, diode tests, and reading hold.

#### Parameters

| <b>      | description      |
|----------|------------------|
| 0 or OFF | Turn beeper off. |
| 1 or ON  | Turn beeper on.  |

#### Query

| command | description   |
|---------|---|
| BEEPer? | Query the state of the beeper. Returns 0 (off) or 1 (on). |

#### Example

|           |                      |
|-----------|----------------------|
| BEEPer ON | Turns on the beeper. |
|-----------|----------------------|

---

### :DATA:POINTs?

Query the number of readings stored in the instrument's internal memory.

#### Parameters

None.

#### Query

| command       | description  |
|---------------|--|
| :DATA:POINTs? | Query the number of readings stored in the multimeter's internal memory. |

---

### SYSTem:ERRor?

Query the multimeter's error queue. Up to 20 errors can be stored in the queue. Errors are retrieved in first-in-first-out (FIFO) order. Each error string may contain up to 80 characters.

#### Query

This query command returns an error code. For example:

```
-102 Syntax error
```

Refer to [Error codes](#) (on page 6-3) for information about the error codes.

---

---

## SYSTem:IDNStr <string>

Use this command to change the identification string.

### Parameters

| <string>               | description  |
|------------------------|--|
| "MANUFACTURER,PRODUCT" | The identification string. No more than 39 characters. |

### Details

To query the identification string, use \*IDN?. Make sure that the DMM is in compatible mode (see [Selecting the language](#) (on page 2-23) for details).

---

---

## SYSTem:LOCal

Place the instrument in the local mode. All keys on the front panel are fully functional.

### Query

None.

---

---

## SYSTem:REMOte

Place the multimeter in the remote mode. All buttons on the front panel, except the LOCAL button, are disabled.

### Query

None.

---

---

## SYSTem:VERSion?

Query the present SCPI version.

### Query

This query command returns the SCPI version. For example:  
1991.0

## TRIGger subsystem

The commands in this subsystem configure and control the trigger operations and are summarized in [TRIGger subsystem summary](#) (on page 5-26).

When the instrument is triggered to start performing measurements, it stores a specified number of measurement readings in the data buffer (memory).

The total number of measurements the instrument takes is the product of the trigger count and sample count. See [Sample count](#) (on page 3-33) and [Trigger count](#) (on page 3-33) for details.

Use the following command to place the instrument in the wait-for-trigger state:

[:INITiate](#) (on page 5-16)

Use the following command to retrieve the stored readings:

[:FETCh\[1|2\]?](#) (on page 5-16)

Use the following command to query the number of stored readings:

[:DATA:POINts?](#) (on page 5-65)

---

## SAMPlE:COUNT <n>|MIN|MAX

Use this command to set the number of readings (samples) the instrument takes per trigger. Select a number from 1 to 50,000 readings per trigger.

### Parameters

| <n>         | description   |
|-------------|---|
| 1 to 50,000 | Select the number of readings (samples) the instrument takes per trigger. |
| MINimum     | Select the minimum value.   |
| MAXimum     | Select the maximum value.   |

### Query

| command           | description                          |
|-------------------|--------------------------------------|
| SAMPlE:COUNT?     | Query the number of samples.         |
| SAMPlE:COUNT? MIN | Query the minimum number of samples. |
| SAMPlE:COUNT? MAX | Query the maximum number of samples. |

## TRIGger:COUNT <n>|MIN|MAX|INFinite

Use this command to specify the number of triggers the instrument will accept before returning to the “idle” state. Select from 1 to 50,000 triggers. Trigger count is ignored while in local operation.

### Parameters

| <n>         | description   |
|-------------|---|
| 1 to 50,000 | Select value for the number of triggers.                                  |
| MINimum     | Select the minimum value.   |
| MAXimum     | Select the maximum value.   |
| INFinite    | Select INFinite to instruct the instrument to take triggers continuously. |

### Query

| command            | description  |
|--------------------|--|
| TRIGger:COUNT?     | Query the number of triggers. Returns “9.90000000E+37” when you select the infinite trigger count. |
| TRIGger:COUNT? MIN | Query the minimum number of triggers.  |
| TRIGger:COUNT? MAX | Query the maximum number of triggers.  |

## TRIGger:DElay <n>|MIN|MAX

Use this command to select a trigger delay time in seconds. The delay is the time between the trigger signal and each sample that follows. Specify a delay time from 0 to 3600 seconds.

### Parameters

| <n>       | description                                  |
|-----------|--|
| 0 to 3600 | Specify a delay time from 0 to 3600 seconds. |

### Query

| command            | description                           |
|--------------------|---------------------------------------|
| TRIGger:DElay?     | Query the trigger delay time.         |
| TRIGger:DElay? MAX | Query the minimum trigger delay time. |
| TRIGger:DElay? MIN | Query the maximum trigger delay time. |

### Details

Refer to [Trigger delay](#) (on page 3-34) for information about sources.

---

## TRIGger:DElay:AUTO <b>

Turn automatic trigger delay on or off.

The delay is determined by function, range, integration time, and AC filter setting. Specifying a delay time automatically turns off the automatic trigger delay.

### Parameters

| <b>      | description                                |
|----------|--|
| 0 or OFF | Turn selected automatic trigger delay off. |
| 1 or ON  | Turn automatic trigger delay on.           |

### Query

| command             | description  |
|---------------------|--|
| TRIGger:DElay:AUTO? | Query the automatic trigger delay mode. Returns 0 (OFF) or 1 (ON). |

---

## TRIGger:SOURce <name>

Use this command to select a trigger source. The instrument accepts a software (BUS) trigger, an immediate internal trigger, or a hardware trigger from the rear-panel EXT TRIG terminal.

### Parameters

| <name>    | description  |
|-----------|--|
| BUS       | Select software trigger.                                       |
| IMMediate | Select immediate internal trigger.                             |
| EXTernal  | Select hardware trigger from the rear-panel EXT TRIG terminal. |

### Query

| command         | description               |
|-----------------|---------------------------|
| TRIGger:SOURce? | Query the trigger source. |

### Details

Refer to [Trigger sources](#) (on page 3-30) for information about sources.





---

## Troubleshooting guide

### In this section:

---

|                           |     |
|---------------------------|-----|
| Troubleshooting .....     | 6-1 |
| Running a self-test ..... | 6-2 |
| Error codes.....          | 6-3 |

## Troubleshooting

This section provides information to help you troubleshoot problems with your instrument.

Refer to the following Websites for information about your instrument:

1. [Keithley Instruments website](http://www.keithley.com) (*http://www.keithley.com*)
2. [Keithley web forum](http://forum.keithley.com) (*http://forum.keithley.com*)

Refer to the [Displaying the instrument's serial number](#) (on page 1-5) section for information about your instrument's serial number.

Refer to the remainder of this section for information about running a self test and error codes.

## Running a self-test

Self-test procedures are built into the Model 2110 for checking that the logic and measurement hardware are functioning properly. Every time the instrument is powered on, these test procedures are performed to make sure the basic functions of the instrument work properly. If any error occurs during self-test procedures, it indicates that parts of the instrument are not operating properly and may need to be serviced.



### CAUTION

Erroneous self-test failures may occur under the following conditions:

- Signals are present on the input terminal during self-test procedure.
- Long test leads act as an antenna, causing pick-up of AC signals.
- Power line voltages are not set correctly.

You may also run self-tests on the instrument that provide additional hardware testing.

**To run a self-test, use the following procedure:**

1. Press the **SHIFT** and **CONFIG (MENU)** keys to display the MENU options.
2. Use the **▶** and **◀** keys to display SYSTEM, and then press the **ENTER** key.
3. Use the **▶** and **◀** keys to display SELF TEST, and then press the **ENTER** key. The instrument runs the test and shows the results on the display as follows:
  - TEST PASS - if the test passes.
  - TEST FAIL - if the test fails. The instrument also lights the **ERR** indicator if the test fails.

If there are errors, refer to [Viewing errors in the error queue](#) (on page 2-24) for information about how to view the errors.

## Error codes

Errors are retrieved in first-in-first-out (FIFO) order. The first error returned is the first error that was stored. When you have read all errors from the queue, the ERROR indicator turns off. The instrument beeps once each time an error occurs.

If more than 20 errors occur, the last error stored in the queue (the most recent error) is replaced with the error code:

```
-350, "Too many errors"
```

No additional errors are saved until you remove errors from the queue. After you remove errors from the queue, the instrument responds with:

```
+0, "No error"
```

The following conditions clear the error queue:

- Turning off the power
- Sending a \*CLS (clear status) command

The \*RST (reset) command does not clear the error queue.

Refer to [Viewing errors in the error queue](#) (on page 2-24) for information about how to view the errors.

This topic provides information about execution errors (EE) and self-test errors (ST).

| Error code                       | Type | Description   |
|----------------------------------|------|---|
| -101 Invalid character           | EE   | An invalid character was found in the command string.   |
| -102 Syntax error.               | EE   | Invalid syntax was found in the command string.   |
| -103 Invalid separator           | EE   | An invalid separator was found in the command string.   |
| -104 Data type error             | EE   | A parameter type error was found in the command string.   |
| -105 GET not allowed             | EE   | A Group Execute Trigger (GET) is not allowed in the command string.                                   |
| -108 Parameter not allowed       | EE   | More parameters were found than needed for the command.   |
| -109 Missing parameter           | EE   | Not enough parameters were received for the command.  |
| -112 Program mnemonic too long   | EE   | A command header with too many characters was received.   |
| -113 Undefined header            | EE   | An invalid command was received.  |
| -121 Invalid character in number | EE   | An invalid character was found in the number specified for a parameter value.                         |
| -123 Numeric overflow            | EE   | A numeric parameter with exponent larger than 32000 was found.  |
| -124 Too many digits             | EE   | A numeric parameter was found whose mantissa contained more than 255 digits, excluding leading zeros. |
| -131 Invalid suffix              | EE   | A suffix was incorrectly specified for a numeric parameter.   |
| -138 Suffix not allowed          | EE   | A suffix was received following a numeric parameter which does not accept a suffix.                   |
| -148 Character not allowed       | EE   | A discrete parameter was received but a character string or a numeric parameter was expected.         |
| -151 Invalid string data         | EE   | An invalid character string was received.   |
| -158 String data not allowed     | EE   | A character string was received but not allowed for the command.                                      |
| -160~~168 Block data errors      | EE   | Block data is not acceptable.   |
| -170~~178 Expression errors      | EE   | The meter does not accept mathematical expression.  |
| -211 Trigger ignored             | EE   | A Group Execute Trigger (GET) or *TRG was received but the trigger was ignored.                       |

| Error code  | Type | Description  |
|---|------|--|
| -213 Init Ignored                                 | EE   | An INITiate command was received but could not be executed because a measurement was already in progress. Send a device clear to halt a measurement in progress and place the meter in the idle state.   |
| -214 Trigger deadlock                             | EE   | A trigger deadlock occurs when the trigger source is BUS and a READ? command is received.  |
| -221 Settings conflict                            | EE   | This error can be generated in one of the following situations: <ul style="list-style-type: none"> <li>Situation 1: You sent a CONFigure or MEASure command with autorange enabled and with a fixed resolution.</li> <li>Situation 2: You turned math on and then changed to a math operation that was not valid with the present measurement function.</li> <li>Situation 3: When the autorange is enabled at the DCI's and ACI's 10A ranges, the error message will be generated.</li> </ul> |
| -222 Data out of range                            | EE   | A numeric parameter value is out of range.   |
| -223 Too much data                                | EE   | A character string was too long.   |
| 223 2nd function mismatch                         | EE   | The 1st and 2nd functions mismatch.  |
| -224 Illegal parameter value                      | EE   | A discrete parameter was received that was not a valid choice for the command.   |
| 225 Function/range mismatch                       |      | The measurement function and the range specified for the function are mismatched.  |
| -230 Data Stale                                   | EE   | A FETCh? command was received, but the memory was empty.   |
| -350 Too many errors                              | EE   | The error queue is full.   |
| -410 Query INTERRUPTED                            | EE   | A command was received that sends data to the output buffer, but the output buffer contained data from a previous command.   |
| -420 Query UNTERMINATED                           | EE   | The instrument was addressed to talk (for example, to send data over the interface), but a command has not been received that will send data to the output buffer.   |
| -430 Query DEADLOCKED                             | EE   | A command was received that generates too much data to fit in the output buffer at the same time that the input buffer was full. Command execution continues, but all data is lost.  |
| -440 Query UNTERMINATED after indefinite response | EE   | The *IDN? command must be the last query command within a command string.  |
| 521 Input buffer overflow                         | EE   | Input buffer overflow.   |
| 522 Output buffer overflow                        | EE   | Output buffer overflow.  |
| 531 Insufficient memory                           | EE   | There is not enough memory to store the requested number of readings in internal memory using the INITiate command. The product of the sample count (SAMPLE:COUNT) and the trigger count (TRIGger:COUNT) must not exceed 2000 readings.  |
| 532 Cannot achieve requested resolution           | EE   | The instrument cannot achieve the requested measurement resolution. You may have specified an invalid resolution in the CONFigure or MEASure command.  |
| 540 Cannot use overload as math reference         | EE   | The instrument cannot store an overload reading (9.90000000E+37) as the math reference for null or dB measurements. The math state is turned off as a result of this condition.  |
| 550 Command not allowed in local                  | EE   | The instrument received a READ? command while in the local mode.   |
| 601 Front panel does not respond                  | ST   | The main CPU U1601 attempts to establish serial communications with the front-panel processor U3. Communication must function in both directions for this test to pass.  |
| 602 RAM read/write failed                         | ST   | This test writes and reads a 55h and AAh checkerboard pattern to each address of RAM U1701. Any incorrect read back will cause a test failure. This error is only readable from the remote interface.  |

| Error code                            | Type | Description   |
|---------------------------------------|------|---|
| 603 Front-End MCU does not respond    | ST   | The main CPU U1601 attempts to establish serial communications with the front-end processor U2001. Communication must function in both directions for this test to pass.  |
| 604 A/D noisy test failed             | ST   | This test configures to the 10 V DC range with the internal 0 V. A 20 ms ADC measurement is performed, and the result is checked against a limit of $0\text{ V} \pm 20\ \mu\text{V}$ .  |
| 605 N2 calibration parameter failed:  | ST   | This error message indicates that N2 calibration parameter is out of range.   |
| 606 N3 calibration parameter failed:  | ST   | This error message indicates that N3 calibration parameter is out of range.   |
| 607 Buffer1 offset out of range       | ST   | This procedure is to test the offset of buffer U507. The result is checked against a limit of $0 \pm 0.1\text{ mV}$   |
| 608 Buffer2 offset out of range       | ST   | This procedure is to test the offset of buffer U508. The result is checked against a limit of $0 \pm 0.1\text{ mV}$   |
| 609 DC gain x1 failed                 | ST   | This procedure is to test the tolerance of DC gainx1 amplifier. The limit of gain tolerance is $\pm 0.005$ .  |
| 610 DC gain x10 failed                | ST   | This procedure is to test the tolerance of DC gainx10 amplifier. The limit of gain tolerance is $\pm 0.05$ .  |
| 611 DC gain x100 failed               | ST   | This procedure is to test the tolerance of DC gainx100 amplifier. The limit of gain tolerance is $\pm 0.5$ .  |
| 612 Ohms 500 nA source failed         | ST   | This test configures to the 10 V DC range with the internal 10 M 100:1 divider R204 connected across the input. The 500 nA ohms current source is connected to produce a nominal 5 V signal. A 20 ms A DC measurement is performed, and the result is checked against a limit of $5\text{ V} \pm 1\text{ V}$ .  |
| 613 Ohms 5 uA source failed           | ST   | This test configures to the 1000 V DC range with the internal 10 M 100:1 divider R204 connected across the input. The 5 $\mu\text{A}$ ohms current source is connected. The compliance limit of the current source is measured. A 20 ms A DC measurement is performed, and the result is checked against a limit of $0.12\text{ V} \pm 0.01\text{ V}$ .   |
| 614 DC 1000V zero failed              | ST   | This test configures to the 1000 V DC range with no input applied. A 20 ms A DC measurement is performed, and the result is checked against a limit of $0\text{V} \pm 5\text{ mV}$ .  |
| 615 Ohms 10 uA source failed          | ST   | This test configures to the 1000 V DC range with the internal 10 M 100:1 divider R204 connected across the input. The 10 $\mu\text{A}$ ohms current source is connected. The compliance limit of the current source is measured. A 20 ms A DC measurement is performed, and the result is checked against a limit of $0.12\text{ V} \pm 0.01\text{ V}$ .  |
| 616 DC current sense failed           | ST   | This test configures to the 3 A DC range. A 20 ms A DC measurement is performed, and the result is checked against a limit of $0\text{ A} \pm 5\text{ A}$ . This test confirms that the DC current sense path is functional. The test limit is set wide because K303 does not open the current input during self-test. This test should catch a DC current sense failure without causing false failures when current inputs are applied during self-test. |
| 617 Ohms 100 uA source failed         | ST   | This test configures to the 1000 V DC range with the internal 10 M 100:1 divider R204 connected across the input. The 100 $\mu\text{A}$ ohms current source is connected. The compliance limit of the current source is measured. A 20 ms A DC measurement is performed, and the result is checked against a limit of $0.12\text{ V} \pm 0.01\text{ V}$ .   |
| 618 DC high voltage attenuator failed | ST   | This test configures to the 1000 V DC range. The 500 nA ohms current source is connected to produce a nominal 5 V signal. A 20 ms A DC measurement is performed, and the result is checked against a limit of $5\text{ V} \pm 1\text{ V}$ .   |

| Error code                         | Type     | Description  |
|------------------------------------|----------|--|
| 619 Ohms 1 mA source failed        | ST       | This test configures to the 1000 V DC range with the internal 10 M 100:1 divider R204 connected across the input. The 1 mA ohms current source is connected. The compliance limit of the current source is measured. A 20 ms A DC measurement is performed, and the result is checked against a limit of $0.12 \text{ V} \pm 0.01 \text{ V}$ .         |
| 620 AC rms zero failed             | ST       | This test configures for the 100 mV AC range with the AC input grounded. The internal residual noise of the AC section is measured and checked against a limit of -10 mV to 70 mV at the output of the RMS-to-DC converter.  |
| 621 AC rms full scale failed       | ST       | This test configures for the 100 m V AC range. The 1 mA ohms current source is switched on to charge the AC input capacitor C614. This produces a pulse on the output of the RMS-to-DC converter, which is sampled 100 ms after the current is applied. A 20 ms A/D measurement is performed and checked against a limit of 2 V to 13 V into the A DC. |
| 624 Unable to sense line frequency | EE<br>ST | The AC line frequency cannot be measured after powering on the instrument. The instrument will assume 50 Hz line operation for all future measurements.  |
| 640 Meas setting failed            | EE       | You cannot command to set through the A/D.   |
| 641 Meas reading failed            | EE       | You cannot command to read from A/D.   |
| 642 Board Protect failed           | EE       | The specific IC is malfunctioning or missing. All communication is blocked.  |
| 650 Panel failed                   | EE       | The main board cannot communicate with the front panel.  |
| 651 Panel Program Checksum Error   | EE       | The checksum from the front panel is incorrect.  |

#### In this section:

---

[Additional Model 2110 information .....](#) 7-1

### Additional Model 2110 information

This manual has prepared you to start using your new Model 2110 instrument.

For additional information on the Model 2110, refer to:

- The Product Information CD-ROM (ships with the product): Contains software tools, drivers, and product documentation.
- The [Keithley Instruments website](http://www.keithley.com) (<http://www.keithley.com>): Contains the most up-to-date information; from the website, you can access:
  - The Knowledge Center, which contains the following handbooks:
    - *The Low Level Measurements Handbook: Precision DC Current, Voltage, and Resistance Measurements*
    - *Switching Handbook: A Guide to Signal Switching in Automated Test Systems*
  - Application notes
  - Updated drivers
- Your local Field Applications Engineer can help you with product selection, configuration, and usage. Check the website for contact information.





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# Maintenance

## In this appendix:

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| Line fuse replacement .....          | A-1 |
| Current input fuse replacement ..... | A-3 |
| Upgrading the firmware .....         | A-4 |

## Introduction

This section provides maintenance information and procedures that can be performed by the operator.

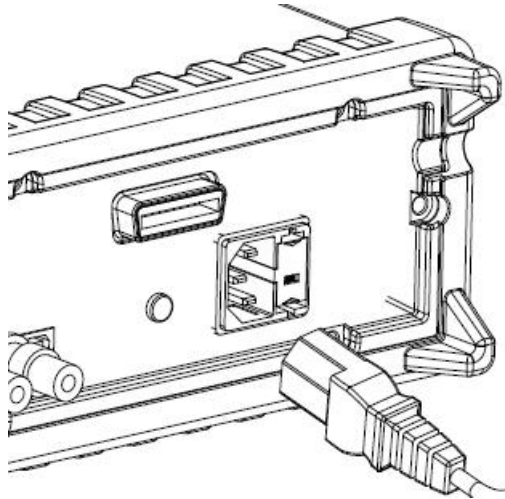
## Line fuse replacement

A fuse located on the Model 2110 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.*

The power line fuse is accessible from the rear panel, adjacent to the AC power receptacle, as shown in the following figure.

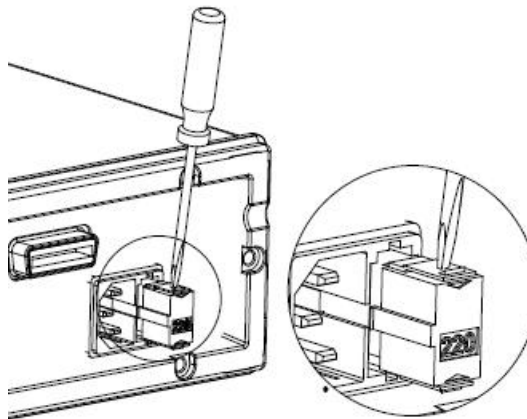
**Figure 38: Plug in power switch**

Perform the following steps to replace the line fuse:

### **⚠ WARNING**

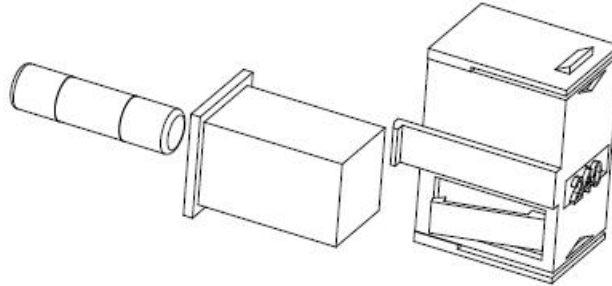
*To prevent injury, death, or instrument damage, use only the correct fuse type.*

1. Power-off the instrument and remove the line cord.
2. The voltage selector container is located next to the AC receptacle. A small tab is located on the top of the container. Using a thin-bladed knife or a screwdriver, pry this tab away from the AC receptacle.
3. Slide the voltage selector container out to gain access to the fuse, as shown in the following figure.

**Figure 39: Remove voltage selector**

4. Snap the fuse out of voltage selector container and replace it with the same type.

**Figure 40: Removing a broken fuse**



5. Push the voltage selector container back into the module.

If the power line fuse continues to blow, a circuit malfunction exists and must be corrected. Return the unit to Keithley Instruments for repair.

## Current input fuse replacement

The Model 2110 uses two fuses to protect it from excessive input current:

- 3 A, 250 V, 5 x 20 mm, slow-blow fuse
- 15 A, 250 V, 5 x 20 mm, slow-blow fuse

### **⚠ WARNING**

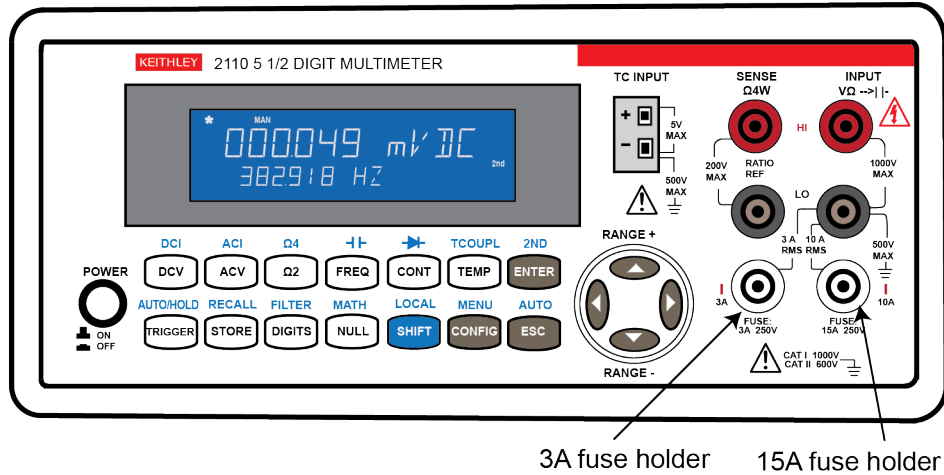
*Disconnect the line cord at the rear panel and remove all test leads connected to the instrument before replacing a current input fuse. Failure to do so could expose you to hazardous voltages that could result in personal injury or death.*

*Replace the fuse with recognized fuses with the same rating (250 V/250 mA T). Failure to use the correct fuse can result in personal injury and instrument damage. If the instrument repeatedly blows fuses, have the unit serviced at an authorized repair facility.*

As shown in the following figure, the current input fuses are located in the current input terminals. Perform the following steps to replace a blown fuse:

1. Push in the fuse holder and turn it to the right until it releases.
2. Pull out the fuse holder to expose the current input fuse.
3. Remove the blown fuse and replace it with the same fuse type and rating.
4. Reinsert the fuse holder, turning it to the left as you push it in. Ensure that the fuse holder is properly seated and secured.

**Figure 41: Current input fuses**



## Upgrading the firmware

Refer to the [Keithley Instruments website \(http://www.keithley.com\)](http://www.keithley.com) for information about upgrading the firmware.

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## Status model

### In this appendix:

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| Clearing registers and queues.....          | B-3  |
| Programming enable registers .....          | B-3  |
| Reading registers .....                     | B-3  |
| Status byte and service request (SRQ) ..... | B-4  |
| Status register sets.....                   | B-8  |
| Status reporting command summary.....       | B-10 |

## Overview

The Model 2110 provides a series of status registers and queues, allowing the operator to monitor and manipulate the various instrument events. The status structure is shown in following figure. The heart of the status structure is the Status Byte Register. This register can be read by the user's test program to determine if a service request (SRQ) has occurred, and what event caused it.

## Status byte and SRQ

The Status Byte Register receives the summary bits of the status register sets, queue, and buffer. The registers monitor the various instrument events. When an enabled event occurs, it sets a summary bit in the Status Byte Register. When a summary bit of the Status Byte and its corresponding enable bit are set (as programmed by the user), the Request Service (RQS) bit will set to indicate that a service request (SRQ) has occurred.

## Status register sets

A typical status register set is made up of an event register and an event enable register.

The event enable register:

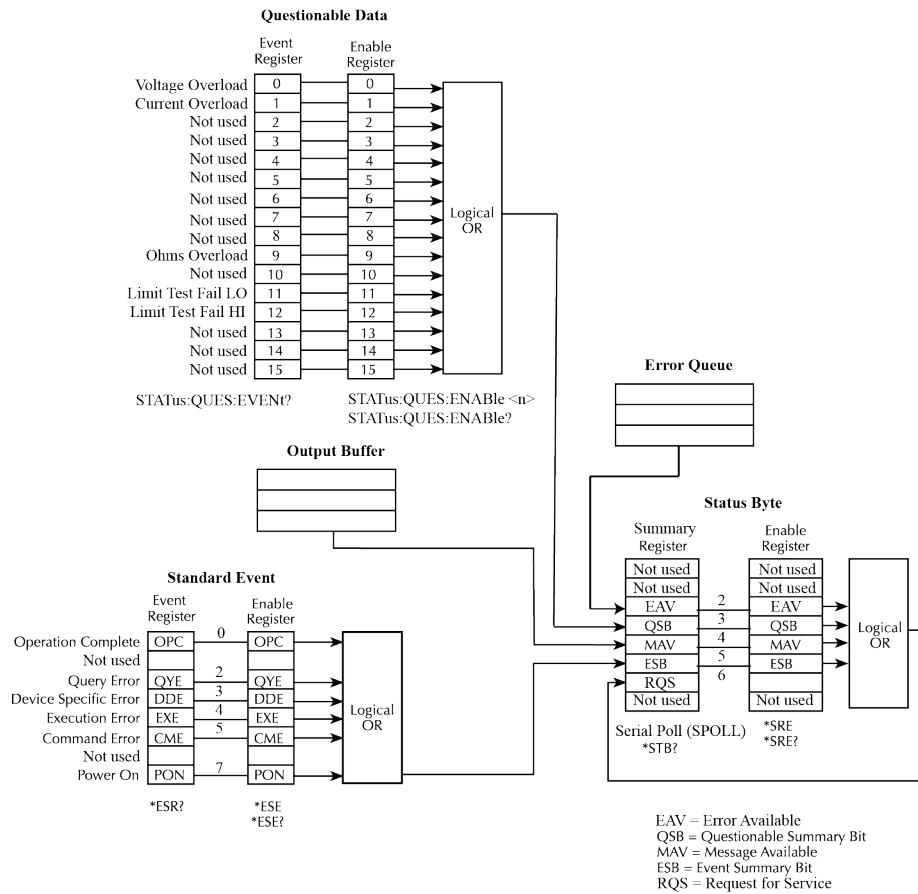
- Accepts both read and write operations
- Indicates bits in the corresponding event register that are ORed together to produce the summary bit of the event register.

When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. When an event register bit and its corresponding enable bit are set (as programmed by the user), the output (summary) of the register will set to 1, which then sets the summary bit of the Status Byte Register.

## Error Queue and Output Buffer

The instrument uses an Output Buffer and an Error Queue. The response messages to query commands are placed in the Output Buffer. As various programming errors and status messages occur, they are placed in the Error Queue. When a queue contains data, it sets the appropriate summary bit of the Status Byte Register.

Figure 42: Status model



## Clearing registers and queues

When the instrument is turned on, the bits of all registers in the status structure are cleared (reset to 0), and the queue and buffer are empty. Commands to reset the Event and Event Enable registers, and the Error Queue, are listed in the following table. In addition to these commands, any enable register can be reset by sending the 0 parameter value with the individual command to program the register.

### Common and SCPI commands to reset registers and clear queues

| Commands   | Description  | Ref.   |
|--|--|--------|
| <b>To reset registers:</b><br>*CLS<br>*SRE 0<br>*PSC 1 | Reset all bits of the following event registers to 0:<br>Standard Event Register<br>Questionable Data Register<br>Clear enable registers:<br>If command sent previously, turning on instrument power clears the enable registers | Note 1 |
| <b>To clear error queue:</b><br>*CLS                   | Clear all messages from Error Queue  | Note 1 |

## NOTE

1. The Standard Event Enable Register is not reset by \*CLS. Send the 0 parameter value with \*ESE to reset all bits of that enable register to 0 (see [Status byte and service request commands](#) (on page B-7)). When the instrument is powered on, the Standard Event Enable Register will not be cleared if users have set the instrument previously by using \*PSC 0.
2. Querying the Standard Event and Questionable Data Registers only clears their respective summary register bits.

## Programming enable registers

The only registers that can be programmed by the user are the enable registers. All other registers in the status structure are read-only registers. The following explains how to determine the parameter values for the various commands used to program enable registers. The actual commands are covered later in this section.

A command to program an event enable register is sent with a parameter value that determines the desired state (0 or 1) of each bit in the appropriate register. An enable register can be programmed using the decimal format.

The bit positions of the register indicate the binary parameter value and decimal equivalent.

## Reading registers

Any register in the status structure can be read by using the appropriate query (?) command. The response message is a decimal value corresponding to a binary-weighted sum of all bits set in the register.



## Status byte and service request (SRQ)

Service request is controlled by two 8-bit registers: The Status Byte Register and the Status Byte Enable Register.

### Status Byte Register

The summary messages from the status registers and queues are used to set or clear the appropriate bits (B2, B3, B4, and B5) of the Status Byte Register. These summary bits do not latch, and their states (0 or 1) are solely dependent on the summary messages (0 or 1). For example, if the Standard Event Register is read, its register will clear. As a result, its summary message will reset to 0, which will then reset the ESB bit in the Status Byte Register.

The bit definitions of the Status Byte Register are described in the following table.

| Status Byte Register |                                |               |   |
|----------------------|--------------------------------|---------------|---|
| Bit                  | Definition                     | Decimal value | Description   |
| 0                    | Not used                       | 1             | Set to 0.   |
| 1                    | Not used                       | 2             | Set to 0.   |
| 2                    | Error Available (EAV)          | 4             | Set bit indicates that a measurement event has occurred.  |
| 3                    | Questionable Summary Bit (QSB) | 8             | One or more bits are set in the Questionable Data Register indicating that an enabled questionable event has occurred (bits have to be "enabled" in the enable register). |
| 4                    | Message Available (MAV)        | 16            | Set summary bit indicates that a response message is present in the Output Buffer.  |
| 5                    | Event Summary Bit (ESB)        | 32            | One or more bits are set in the Standard Event Register, indicating that an enabled standard event has occurred (bits have to be "enabled" in the enable register).       |
| 6                    | Request Service (RQS)          | 64            | Set bit indicates that an enabled summary bit of the Status Byte Register is set and the instrument requires service (Serial Poll).                                       |
| 7                    | Not used                       | 128           | Set to 0.   |

### Using the Message Available Bit (MAV)

The Output Buffer holds response messages. Response messages are the messages sent in response to query commands. When a response message is placed in the Output Buffer, the Message Available Bit (MAV) (B4) in the Status Byte Register sets. A data message is cleared from the Output Buffer when it is read. The Output Buffer is considered cleared when it is empty. An empty Output Buffer clears the MAV bit in the Status Byte Register. A message is read from the Output Buffer by addressing the instrument to talk after the appropriate query is sent.

Use the READ? command to initiate measurements after the trigger conditions are met.

Use the INITiate command to store readings in the instrument's internal memory.

Use the FETCH? command to transfer readings to the instrument's Output Buffer.

When the instrument takes the first reading in response to a READ? command, the MAV bit is set indicating that a message is in the Output Buffer.

## Service request

The generation of a service request is controlled by the Status Byte Enable Register. This register is programmed by you and is used to enable or disable the setting of bit B6 (RQS) by the Status Summary Message bits (B2, B3, B4, and B5) of the Status Byte Register. The summary bits are logically ANDed (&) with the corresponding enable bits of the Status Byte Enable Register. When a set (1) summary bit is ANDed with an enabled (1) bit of the enable register, the logic "1" output is applied to the input of the OR gate, and then sets the RQS bit in the Status Byte Register.

The individual bits of the Status Byte Enable Register can be set or cleared by using the \*SRE common command. To read the Status Byte Enable Register, use the \*SRE? query command. The Status Byte Enable Register clears when power is cycled or a parameter value of 0 is sent with the \*SRE command (for example, \*SRE 0). The commands to program and read the SRQ Enable Register are described in [Status byte and service request commands](#) (on page B-7).

### NOTE

If you have set the instrument previously by using \*PSC 0, the Status Byte Enable Register will not be cleared at power-on.

## Status structure

### Using serial polling and SRQ

Any enabled event summary bit that goes from 0 to 1 will set bit B6 and generate a SRQ (service request). In your test program, you can periodically read the Status Byte to check if an SRQ has occurred, and what caused it. If an SRQ occurs, the program can, for example, branch to an appropriate subroutine that will service the request.

Typically, SRQs are managed by the serial poll sequence of the instrument. If an SRQ does not occur, bit B6 of the Status Byte Register remains cleared, and the program proceeds normally after the serial poll is performed. If an SRQ does occur, bit B6 of the Status Byte Register will set, and the program can branch to a service subroutine when the SRQ is detected by the serial poll.

B6 stays set until all Status Byte summary bits are reset.

The serial poll automatically resets B6 of the Status Byte Register. This allows subsequent serial polls to monitor bit B6 for an SRQ occurrence generated by other event types. After a serial poll, the same event can cause another SRQ, even if the event register that caused the first SRQ has not been cleared.

The Master Summary Status Bit (MSS) is set when an enabled summary bit of the Status Byte Register is set. This bit (B6) may also be interpreted as a Request Service (RQS) bit. Depending on how it is used, Bit B6 of the Status Byte Register is either the Request for Service (RQS) bit or the Master Summary Status (MSS) bit:

- When using the serial poll sequence to obtain the status byte (serial poll byte), B6 is the RQS bit.
- When using the \*STB command to read the Status Byte Register, B6 is the MSS (Message Summary Status) bit.

The serial poll, although automatically resetting the RQS bit, does not clear MSS. The MSS remains set until all Status Byte summary bits are reset.

#### **To use an SRQ:**

Configure the instrument to generate an SRQ when the ESB bit is set. Use the Status Byte Enable Register (SRE) to select the low-level SRQ signal set by summary bits. When the status byte B6 is set, the instrument automatically sends the SRQ interrupt message to the bus controller, which may poll the instruments on the bus to identify which one requested service. Querying the Status Byte that is using the serial poll or querying the event register with the summary bit that caused the service request will clear the request service.

#### **To use a serial poll:**

You can send the serial poll message to read the Status Byte Summary Register. The serial poll will clear the RQS bit automatically in the Status Byte Summary Register, but no other bits will be affected.

Since synchronization between the bus controller program and the instrument is not guaranteed by the IEEE-488.2 standard, you can send the \*OPC? command to make sure that commands are completed. Using a serial poll before \*RST, \*CLS, or other commands have completed can cause reported conditions to be reported again.

## Knowing when a command sequence is finished

Use the following commands to find out when a command sequence has finished.

1. Send a DCL general bus command to clear the Output Buffer and bus controller.
2. Send a \*CLS command to clear all bits in the Event Register.
3. Send a \*ESE 1 command to instruct the instrument to set the ESB bit in the Status Byte when the OPC event in the ESR is set.
4. Send the \*OPC command to set the Operation Complete (OPC) bit in the Standard Event Register after all pending commands have been executed.
5. Configure the instrument to generate an SRQ when the ESB bit is set.

## SPE, SPD (serial polling)

The SPE, SPD General Bus Command sequence is used to serial poll the instrument. Serial polling obtains the serial poll byte (status byte). Typically, serial polling is used by the controller to determine which of several instruments has requested service with the SRQ line.

## Read the Status Byte by using \*STB?

Reading the status byte with the \*STB? command is similar to a IEEE-488 serial poll. However, the \*STB? command:

- Does not clear the RQS bit (B6) in the Status Byte Register.
- Is processed like an ordinary command and completes only after previous commands have completed making it impossible to poll.

## Status byte and service request commands

The commands to program and read the Status Byte Register and Status Byte Enable Register are listed in the following table. For details on programming and reading registers, see Programming enable registers.

### NOTE

To reset the bits of the Status Byte Enable Register to 0, use 0 as the parameter value for the \*SRE command (for example, \*SRE 0).

\*CLS and STATus:PRESet commands have no effect on the Status Byte Enable Register.

| Status Byte and Status Byte Enable Register commands |  |
|--|--|
| Command  | Description  |
| *SRE 0   | Reset the Status Byte Enable Register.                                       |
| *SRE <NRf>   | Program the Status Byte Enable Register:<br><NRf> = 0 to 255 decimal format. |
| *SRE?  | Read the Status Byte Enable Register.  |

## Status register sets

There are two status register sets in the status structure of the instrument: Standard Event Status and Questionable Event Status.

### Standard Event Register

The bit definition of the Standard Event Register is shown in the following table.

You will have to use the \*ESE command and the appropriate decimal value for each bit to set the enable register mask.

For example, enable “operation complete” by using the \*ESE 1 command.

#### NOTE

All errors in the error queue are recorded as an error condition (including bits 2, 3, 4, or 5 of the Standard Event Register). The only exception is if you read the error queue using the `SYSTem:ERRor?` command.

#### NOTE

All reading overload conditions are reported to the Standard Event Register bit 3 from the Questionable Data Event Register bits 0, 1, or 9. However, no reading overload conditions are reported to the instrument's Error Queue.

| Standard Event Register |                              |               |   |
|-------------------------|------------------------------|---------------|---|
| Bit                     | Definition                   | Decimal value | Description   |
| 0                       | Operation Complete           | 1             | Set bit indicates that all pending selected device operations are completed and the instrument is ready to accept new commands. This bit only sets in response to the *OPC command. See <a href="#">*OPC — operation complete command</a> (on page 5-6) and <a href="#">*OPC? — operation complete query</a> (on page 5-6) for details.   |
| 1                       | Not used.                    | 2             | Set to 0.   |
| 2                       | Query Error (QYE)            | 4             | Set bit indicates that you attempted to read data from an empty Output Buffer; a new command line was received before a previous query was read; or both the input and Output Buffers are full.   |
| 3                       | Device-Dependent Error (DDE) | 8             | Set bit indicates that an instrument operation did not execute properly due to some internal condition.   |
| 4                       | Execution Error (EXE)        | 16            | Set bit indicates that the instrument detected an error while trying to execute a command.  |
| 5                       | Command Error (CME)          | 32            | Set bit indicates that a command error has occurred. Command errors include: <ul style="list-style-type: none"> <li>IEEE-488.2 syntax error — instrument received a message that does not follow the defined syntax of the IEEE-488.2 standard.</li> <li>Semantic error — instrument received a command that was misspelled or received an optional IEEE-488.2 command that is not implemented.</li> <li>The instrument received a Group Execute Trigger (GET) inside a program message.</li> </ul> |
| 6                       | Not used.                    | 64            | Set to 0.   |
| 7                       | Power ON (PON)               | 128           | Set bit indicates that the instrument has been turned off and turned back on since the last time this register has been turned off.   |

### Monitor the contents of the Output Buffer by using \*OPC

The \*OPC command causes the instrument to set the Operation Complete Bit (OPC) after all pending operations are complete.

The \*OPC? operation complete query places an ASCII “1” in Output Buffer after all pending instrument operations are complete.

Typically, either one of these commands is sent after the INITiate command. The INITiate command is used to take the instrument out of idle in order to perform measurements.

- After the instrument completes all programmed commands, the instrument returns to the idle state. Then the instrument completes all pending commands including:
- \*OPC command. Completing this command sets the OPC bit
- \*OPC? command. Completing this command places an ASCII “1” in Output Buffer

If there are too many messages in the Output Buffer before the \*OPC command is sent, the buffer cannot accept any additional messages and the instrument will stop taking readings.

## Questionable Data Register

The Questionable Data Register indicates when measurements result in any of the following conditions by setting the appropriate bit:

- Voltage range overload
- Current range overload
- Out-of-limit conditions
- Ohms overload

All of the set bits are summarized to the Questionable Summary Bit (QSB) (B3). A set summary bit indicates that an enabled questionable event has occurred.

The bits of the Questionable Data Register are described in the following table. Use the `STATus:QUESTionable:ENABle` command to set the contents of the Event Enable Registers.

| Questionable Data Register |                    |               |   |
|----------------------------|--------------------|---------------|---|
| Bit                        | Definition         | Decimal value | Description   |
| 0                          | Voltage overload   | 1             | Range overload on DC or AC volts, frequency, period, diode or ratio function. |
| 1                          | Current overload   | 2             | Range overload on DC or AC current function.                                  |
| 2                          | Not used           | 4             | Set to 0.   |
| 3                          | Not used           | 8             | Set to 0.   |
| 4                          | Not used           | 16            | Set to 0.   |
| 5                          | Not used           | 32            | Set to 0.   |
| 6                          | Not used           | 64            | Set to 0.   |
| 7                          | Not used           | 128           | Set to 0.   |
| 8                          | Not used           | 256           | Set to 0.   |
| 9                          | Ohms overload      | 512           | Range overload on 2 or 4-wire ohm function.                                   |
| 10                         | Not used           | 1024          | Set to 0.   |
| 11                         | Limit Failed at LO | 2048          | Reading is less than the lower limit under limit test.                        |
| 12                         | Limit Failed at HI | 4096          | Reading is more than upper limit under limit test.                            |
| 13                         | Not used           | 8192          | Set to 0.   |
| 14                         | Not used           | 16384         | Set to 0.   |
| 15                         | Not used           | 32768         | Set to 0.   |

## Status reporting command summary

Refer to [STATus subsystem summary](#) (on page 5-25) for information about status commands.

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## Communication interface

### In this appendix:

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Communication interfaces ..... C-1

## Communication interfaces

This section shows you how to connect instruments to the following communication interfaces:

- Universal serial bus (USB)
- General purpose interface bus (GPIB or IEEE-488)

It describes how to configure and troubleshoot these interfaces on computers with Microsoft® Windows® 2000, Windows XP®, Windows Vista®, and Windows 7® operating systems.

It also describes the I/O software, drivers, and application software that can be used with Keithley's instruments.

## Selecting an interface

The Keithley Instruments Model 2110 supports the following remote interfaces:

- GPIB (optional)
- USB

The Model 2110 can only be controlled from one remote interface at a time. The first interface that receives a message takes control of the instrument. It will ignore the other interfaces until the instrument is taken back to local operation.

## USB communications

To use the rear-panel USB connection, you must have the Virtual Instrument Software Architecture (VISA) layer on the host computer. See [How to install the Keithley I/O Layer](#) (on page C-15) for more information.

VISA contains a USB class driver for the USB Test and Measurement Class (USBTMC) protocol which, once installed, allows the Microsoft® Windows® operating system to recognize the instrument.

When a USB device that implements the USBTMC or USBTMC-USB488 protocol is plugged into the computer, the VISA driver automatically detects the device. It is important to note that only USBTMC and USBTMC-USB488 devices are automatically recognized by the VISA driver. Other USB devices, such as printers, scanners, and storage devices, are not recognized.

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



## NOTE

The full version of National Instruments (NI<sup>®</sup>) VISA provides a utility to create a USB driver for any other kind of USB device that you want to communicate with VISA. For more information, see the [NI VISA website](http://www.ni.com) (see National Instruments VISA site - <http://www.ni.com>).

### Communicate with the instrument

To communicate with the USB device, you need to use NI-VISA<sup>™</sup>. 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]

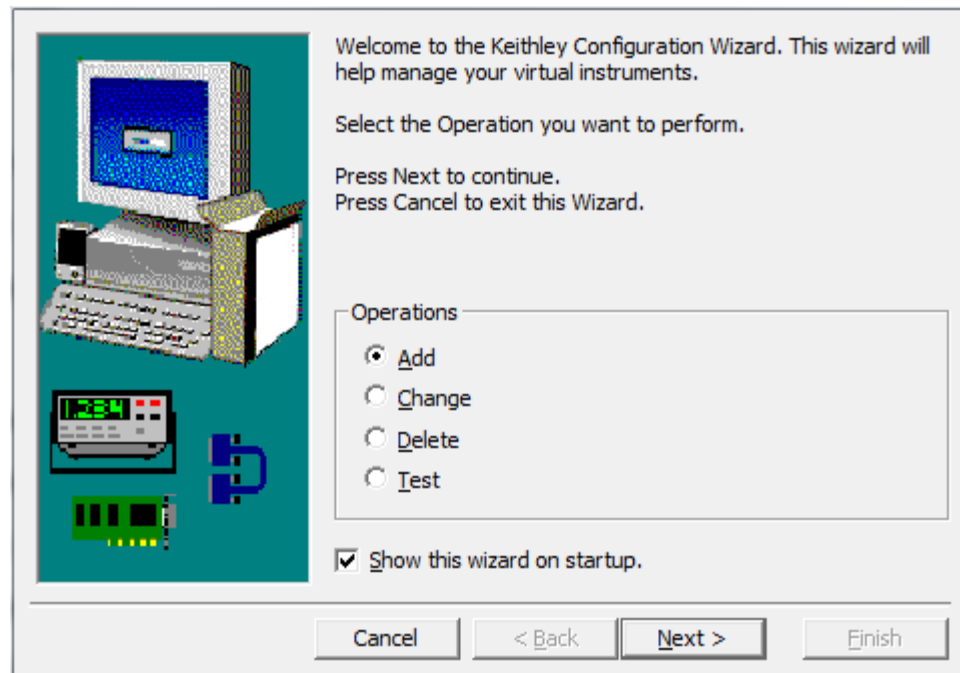
This requires that you determine the parameters. You can gather this information by running a utility that automatically detects all instruments connected to the computer.

If you installed the Keithley I/O Layer, the Keithley Configuration Panel is available from the Microsoft<sup>®</sup> Windows<sup>®</sup> Start menu in the Keithley Instruments menu.

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

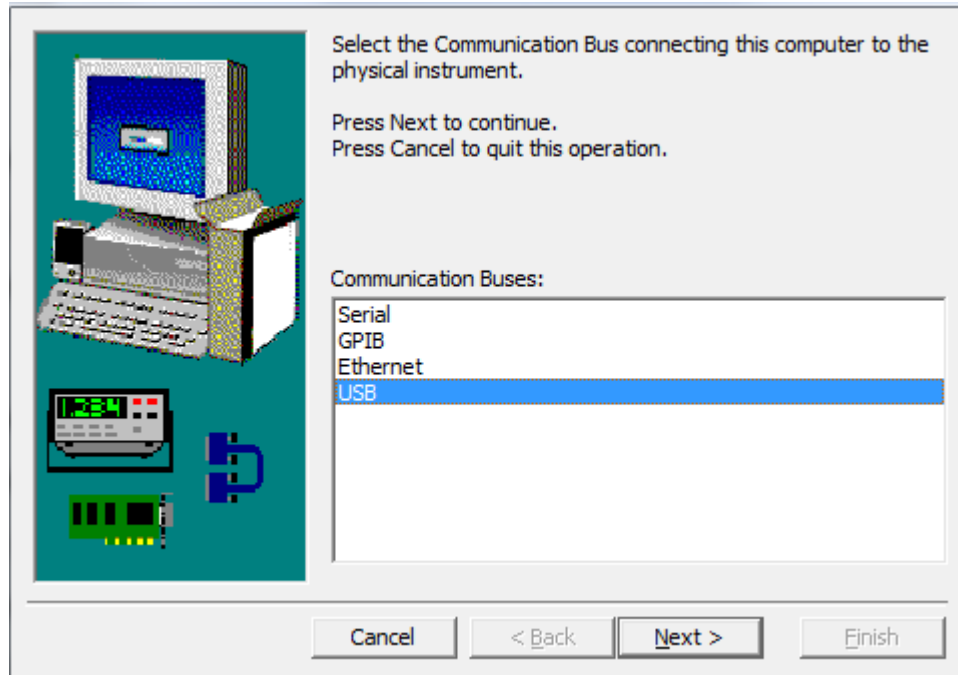
1. Start the Keithley Configuration Panel. The Select Operation dialog box is displayed.
2. Select **Add**.

**Figure 43: Select Operation dialog box**



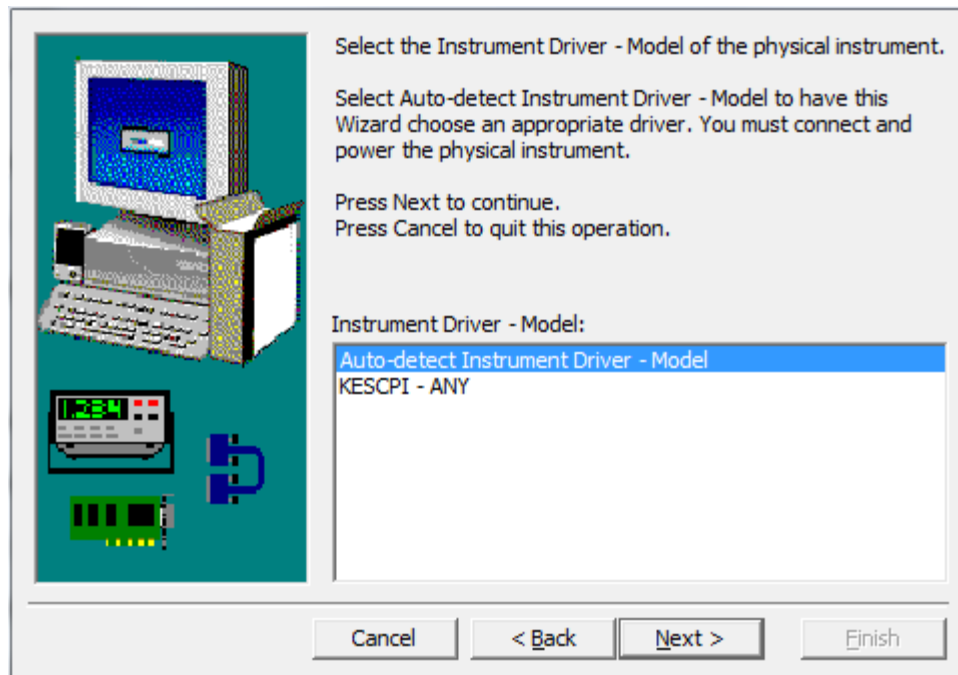
3. Click **Next**. The Select Communication Bus dialog box is displayed.

Figure 44: Select Communication Bus dialog box



- 4. Select **USB**.
- 5. Click **Next**. The Select Instrument Driver dialog box is displayed.

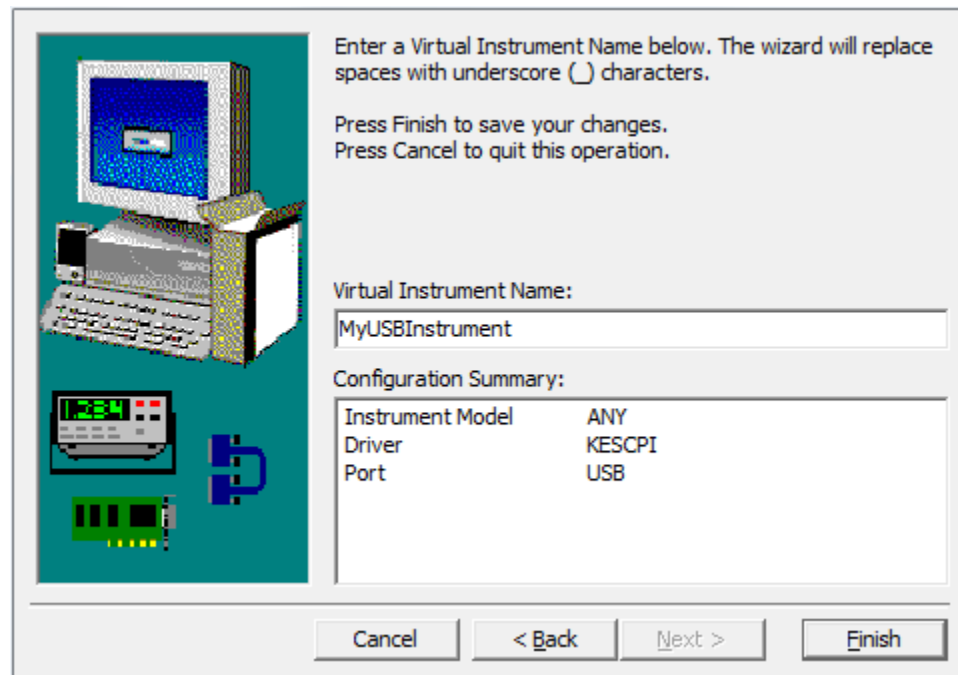
Figure 45: Select Instrument Driver dialog box



- 6. Select **Auto-detect Instrument Driver - Model**.
- 7. Click **Next**. The Configure USB Instrument dialog box is displayed with the detected instrument VISA resource string displayed.

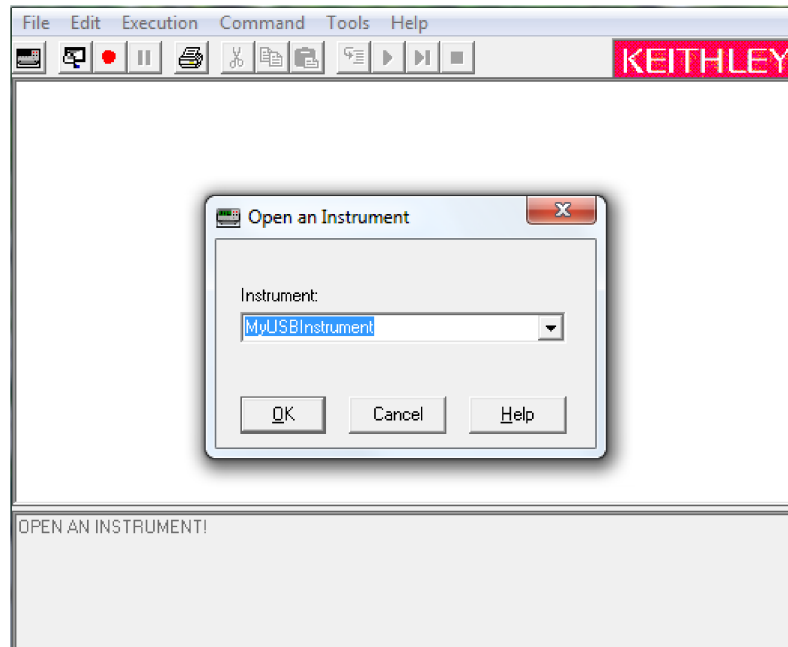
- Click **Next**. The Name Virtual Instrument dialog box is displayed.

**Figure 46: Name Virtual Instrument dialog box**



- In the Virtual Instrument Name box, enter a name that you want to use to refer to the instrument.
- Click **Finish**.
- Click **Cancel** to close the Wizard.
- Save the configuration. From the Configuration Utility, select **File > Save**.
- In the Keithley Communicator, select **File > Open Instrument** to open the instrument you just named.

Figure 47: Keithley Communicator Open Instrument



14. Click **OK**.
15. 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 Agilent IO Libraries on your system, you can run Agilent Connection Expert to check out your USB instruments. See their documentation for information.

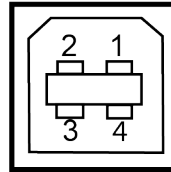
### **Pass/fail output from USB connector**

The USB connector on the instruments rear panel is a series B connector. When the USB interface is disabled (IEEE-488 interface is selected), the internal pass and fail TTL output signals (limit testing) will be transmitted via the USB port.

The pass and fail signals are low true and indicate the Math Pass/Fail Limit Test result for the next reading to be output to the GPIB interface. The signals are active low for approximately 2ms ( $\pm 100 \mu$  sec) for each reading taken. The following figure shows the USB connector (series B).

**Figure 48: USB connector**

Type B

Instrument connector  
(rear panel)

| Contact number | Signal name | Typical wiring assignment | Description     |
|----------------|-------------|---------------------------|-----------------|
| 1              | VBUS        | Red                       | Floating        |
| 2              | D-          | White                     | Limit Test Pass |
| 3              | D+          | Green                     | Limit Test Fail |
| 5              | GND         | Black                     | GND             |

**NOTE**

If you turn off the USB interface, the Pass/Fail output function will turn on automatically.

If you want to use the Pass/Fail signal output, you must use the GPIB interface for remote control.

Disconnect the USB cable from your instrument while using the Pass/Fail signal output.

**To turn on and off the pass/fail output:**

1. Press the **SHIFT** key, and then press the **CONFIG** key.
2. Use the **▶** and **◀** keys to select **INTERFACE**.
3. Press **ENTER**.
4. Use the **▶** and **◀** keys to:
  - Select **GPIB** to turn on the output.
  - Select **USB** to turn off the output.
5. Press **ENTER**.

---

## Additional USB information

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This section provides further details and more advanced information about the USB bus and test-and-measurement instruments.

### 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.

There are two types of USB hubs that you can use with Model 2110:

- **Bus powered:** This type of hub draws its power from the USB bus and can only supply 100 mA (USB 2.0) per port.
- **Self powered:** This type of hub has an external power supply and can supply up to 500 mA per port (USB 2.0).

## GPIB setup

This section contains information about GPIB standards, connections, and address selection.

### NOTE

The GPIB connector is optional and may not be present on your instrument.

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## GPIB standards

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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.

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## Install the GPIB cards in your computer

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Refer to the manufacturer's documentation for information about installing the GPIB cards.

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## Install the GPIB driver software

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Check the documentation for your GPIB controller for information about where to acquire drivers. Keithley Instruments also recommends that you check the vendor's website for the latest version of drivers or software.

It is important that you install the drivers before you connect the hardware to prevent associating the incorrect driver to the hardware.

## Communication with the instrument

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The GPIB driver software you installed installs an interactive dumb terminal program that allows you to send commands to the instrument. The program directly calls the GPIB driver support libraries.

For the KPCI-488LPA and KUSB-488B GPIB controller from Keithley Instruments, the configuration utility is called the KI-488 Diagnostic Tool. It is available from the Windows Start menu at **Keithley Instruments > KI-488 > KI-488 Diagnostic Tool** after installing the Keithley I/O layer.

For the KUSB-488A GPIB controller from Keithley Instruments, the configuration utility is called TrTest. It is available from the Microsoft® Windows® Start Menu at **Keithley Instruments > GPIB-488-CEC > TrTest**.

For National Instruments (NI™) GPIB controllers, you can use NI-MAX. Start NI-MAX. If your hardware is installed correctly, you will see the controller in the GPIB section of the tree control on the left side. Select it and right-click to see an option to communicate with the instrument.

### NOTE

If you want to use the GPIB controller with an instrument driver (such as VXIPnP or IVI) or high-level software, you must also install I/O software, which installs the VISA layer. See [How to install the Keithley I/O Layer](#) (on page C-15).

## Terminator

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When receiving data over the GPIB, the instrument terminates on any line feed character or any data byte with EOI asserted (line feed with EOI asserted is also valid). When sending data through the GPIB drivers, it is not necessary to append a line feed character to all outgoing messages. The EOI line is asserted with the last character sent.

However, if you want your program to communicate with all I/O buses on the instrument (GPIB and USB), it is good practice to add a line feed to the end of the outgoing command. Use VISA, and the same program will work with all the I/O buses by changing the resource string in the VISA Open method.

## Front-panel GPIB operation

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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.

### Local key

The SHIFT (LOCAL) key cancels the remote state and restores local operation of the instrument.

## GPIB reference

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### General bus commands

General commands are commands that have the same general meaning, regardless of the instrument (for example, DCL). The following table lists the general bus commands.

#### General bus commands

| Command  | Effect on Model 2110  |
|----------|---|
| REN      | Goes into remote operation when next addressed to listen. See <a href="#">REN</a> (on page C-9) for details.                |
| IFC      | Goes into talker and listener idle states. See <a href="#">IFC</a> (on page C-9) for details.                               |
| LLO      | <b>LOCAL</b> key locked out. See <a href="#">LLO</a> (on page C-9) for details.   |
| GTL      | Cancel remote; restore Model 2110 front-panel operation. See <a href="#">GTL</a> (on page C-9) for details.                 |
| DCL      | Returns the Model 2110 and all devices on the GPIB to known conditions. See <a href="#">DCL</a> (on page C-10) for details. |
| SDC      | Returns the Model 2110 to known conditions. See <a href="#">SDC</a> (on page C-10) for details.                             |
| GET      | Initiates a trigger. See <a href="#">GET</a> (on page C-10) for details.  |
| SPE, SPD | Serial polls the Model 2110. See <a href="#">SPE, SPD</a> (on page C-10) for details.                                       |

### REN

The remote enable (REN) command is sent to the Model 2110 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Setting REN true does not place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote operation.

### IFC

The interface clear (IFC) command is sent by the controller to place the Model 2110 in the talker idle state and the listener idle state.

Transfer of command messages to the instrument and transfer of response messages from the instrument are not interrupted by IFC. If transfer of a response message from the instrument was suspended by IFC, transfer of the message will resume when the instrument is addressed to talk. If transfer of a command message to the instrument was suspended by IFC, the rest of the message can be sent when the instrument is addressed to listen.

### LLO

When the instrument is in remote operation, all front-panel controls are disabled, except the LOCAL key (and the POWER switch). The local lockout (LLO) command disables the LOCAL key.

### GTL

Use the go to local (GTL) command to put a remote-mode instrument into local mode. Leaving the remote state also restores operation of all front-panel controls.



## DCL

Use the device clear (DCL) command to clear the GPIB interface and return it to a known state. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously.

When the Model 2110 receives a DCL command, it:

- Clears the input buffer, output queue, and command queue
- Cancels deferred commands
- Clears any command that prevents the processing of any other device command

A DCL does not affect instrument settings and stored data.

## SDC

The selective device clear (SDC) command is an addressed command that performs essentially the same function as the device clear (DCL) command. However, because each device must be individually addressed, the SDC command provides a method to clear only selected instruments, instead of clearing all instruments simultaneously with the DCL command.

When the Model 2110 receives an SDC command, it clears the input buffer and output queue, cancels deferred commands, and clears any command that prevents the processing of any other device command. An SDC command does not affect instrument settings and stored data.

## GET

The group execute trigger (GET) command is a GPIB trigger that triggers the instrument to take readings from a remote interface.

## SPE, SPD

Use the serial polling sequence to obtain the Model 2110 serial poll byte. The serial poll byte contains important information about internal functions (see [Status model](#) (on page B-1)). Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. The serial polling sequence may be performed at any time to obtain the status byte from the Model 2110.

## GPIB status indicators

The ADR status indicator shows that the instrument is controlled via the GPIB Interface.

## Configure the GPIB controllers

Each instrument on a GPIB bus needs a unique address from a range of 0 to 30. Generally, the GPIB host controller is on address 0. However, there are GPIB controllers that adopt the address of 21. To be safe, do not configure any of the instruments for 21 or 0.

If you do need to change the host controller address, consult the controller documentation.

For the KPCI-488LPA and KUSB-488B GPIB controller from Keithley Instruments, the configuration utility is called the KI-488 Diagnostic Tool. It is available from the Microsoft® Windows® Start menu at **Keithley Instruments > KI-488 > KI-488 Diagnostic Tool**.

For the KUSB-488A GPIB controller from Keithley Instruments, the configuration utility is called GPIB Configuration. It is available from the Windows Start Menu at **Keithley Instruments > GPIB-488 > GPIB Configuration**.

For National Instruments (NI™) GPIB controllers, you can use NI-MAX. Start NI-MAX. If your hardware is installed correctly, you will see the controller in the GPIB section of the tree control on the left side. Select it and right-click to see an option to configure the controller. Do not forget to save your settings.

## Supplied software

The majority of software applications and all instrument drivers from Keithley Instruments depend on some, or all, of 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 included on the CD-ROMs that came with your instrument, and are also available for download at the [Keithley Instruments support website](http://www.keithley.com/support) (<http://www.keithley.com/support>).

## Instrument driver types

---

There are several different styles of instrument drivers. Keithley Instruments provides three different instrument drivers for the Model 2110: A native LabVIEW driver, an IVI-C driver, and 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, you would pick a native LabVIEW driver. If a native LabVIEW driver is not available then you can use an IVI-C driver as LabVIEW has the option of creating a wrapper for the IVI-C driver.

LabVIEW supports IVI-COM drivers but they are definitely not the first or second choice. However, if they are the only driver types 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 (Vixie) plug-and-play (VXIPnP) style drivers are Win32 DLLs that have some standard functions defined by the VXIPnP Alliance, 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 would 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

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### 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 (currently, Linux® on x86, Mac OS® X, and Microsoft® Windows®).

National Instruments (NI™) maintains a native [LabVIEW driver style guide](http://zone.ni.com/devzone/cda/tut/p/id/3271) (<http://zone.ni.com/devzone/cda/tut/p/id/3271>).

### LabVIEW driver wrappers

All IVI-C drivers have a function panel file (.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, since a DLL only has a flat API entry point scheme (unlike COM or .NET). Any CVI-generated .fp file can be imported into LabVIEW and LabVIEW will generate a wrapper for the DLL. The drawback here is that the driver is dependent on the DLL, which is not portable and is therefore Windows-specific.

## Obtaining instrument drivers

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**To see what drivers are available for your instrument:**

1. Go to the [Keithley Instruments support website](http://www.keithley.com/support) (<http://www.keithley.com/support>).
2. Enter the model number of your instrument.
3. Select Software Driver from the list.

For LabVIEW™, you can also go to National Instrument's website and search their instrument driver database.

---

## Instrument driver examples

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All Keithley drivers come with examples written in several programming languages that show you how to do the most common things with the instruments.

Install the driver. The examples are in the Microsoft® Windows® Start menu, under **Keithley Instruments > Model Number** (where Model Number is the instrument model number).

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## IVI shared components

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The IVI shared components are a similar 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 major problem with VXIPnP drivers was that the API was not specific to the instrument. For something as standard as measuring DC volts on a digital multimeter (DMM), it would be a good idea if there were a set of standard functions to do this.

The [IVI Foundation](http://www.ivifoundation.org) (<http://www.ivifoundation.org>) defined a set of application programming interfaces (APIs) for the following instruments: DMM, function generator, DC power supply, scope, switch, spectrum analyzer, RF signal generator and power meter. They are currently working on class APIs for some other instrument types.

There are two types of IVI drivers: IVI-COM drivers use Microsoft® COM technology to expose driver functionality, while 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 [Making the Case for IVI](http://pacifmindworks.com/docs/Making%20the%20Case%20for%20IVI.pdf) (<http://pacifmindworks.com/docs/Making%20the%20Case%20for%20IVI.pdf>).

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## NI CVI runtime engine

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

---

## NI IVI Compliance Package

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The National Instruments (NI™) IVI Compliance Package 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).

The KIOL contains:

- NI-VISA™ Runtime-Time Engine
- Keithley Configuration Panel
- Keithley Communicator

---

### NI-VISA Runtime

NI-VISA™ is National Instruments (NI™) implementation of the VISA standard. There are two versions: a full version and a run-time version. The Keithley I/O Layer (KIOL) contains a licensed version of the NI-VISA Run-Time Engine that contains only the binary files (DLLs) that allow the NI-VISA drivers to operate.

If you already have NI software (such as LabVIEW™ or LabWindows™) installed, you have a valid license that can be used with Keithley drivers and application software.

If you do not have NI software installed, you must install the KIOL to install the the drivers.

---

### Keithley Configuration Panel

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

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### Keithley Communicator

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

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### Computer requirements for the Keithley I/O Layer

The Keithley I/O Layer version C02 supports the following operating systems:

- Microsoft® Windows® (32-bit & 64-bit) Business with Service Pack 1 or later
- Microsoft Windows Vista® Business (32-bit & 64-bit) with Service Pack 2 or later
- Windows XP Professional (32-bit) with Service Pack 3 or later
- Windows 2000 Professional with Service Pack 4 plus update KB891861 or later

Note that Windows 95, Windows 98, Windows ME, Windows NT, Windows XP (64-bit) operating systems are not supported.

## How to uninstall previous versions of the Keithley I/O Layer

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If you have an earlier version of the Keithley I/O Layer software installed on your computer, you must uninstall it.

### *To uninstall the Keithley I/O layer:*

1. From the Control Panel, select **Add/Remove Programs**.
2. Uninstall the following components:
  - Keithley I/O Layer
  - Keithley I/O Layer Suite
  - Keithley SCPI-based Instrument IVI-C Driver
  - NI-VISA Run-Time Engine x.x.x (if present) (x.x.x is the VISA version)
3. Reboot your computer.

## How to install the Keithley I/O Layer

---

### NOTE

Before installing, it is a good idea to check the [Keithley Instruments website](http://www.keithley.com) (<http://www.keithley.com>) to see if a later version of the Keithley I/O Layer is available. On the website, select the **Support** tab, under **model number**, type KIOL, and select **Software Driver**.

You can install the Keithley I/O Layer from the CD-ROM that came with your instrument, or from the download from the Keithley website.

The software installs the following components:

- Microsoft® .NET Framework
- NI™ IVI Compliance Package
- NI-VISA™ Run-Time Engine
- Keithley SCPI-based Instrument IVI-C driver
- Keithley I/O Layer

### *To install the Keithley I/O Layer from the CD-ROM:*

1. Close all programs.
2. Place the CD-ROM into your CD-ROM drive.
3. Your web browser should start automatically and display a screen with software installation links. If you need to manually open the web page, use a file explorer to navigate to the CD-ROM drive and open the file named `index.html`.
4. From the web page, select the **Software** category and click Keithley I/O Layer.
5. Accept all defaults.
6. Click **Next**.
7. Click **Install**.
8. Reboot your computer.

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

1. Download the Keithley I/O Layer Software from the [Keithley Instruments website](http://www.keithley.com) (<http://www.keithley.com>) as described in the note. The software is a single compressed file and should be downloaded to a temporary directory.
2. Run the downloaded file from the temporary directory.
3. Follow the instructions on the screen to install the software.
4. Reboot your computer.

**Special installation considerations**

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Situations may occur during installation that cannot be handled automatically by the installation utility. The installation utility will warn you if one of these situations is detected. The sections below describe the action you must take before the installation can be completed.

**Mismatch between IVI Shared Components and IVI Engine Detected**

The IVI Shared Components and IVI Engine are software components that may be installed by various test and measurement software applications, instrument drivers, and so on. Keithley I/O Layer software requires that these components, if present, be compatible versions. The installation utility will detect a mismatch, which must be corrected before the software installation can proceed. If this situation is detected, the Keithley I/O Layer software installation will automatically stop.

The recommended way to resolve this situation is to install the IVI Compliance Package (ICP) software from National Instruments (NI™). You may download the ICP software and release notes from National Instrument's website. When the ICP installation is complete, restart the Keithley I/O Layer software installation.

**Non-National Instruments VISA detected**

VISA software is used to communicate with the instrument and may be installed by various test and measurement software applications, instrument drivers, and so on. Keithley I/O Layer software requires and will install National Instruments NI-VISA™ software. The installer will detect if another vendor's version of VISA is already installed on the computer. If this occurs, the installer will pause and display a warning message. The warning message displays the vendor of the detected VISA in its title bar, if this can be determined. Make a note of the vendor name. At this point, you may elect to continue the installation, which will overwrite the existing VISA installation with NI-VISA. This will allow the Keithley I/O Layer software to operate properly, but may cause other applications or instrument drivers that were dependent on the existing VISA to malfunction.

**The recommended way to resolve this situation is to perform the following steps:**

1. Exit the Keithley I/O Layer software when the warning message is displayed. Make note of the VISA vendor in the warning message (if any).
2. Uninstall the non-NI VISA software.
3. Uninstall Tektronix VISA by selecting OpenChoice TekVISA from the Control Panel Add/Remove programs list.
4. Uninstall Agilent VISA by selecting Agilent I/O Libraries Suite from the Control Panel Add/Remove programs wizard list.

5. Uninstall other versions of VISA by selecting the appropriate entry from the Control Panel Add/Remove Programs Wizard list.
6. Restart the Keithley I/O Layer software installation.
7. If the pre-existing version of VISA was supplied by Tektronix or Agilent (as displayed in the warning message), you may safely reinstall that version of VISA once Keithley I/O Layer software installation is complete. When you reinstall Tektronix or Agilent VISA, it may prompt you to preserve the current VISA version, which you should do. This will usually restore the operation of any dependent applications or drivers.
8. If the pre-existing version of VISA was supplied by a vendor other than Tektronix or Agilent, we recommend that you do not reinstall it, because this will likely cause the Keithley I/O Layer software to malfunction.

## Installation troubleshooting

---

If problems occur during installation, it might be helpful to install the components individually. Error messages might appear that will help you resolve the installation issue.

If problems occur during installation:

1. Follow the instructions to uninstall all the KIO Layer components in [Special installation considerations](#) (on page C-16).
2. Rerun the KIO Layer installer. Note where the installer unpacks the files (usually in a temporary folder).
3. Cancel the installer.
4. Go to the folder where the files were unzipped.
5. Run the setup.exe for each of the following components in the following order:
  - IVI Compliance Package (ICP)
  - NI-VISA™ Run-Time Engine
  - KIO Layer
  - Keithley SCPI Driver
6. Ignore all the other folders.
7. Reboot the computer.

## Modifying, repairing, or removing Keithley I/O Layer software

---

The Keithley I/O Layer interconnects many other installers.

To remove all the KIO Layer components, you need to uninstall the following applications using Control Panel Add/Remove programs:

- National Instruments NI™ IVI Compliance Package
- National Instruments NI-VISA™ Run-Time Engine
- IVI Shared Components
- Visa Shared Components
- Keithley SCPI Driver

After uninstalling components, reboot the computer.



## Addressing instruments with VISA

VISA allows you to communicate with the instrument on different communication buses by changing a resource string that gets passed in with the `viOpen` function, in VISA-C, or with the `Open` method on the VISA-COM resource manager object.

For detailed information about the format of the resource string, refer to the VISA specification VPP4.3 at the IVI Foundation website, or refer to the help file provided by the vendor of the VISA implementation you are using.

The following sections describe the resource strings for some of the communication types that Keithley supports. Any field that has `[]` (square brackets) around it is optional and will revert to a default value.

### Addressing instruments using USB

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

*board* is not used (0).

*manufacturer ID* is the USB.org reserved four-digit hexadecimal code for the instrument vendor company. Keithley Instruments hexadecimal code is 05E6.

*model code* is the model number of the instrument. For example, when addressing a Model 707B, use 707B.

*serial number* is the serial number of the instrument.

*USB interface number* identifies which USBTMC interface on the instrument to address (usually 0).

## NOTE

Also see USB VISA identifiers.

## Addressing instruments through GPIB

---

There are two different resource classes in VISA for the GPIB bus.

**INSTR** is the basic class that everyone uses. It allows application software to send and receive data and commands without dealing with some low level GPIB nuances. This class is recommended for typical GPIB communication.

The **INTFC** class allows finer control over the GPIB controller card in the computer. You must comply with the IEEE-488.1 protocol and tell the instrument to listen and the controller to talk before sending a message to the instrument. This class allows you to communicate to the instrument using low-level GPIB commands. Refer to your VISA documentation for more details on how to use this class.

The GPIB INSTR resource class format is:

```
GPIB[board][:primary address][:secondary address][:INSTR]
```

*board* is the number of the GPIB card, if there are more than one in the computer. If there is only one GPIB card, don not include *board*, but do not leave a space.

*primary address* is the main GPIB address of the instrument, which can be changed, if necessary, through the front panel of the instrument.

*secondary address* is for secondary addressing in GPIB. Some instruments have subinstruments or cards inside the main instrument or backplane. The primary address identifies the main instrument. The secondary address identifies subinstruments. Refer to the instrument user manual for the secondary address, if applicable.

## Sending raw commands to an instrument

---

The next sections show you how to use VISA-C and VISA-COM to send raw instrument commands without using the instrument drivers.

**VISA-C sample code**

The following is a simple C/C++ console application that reads back the instrument identification string using VISA-C. You need to include visa.h and link with the visa32.lib file.

```
#include "stdafx.h"
#include <visa.h>

#define checkErr(fCall)      if (error = (fCall), (error = (error <
    0) ? error : VI_SUCCESS)) \
                            {goto Error;} else error = error

int _tmain(int argc, _TCHAR* argv[])
{
    ViSession defaultRM, vi;
    char buf [256] = {0};
    ViStatus  error = VI_SUCCESS;

    /* Open session to GPIB device at address 22 */
    checkErr(viOpenDefaultRM(&defaultRM));
    checkErr(viOpen(defaultRM, "GPIB0::14::INSTR", VI_NULL,VI_NULL, &vi));

    /* Initialize device */
    checkErr(viPrintf(vi, "*RST\n"));

    /* Send an *IDN? string to the device */
    checkErr(viPrintf(vi, "*IDN?\n"));
    ViUInt16 status = 0;
    do
    {
        checkErr(viReadSTB(vi, &status));
        printf("ReadSTB = %X\n", status);
    } while(status == 0);

    /* Read results */
    checkErr(viScanf(vi, "%t", &buf));
    /* Print results */
    printf ("Instrument identification string: %s\n", buf);

    /* Close session */
    checkErr(viClose(vi));
    checkErr(viClose(defaultRM));

Error:

    if(error < VI_SUCCESS)
        printf("Visa Error Code: %X\n", error);
    printf("\nDone - Press Enter to Exit");
    getchar();

    return 0;
}
```

### VISA-COM sample code

This example gets the instrument identification string using VISA-COM in C#.

The first thing to do is add a reference to the VISA-COM interop DLL, which is usually located at C:\Program Files\IVI Foundation\VISA\VisaCom\Primary Interop Assemblies\Ivi.Visa.Interop.dll.

```
using Ivi.Visa.Interop;

namespace WindowsApplication1
{
    public class IdnSample: System.Windows.Forms.Form
    {
        private Ivi.Visa.Interop.FormattedIO488 ioDmm;
        //
    }
    private void IdnSample_Load(object sender, System.EventArgs e)
    {
        ioDmm = new FormattedIO488Class();

        SetAccessForClosed();
    }

    private void btnInitIO_Click(object sender, System.EventArgs e)
    {
        try
        {
            ResourceManager grm = new ResourceManager();
            ioDmm.IO = (IMessage)grm.Open("GPIB::16::INSTR",
                AccessMode.NO_LOCK, 2000, "");
            ioDmm.IO.TerminationCharacterEnabled = true;
        }
        catch (SystemException ex)
        {
            MessageBox.Show("Open failed on " + this.txtAddress.Text + " " +
                ex.Source + " " + ex.Message, "IdnSample", MessageBoxButtons.OK,
                MessageBoxIcon.Error);
            ioDmm.IO = null;
        }
    }
}
```

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