FLUKE

BT5300 Series

Battery Tester

User Manual

8/2021

LIMITED WARRANTY AND LIMITATION OF LIABILITY

Each Fluke product is warranted to be free from defects in material and workmanship under normal use and service. The warranty period for BT5300 series and SW1080 is three years, and one year for SW9010, and begins on the date of shipment. Parts, product repairs, and services are warranted for 90 days. This warranty extends only to the original buyer or end-user customer of a Fluke authorized reseller, and does not apply to fuses, disposable batteries, or to any product which, in Fluke's opinion, has been misused, altered, neglected, contaminated, or damaged by accident or abnormal conditions of operation or handling. Fluke warrants that software will operate substantially in accordance with its functional specifications for 90 days and that it has been properly recorded on non-defective media. Fluke does not warrant that software will be error free or operate without interruption.

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Introduction

Product Overview

The Fluke BT5310/ BT5311/ BT5320/ BT5321 Battery Tester (the “Product” or “Instrument”) can measure the AC resistance (using 1 kHz signal) and DC voltage of batteries simultaneously. The Product features high accuracy and high measurement speed, rich remote interfaces, and meets the requirements for accuracy, speed and reliability of test instruments in the automated production of batteries. And the 4.3-inch LCD display and the intuitive operation make it easier to operate the Instrument during manual testing.

Fluke switch system SW9010 and SW1080 is dedicated to battery measurement. SW9010 Multiplexer Card can be installed to the Battery Tester to form a battery test system with up to 64 channels. If more channels are needed, the system can be extended to up to 320 channels by using a SW1080 Switch Mainframe.

Features

- Three-in-one battery test system

  Integrate three instruments: high-accuracy battery tester, high-accuracy voltmeter and multiplexer card.

- High accuracy measurements

  The resistance resolution of 0.1 μΩ and accuracy of 0.2% of reading meet the increasingly stringent requirements of battery cell internal resistance test. The voltage resolution of 1 uV and accuracy of 18 ppm of reading is comparable to that of the mainstream 7.5-digit multimeters.

- High-speed measurements

  By using the unique Scan mode, the internal resistance and voltage test of up to 256 cells can be completed in 30 seconds (including measuring, channel switching and the communication time between the instrument and the computer).

- Stable reading

  The Multiplexer Cards ensure the consistency of its anti-eddy current circuit design reduces the impact of eddy currents on the test, and test results between channels results. The SENSE and SOURCE lines of the test leads are separated to avoid the effects of eddy current and ensure stable readings during manual testing.

- Simple development

  A Serial (RS-232) and a Ethernet interface is provided to control the Instrument, and the remote SCPI command is compatible with mainstream battery testers in the market, which is convenient for customers to replace the existing battery tester to improve the accuracy of the OCV test system.

- High allowable total line resistance

  Even with the smallest range of 3 mΩ, the Fluke Battery Testers support allowable total line resistance up to 10 Ω, supporting longer and thinner test cables, which greatly reduces the occurrence of mismatches between the test range and the measured value.

- Support High-Z inputs

  The default input impedance of the Battery Tester is 10 MΩ, which can be set to High-Z (>10 GΩ) to avoid unstable test results caused by high impedance of the unit under test (such as the enclosure potential contact check of pouch batteries).

- High safety

  The Multiplexer Card has a built-in self-recovery fuse PTC for each channel to ensure the system is protected in the event of short-circuit.

- Versatility

  Any channel of the Multiplexer Card can be configured to one of the two functions below.

  - AC internal resistance and DC current
  - Enclosure potential contact check

How to Contact Fluke

Fluke Corporation operates worldwide. For local contact information, go to our website: cn.fluke.com (Chinese) or www.fluke.com/en-us/support/manuals (English). To register your product, view, print, or download the latest manual or manual supplement, go to our website.

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Safety Information

Warning and Caution

A **Warning** identifies hazardous conditions and procedures that are dangerous to the user. A **Caution** identifies conditions and procedures that can cause damage to the Product or the equipment under test.

⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury and for safe operation of the Product:

- **Read all safety information before you use the Product.**
- **Carefully read all instructions.**
- **Do not alter the Product and use only as specified, or the protection supplied by the Product can be compromised.**
- **Examine the case before you use the Product. Look for cracks or missing plastic. Carefully look at the insulation around the terminals.**

- **Do not use the Product around explosive gas, vapor, or in damp or wet environments.**
- **Do not use the Product if it operates incorrectly.**
- **Disable the Product if it is damaged.**
- **Do not use the Product if it is altered or damaged.**
- **Use only the mains power cord and connector approved for the voltage and plug configuration in your country and rated for the Product.**
- **Replace the mains power cord if the insulation is damaged or if the insulation shows signs of wear.**
- **Disconnect the mains power cord before you remove the Product covers.**
- **Make sure the ground conductor in the mains power cord is connected to a protective earth ground. Disruption of the protective earth could put voltage on the chassis that could cause death.**
- **Do not put the Product where access to the mains power cord is blocked.**
- **Measure a known voltage first to make sure that the Product operates correctly.**
- **Use the correct terminals, function, and range for measurements.**
- **Use only cables with correct voltage ratings.**
- **Do not use test leads if they are damaged. Examine the test leads for damaged insulation and measure a known voltage.**
- **Do not make connections on hazardous live conductors in damp or wet environments.**
- **Do not operate the Product with covers removed or the case open. Hazardous voltage exposure is possible.**
- **Keep fingers behind the finger guards on the probes.**
- **Do not apply more than the rated voltage, between the terminals or between each terminal and earth ground.**
- **Do not touch voltages >30 V ac rms, 42 V ac peak, or 60 V dc.**
- **Use only specified replacement fuses.**
- **Have an approved technician repair the Product.**
- **Use this Product indoors only.**

Symbols

Table 1 lists the symbols that can be used on the Product or in this document.

Table 1. Symbols

Symbols	Description
	WARNING. RISK OF DANGER.
	WARNING. HAZARDOUS VOLTAGE. Risk of electric shock.
	Consult user documentation.
	Fuse
	AC (Alternating Current)
	Earth
	Conforms to European Union directives.
	This product complies with the WEEE Directive marking requirements. The affixed label indicates that you must not discard this electrical/electronic product in domestic household waste. Product Category: With reference to the equipment types in the WEEE Directive Annex I, this product is classed as category 9 "Monitoring and Control Instrumentation" product. Do not dispose of this product as unsorted municipal waste.

Model Comparison Table

Table 2 Lists functional comparison of different models.

Table 2. Product features table

Feature	BT5310	BT5311	BT5320	BT5321
DC V	6.5-digit		7.5-digit	
Add SW9010 Multiplexer Cards to the inside of the Instrument	No	Yes. Up to 2 modules	No	Yes. Up to 2 modules
Connect the external SW1080 Switch Mainframe	Yes	Yes	Yes	Yes

The following are recommended models for different applications.

- Manually use the Instrument or integrate it into the test system but do not use the Fluke switch system

  6.5-digit DC V — BT5310

  7.5-digit DC V — BT5320

- System integration application and use the Fluke switch system

Channel count needed[1]	DC V	Recommended tester model
≤ 64	6.5-digit	BT5311
	7.5-digit	BT5321
65 to 256	6.5-digit	BT5310
	7.5-digit	BT5320
257 to 320	6.5-digit	BT5311
	7.5-digit	BT5321

[1] *A single SW9010 Multiplexer Card supports 32 channels, the user can select the number of the SW9010 cards according to the number of channels needed. If the channel count is more than 64, a SW1080 Switch Mainframe is needed.*

Operation Features

This section describes the operation panel of the Product and the location and function of the display screen. Please read this section carefully before operating the Product. See the section *Remote Control* for remote operation instructions.

The content of this manual is based on BT5321. As different models have different features, some of the information in this manual may not be applicable to your product.

Front Panel

The front panel of the Product includes a standby button, display, function buttons, navigator buttons and system setup buttons. As shown in *Figure 1*.

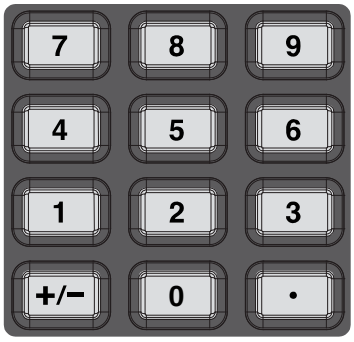
Table 3 lists the features and functions of each component on the front panel.

Figure 1. Front panel

Table 3. Controls on the front panel

Item	Description
1	 **Standby button** Set the Product to the standby mode. In the standby mode, the display is off and the buttons do not work. The standby mode also disable remote operation. See the section *Power* on and Standby. - Press the button briefly to switch the Product between standby and working mode.
2	 **Function softkeys** The blue F1 to F5 function buttons correspond to the five softkeys from left to right at the bottom of the screen, so each function key is equivalent to the appropriate softkey. The displayed label of the soft key varies depending on the function and interface.

Item	Description
❸	 **Navigation keys (up, down, left, and right)** Press the keys to go through all selectable functions on the screen and select one of them, the currently selected function will be highlighted in yellow.
❹	**USB port** Reserved for future function extension.
❺	I GUARD 1V RMS MAX V GUARD **Ground/Guard terminals** The I-GUARD is used for protection of Source terminals, the V-GUARD is used for protection of SENSE terminals.
❻	SOURCE HI 11V RMS MAX LO 1V RMS MAX **Source terminals** Source terminals for 4-wire measurement method, used to output AC excitation current.
❼	SENSE 4 WIRE Ω 2 WIRE DCV HI 11V RMS MAX LO 1V RMS MAX **Sense terminals** When measurement function is ACR+DCV or ACR supported by 4 wire measurement method, Sense terminals are used to measure induced voltage drop by AC excitation current; When measurement function is DCV, Sense terminals are used for DCV measurement.
❽	**Display** 4.3-inch, 480 x 272 pixel screen. See the section *Display Screen*.
❾	ZERO **Zero** Under the measurement mode, press this button to perform zero adjustment. See the section *Zero-Adjust* for details.

Item	Description
⑩	 **Trigger** Execute the external triggering manually. See the section *Trigger* for details.
⑪	 **Setup** Enter the Instrument Setup which includes device information, instrument settings, communication settings. See the section *Instrument Setup* for details.
⑫	 **Channel** Enter the Channel Configuration. See the section *Input and Channel Configuration* for details.
⑬	 **Function** Switch between measurement functions: ACR+DCV, ACR, DCV. See the section *Measurement Function* for details.
⑭	 **Measure** Enter the Measurement mode. See the section *Measuring with Test Leads* and *Measuring Through Multiplexer Cards* for details.
⑮	 **Numeric keys** Used to enter numbers and symbols.

Display Screen

The Screen is divided into three areas: status bar, main display area and softkey area, as shown in *Figure 2*.

The **Status Bar** displays the current channel number and the status of average, comparator and zero status etc.

The **Main Display area** is for displaying measurements, compare results. The main display area displays different content depending on the current working mode and location, as detailed in the relevant sections below.

The **Softkey area** is at the bottom of the screen. Some of 5 soft keys may have no label, which means that the key has no functions.

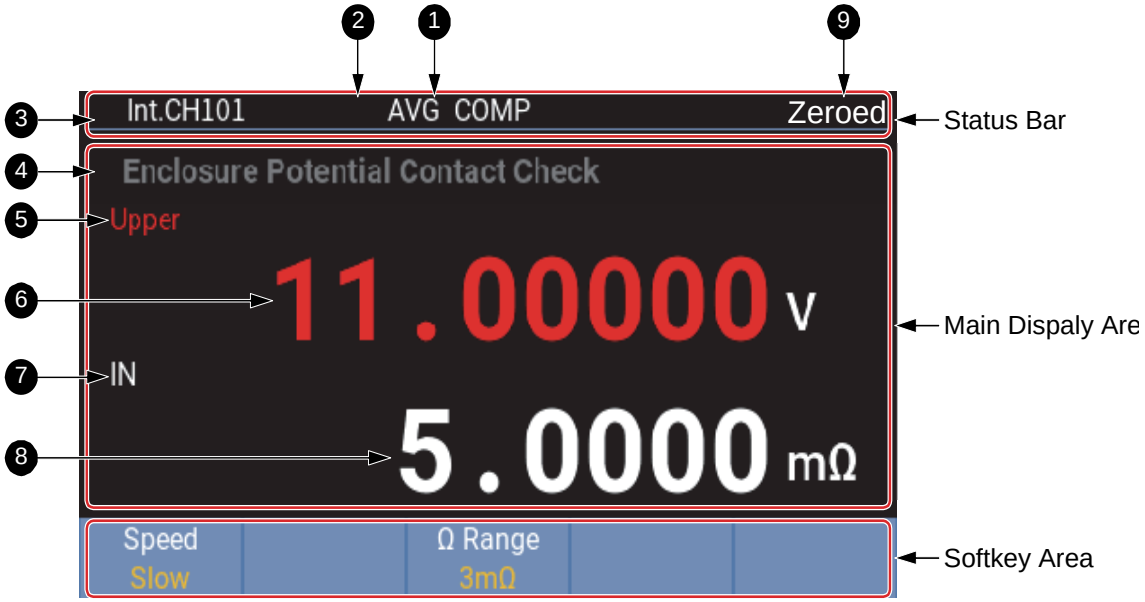


Figure 2. Display screen

Note

The screen displayed in *Figure 2* is only to illustrate the information that can be displayed on the screen, and not all the items can be displayed at the same time.

Table 4. Display screen

Item	Description
❶	**Comparator status** When the Comparator is ON, the **COMP** indicator is displayed on the screen; and no any information is displayed if the Comparator is OFF. See the section *Comparator* for more details.
❷	**The average function status.** When the Average is ON, the **AVG** indicator is displayed on the screen; and no any information is displayed if the Average is OFF. See the section *Average* for more details.
❸	**Current channel indicator** Indicate the channel selected. See the section *Channel Number* for more information about channel numbers.

Item	Description
❹	**Measurement function indicator** The selected measurement function is displayed when the Module Selection is enabled. See the section *Measurement Function* for more information about measurement functions.
❺	**Compare results** The judgment result of the comparator is displayed at the upper-left position of the measured value if the Comparator is ON. And this is the judgment result of voltage. - **Upper:** The measured value is higher than the upper threshold. - **In**: The measured value is between the upper and lower threshold. - **Lower:** The measured value is lower than the lower threshold. See the section *Comparator* for more details.
❻	**Measured voltage** See the section *DCV* for more details.
❼	The same as e. But this is the judgment result of resistance. See the section *Comparator* for more details.
❽	**Measured resistance** See the section *ACR* for more details.
❾	**Zero indicator** When the current measurement range of the Production is zeroed successfully, the Zeroed indicator is displayed on the screen; and no information is displayed if the current measurement range is not zeroed or zero failed. See the section *Zero-Adjust* for more details.

Rear Panel

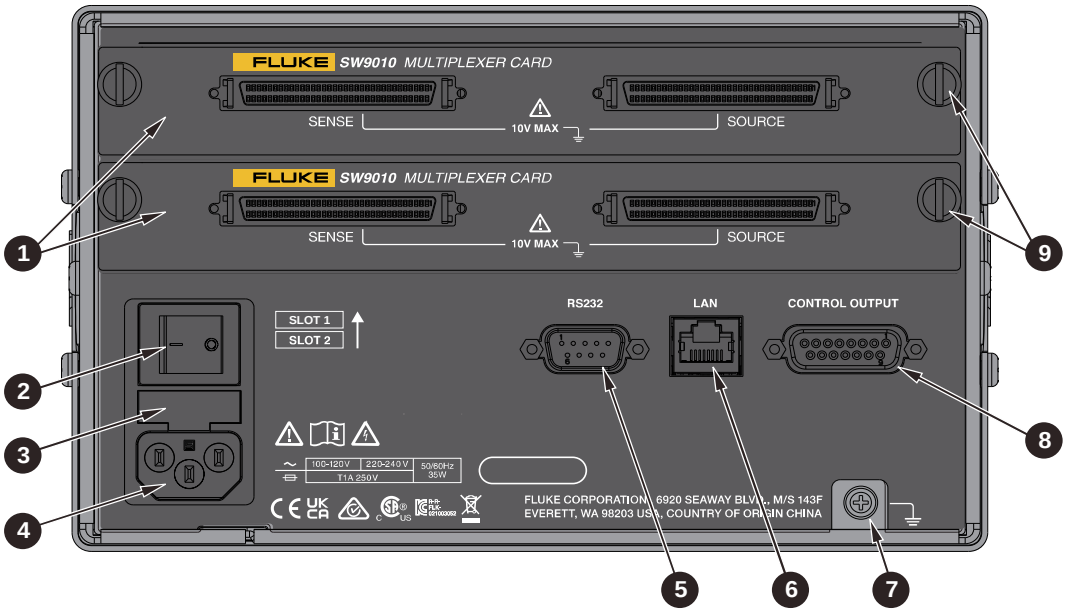


Figure 3. Rear panel

Table 5. Rear panel feaures

Item	Description
1	**Multiplexer cards** - Multiplexer cards can be inserted into the Instrument. The Instrument has two built-in slots and up to 2 SW9010 Multiplexer Cards can be installed. See the section *Install Multiplexer Cards* and *Connect the Cell* for more details.
2	**Mains power switch** Power on or off the Product. - I: power on - O: power off
3	**Fuse** See the section *Change the Fuse* for more information about the fuse.
4	**Mains power connector** See the section *Connect to Power* for more information on power supply connection.
5	**RS-232 interface** Serial port. See the section *Remote Interface* for details.
6	**LAN interface** Ethernet interface for remote operation. See the section *Connect to Power and Ground* for details.

Item	Description
❼	**Earth** Chassis earth. See the section *Connect to Power and Ground* for details.
❽	**Control Output connector** Connect to SW1080 Switch Mainframe. See the section *Connection Between the Product and the Switch Mainframe*.
❾	**Locking screw** Each Multiple Card is fastening to the Product or the SW1080 Switch Mainframe though the two screws on the left and right respectively. See the section *Install Multiplexer Cards* for details.

Preparation

Conventions

For keys, buttons, menus, options, fields and components mentioned in this Manual:

Bold fonts are generally used to indicate printed words or names of keys/buttons on the Product's panel.

"Bold fonts within quotation marks" are generally used to indicate the content or options displayed on the Product's screen.

Fonts in blue generally refer to hyperlinks, including links to the Internet and cross-references within this Manual. The targeted content can be found by clicking the links directly.

For readability purposes, list items are generally not enclosed in double quotes, because they are generally easy to identify to be the content on screen and panel by context.

Standard Packaging

To prevent damage during shipment, the Product is shipped in a specially designed package. Please check the Product carefully and inform the carrier of any damage.

When unpacking the Product, please check the standard equipment listed in *Table 6* and other ordered parts listed on the packing list. If there is any shortage of parts, please inform the nearest Fluke Technical Service Center or the Service Center in place of purchase.

If you need to reship the Product, please use the original package. If the original package is not available, a new package can be ordered from Fluke according to the Product's model and part number

Figure 4 and *Table 6* list the standard equipment that comes with the Product. Please see *Table 7* for optional accessories.

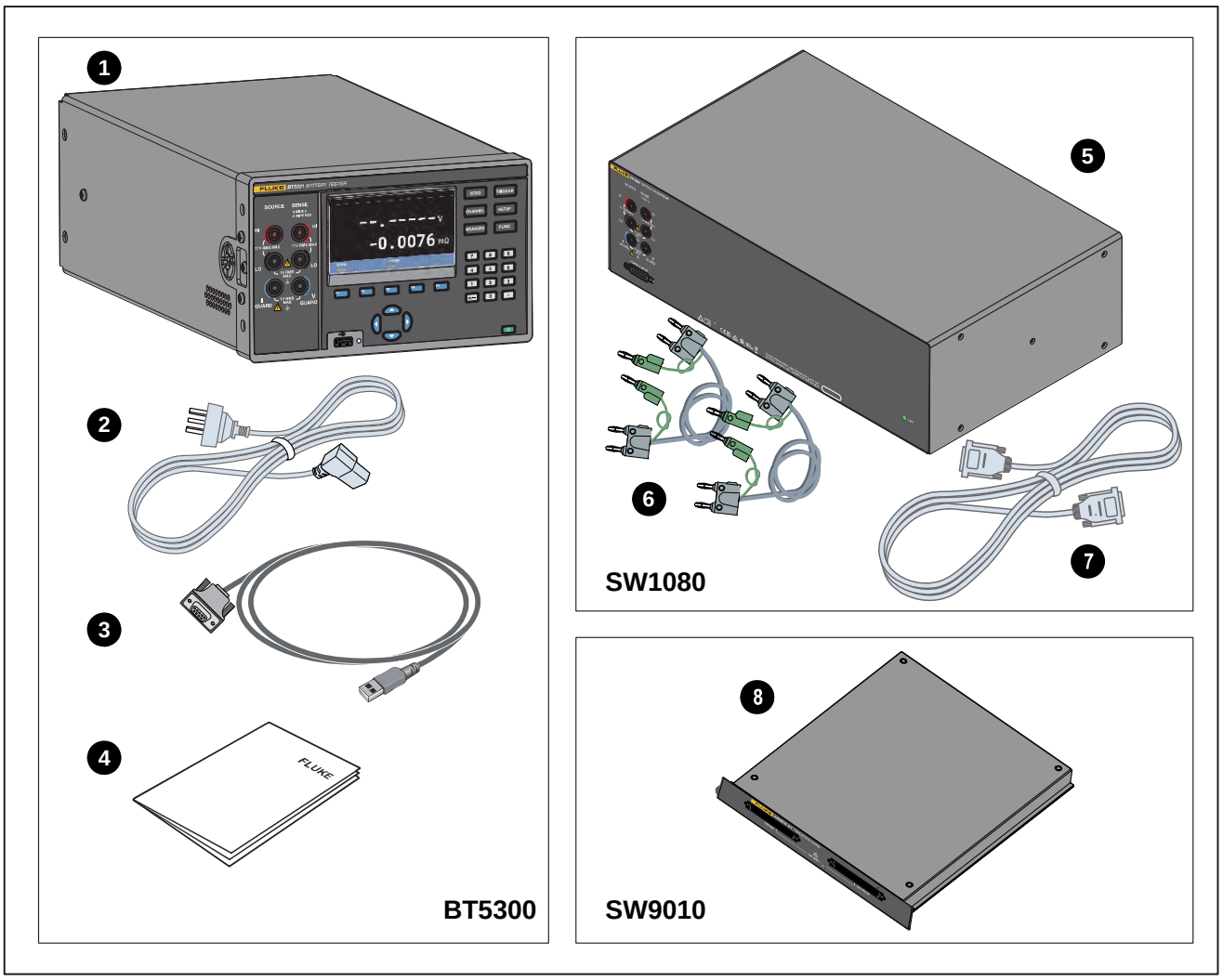


Figure 4. Standard equipment

Table 6. Standard equipment

Item	Description	Part number	BT5300	SW1080	SW9010
1	Battery Tester main unit	BT5310: 5306406 BT5311: 5306414 BT5320: 5306423 BT5321: 5306438	1		
2	Power cord, 10 A/250 V		1		
3	RS-232 serial cable	2683906	1		
4	Calibration report		1		
5	Switch Mainframe	5306445		1	

Item	Description	Part number	BT5300	SW1080	SW9010
6	Shield twist cables	1943483		2	
7	Connection cable for the Switch Mainframe	1943483		1	
8	Multiplexer cards	5306450			1
Not shown	Safety Information	5309262	1	1	
	GOING GREEN CARD	4253109	1	1	

Table 7. Optional accessories

Item	Description	Part number
1	BTL310 test lead	5306461
2	Ethernet cable	4396147
3	Protective boot for front panel	4281980
4	Protective boot for rear panel	4281971
5	Handle	4281998
6	Fuse, 1 A/250 V (Slow fuse)	808055

Set the Handle Position

An optional handle is available to easily transport the Product. The handle can also used as a stand to place the Product on a flat surface which is convenient for users to observe the screen from a certain angle. _Figure 5_ shows the various handle positions and also shows how to remove and install the handle and the protective rubber boots.

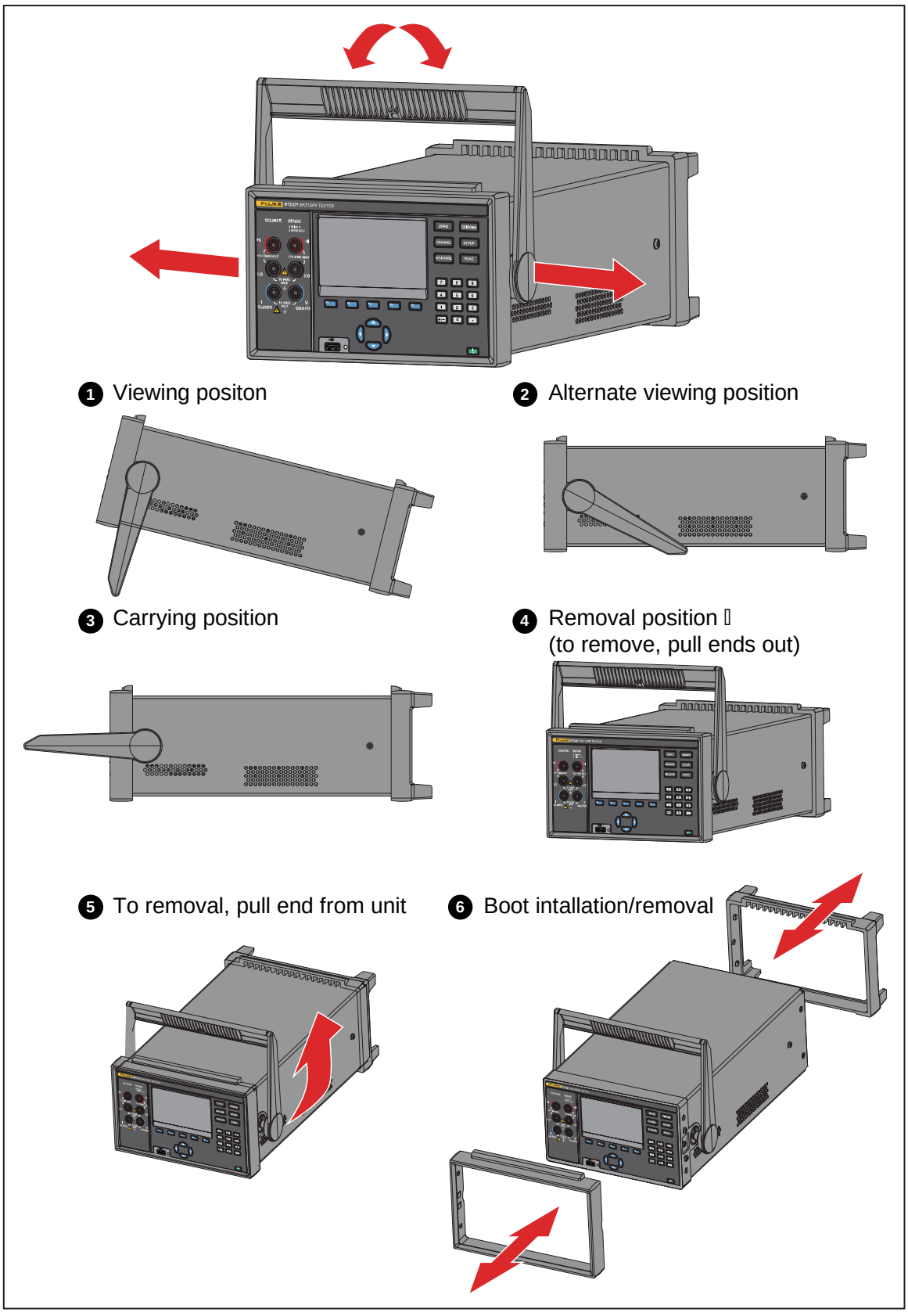


Figure 5. Use the tilt stand

Connect to Power and Ground

The Product is shipped with a mains power cord, 250 V/10 A. Once the power supply voltage is checked and it is properly grounded, use the mains power cord to connect to the Product to the power outlet. As shown in *Figure 6*.

⚠⚠ WARNING

To prevent possible electrical shock, fire, or personal injury:

- **Use only the mains power cord and connector approved for the voltage and plug configuration in your country and rated for the Product.**
- **Replace the mains power cord if the insulation is damaged or if the insulation shows signs of wear.**
- **Make sure the ground conductor in the mains power cord is connected to a protective earth ground. Disruption of the protective earth could put voltage on the chassis that could cause death.**
- **Do not put the Product where access to the mains power cord is blocked.**

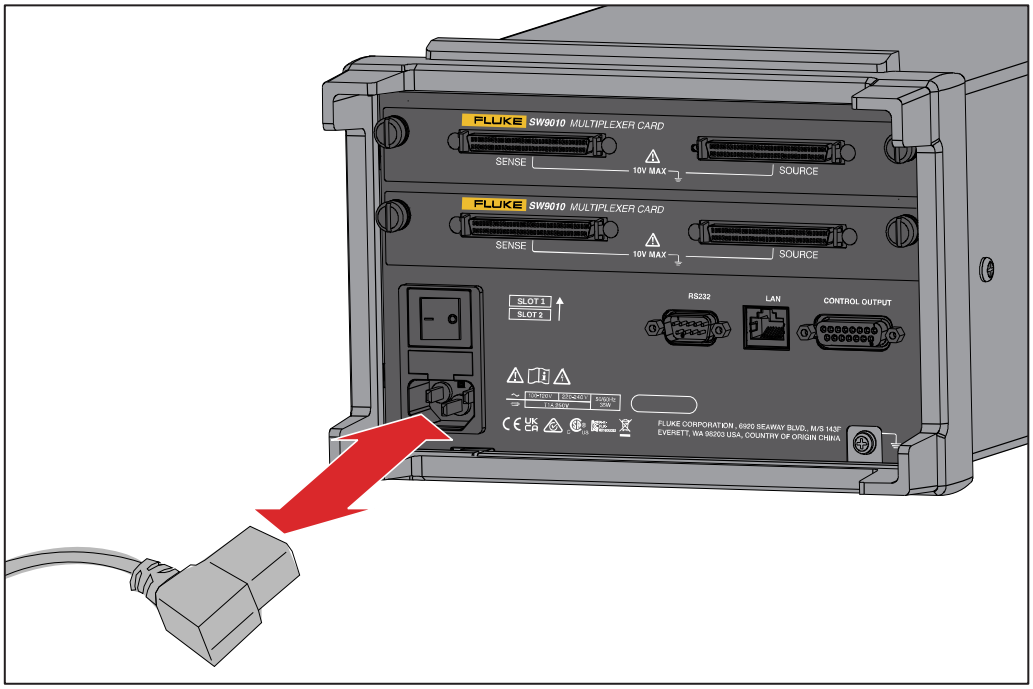


Figure 6. Mains power cord connection

Power on and Standby

As shown in *Figure 7*, the Product has a mains power switch located on the rear panel that supplies power to the unit, and a Standby key (⏻) on the front panel that put the Product in the standby mode. Push the (**I**) side of the mains power switch to power on the Product. As the Product powers on, a startup screen is shown on the display while the Product perform a self-check. If the Product detects any errors, an error message is shown on the screen that contains the error description along with an error code to help troubleshoot the problem.

Once the Product is powered on, use the Standby key (⏻) to put the Product in standby. In the standby mode, the display, buttons and functions are disabled while the internal components remains powered on and warmed up.

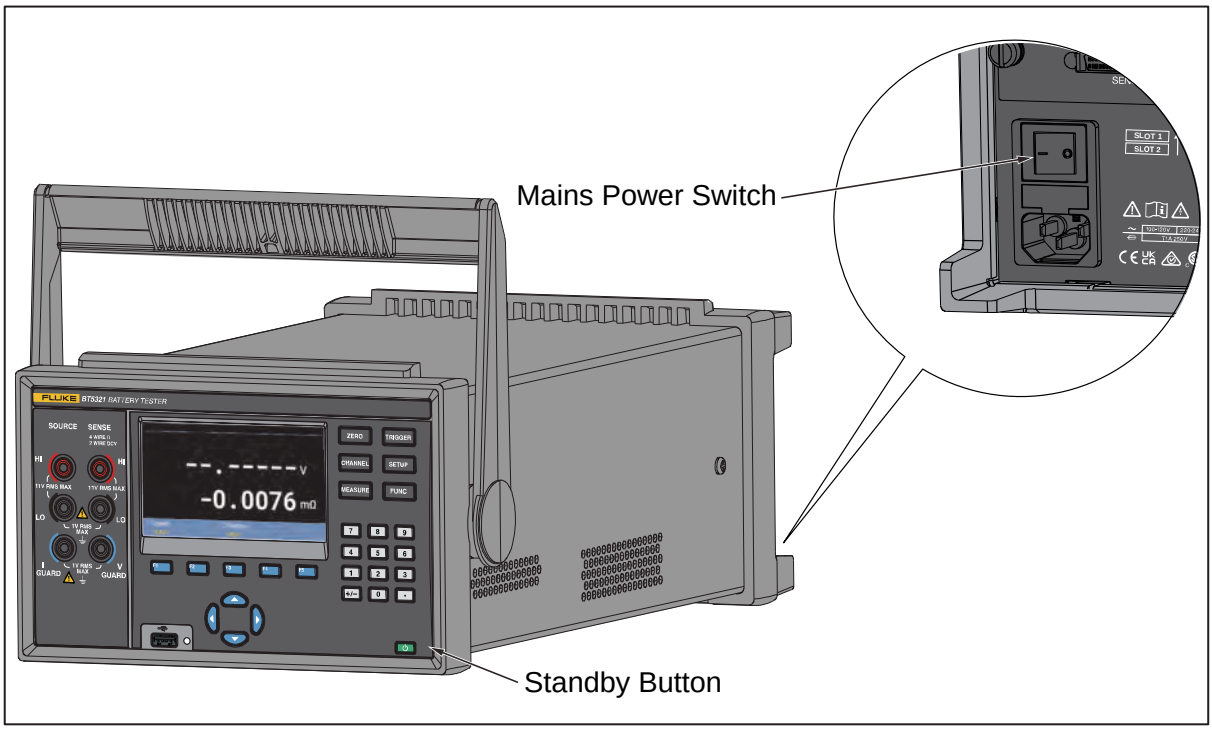


Figure 7. Power on and standby

Setting the Line Frequency

To suppress the influence of common mode interference on measurement, the frequency can be filtered according to the power frequency setting of the place of use.

Warm-Up the Product

It is recommended that the Product be warmed up before use. This will ensure the performance to the specifications listed in the section *Specifications*. The Product should be warmed up for at least 30 minutes (BT5310/BT5311) or 60 minutes (BT5320/BT5321).

Inspection Before Testing

Before using the Product fo the first time, verify that it operates normally to ensure that no damage occurred during storage or shipping. If you find any damage, please contact the nearest Fluke Authorized service center or your Fluke representative. See the section *How to Contact Fluke*.

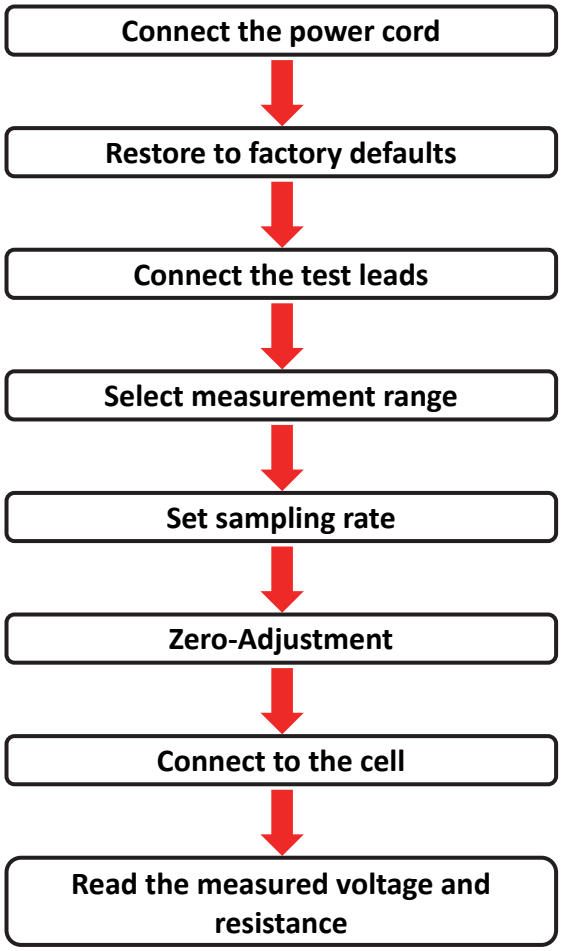
Before using the Product, perform the following inspection to ensure that it is operating properly.

Table 8. Chek-list before testing

Check point	Check content
Instrument appearance (both front and rear panels)	- No visible damage or cracks. - No internal circuity is exposed.
Test cables and power cord	Metal parts should be insulated without exposed parts.
Good test sample	Measure a known good circuit, and ensure the Product can display the correct measurement value.
Bad test sample	Measure a known bad circuit, and ensure the Product can display the correct measurement value.

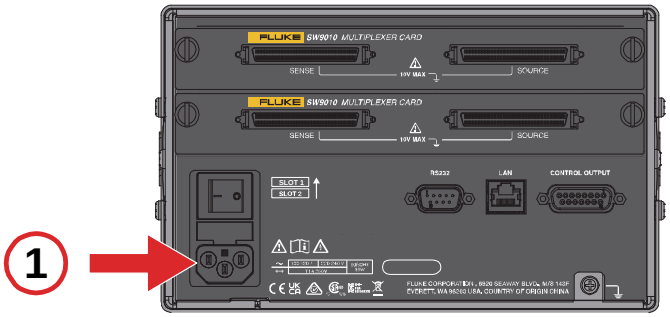
Measuring with Test Leads

To measure with test leads:



Connect the Power Cord

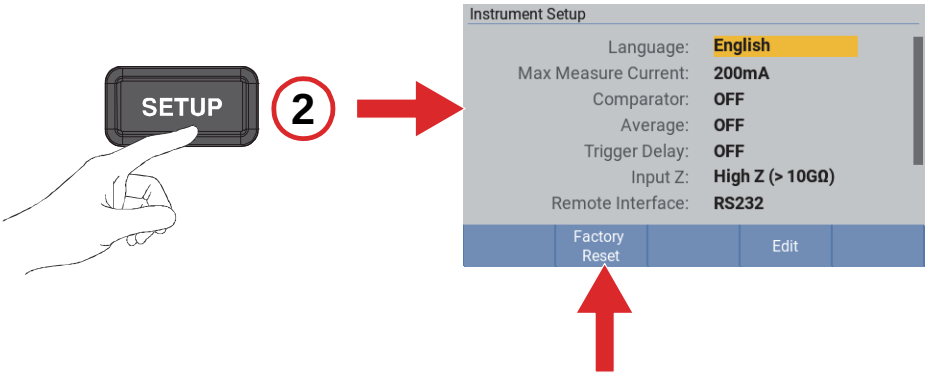
1. Connect the power cord and power on the Product according to the description in the section *Connect to Power and Ground*.



Restore to Factory Defaults

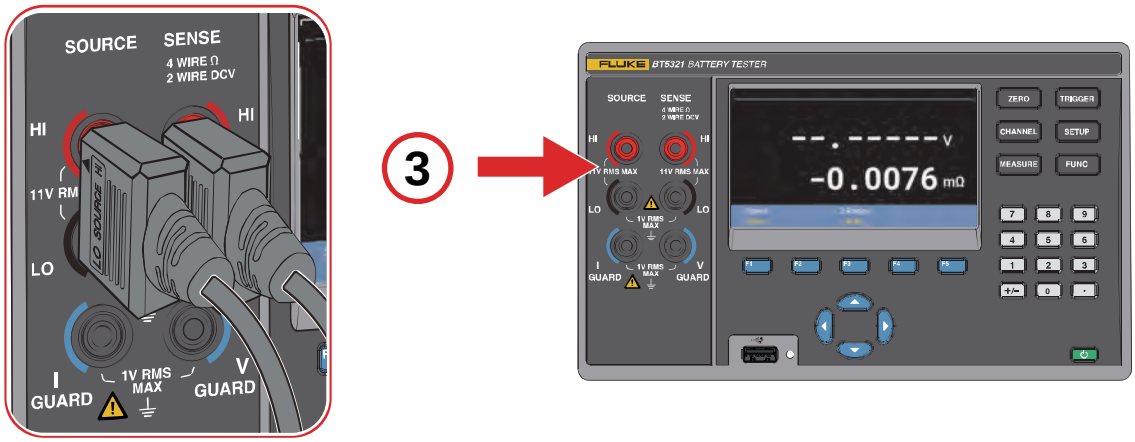
2. Reset the Product to factory defaults according to the description in the section *Restore to Factory Defaults*.

   The default setting of the Product is using the front terminals to measure.



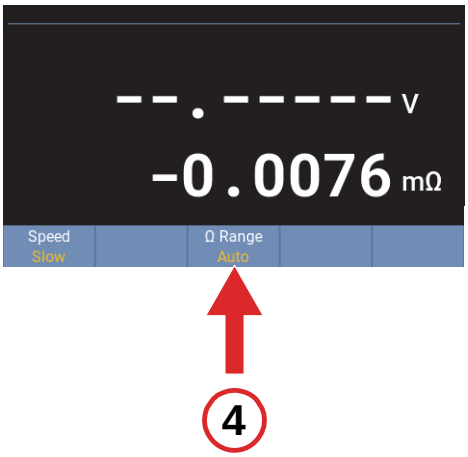
Connect the Test Leads

3. Connect the test leads with probes to the front terminals according to the description in the section *Front Inputs*.



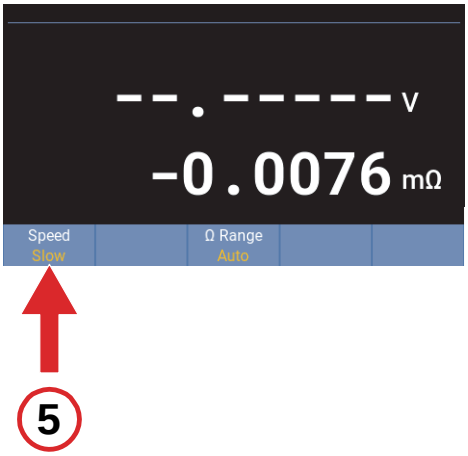
Select Measurement Range

4. Select the appropriate measurement range according to the description in the section *Changing Resistance Range*.



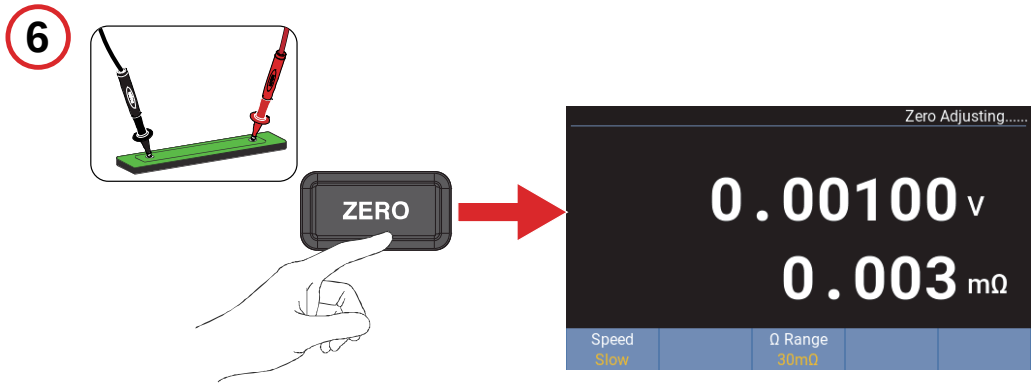
Set Sampling Rate

5. Select the appropriate sampling rate according to the description in the section *Changing Measurement Speed*.



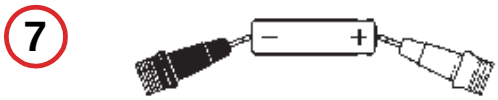
Zero-Adjustment

6. Connect the test leads to the zero-adjust board, zero the Product according to the description in the section *Zero-Adjust*.



Connect to the Cell

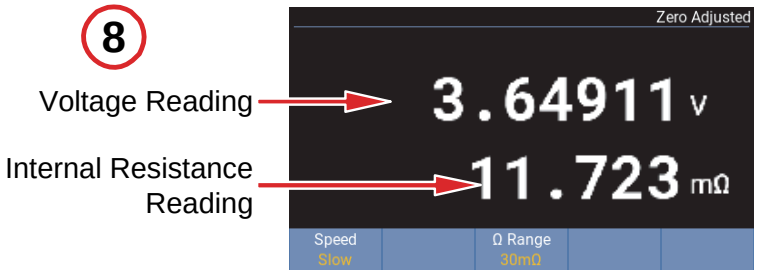
7. Connect the probes to the cell.



Read the Measured Voltage and Resistance

8. Read the measured voltage and internal resistance value.

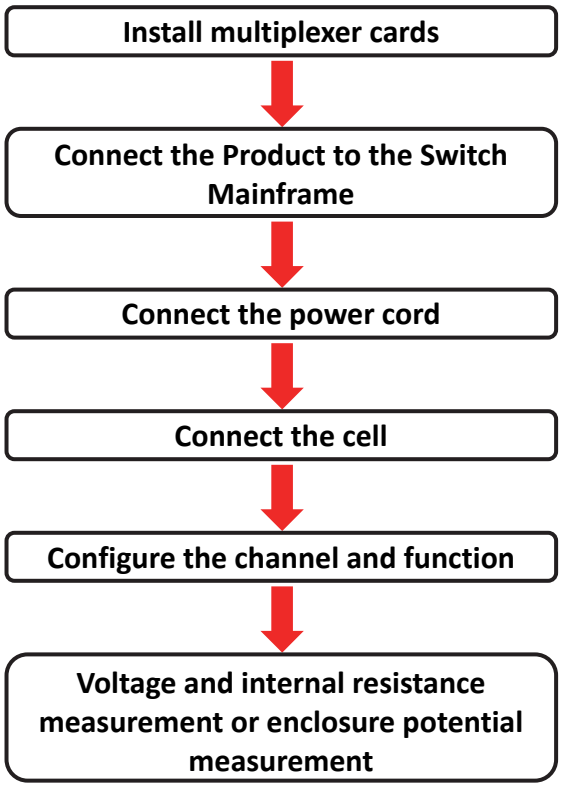
   See the section *Display Screen*.



Measuring Through Multiplexer Cards

Multiplexer Cards are normally controlled remotely to perform measurements. See the section *Input Channel Slection/Route Scan Programming Examples* for more information. This example explains how to measure the voltage, internal resistance and enclosure potential of a cell using a single channel manually.

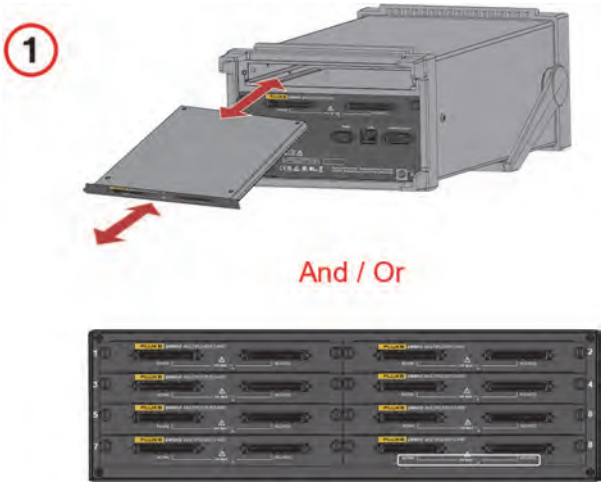
To measure through Multiplexer Cards:



Install Multiplexer Cards

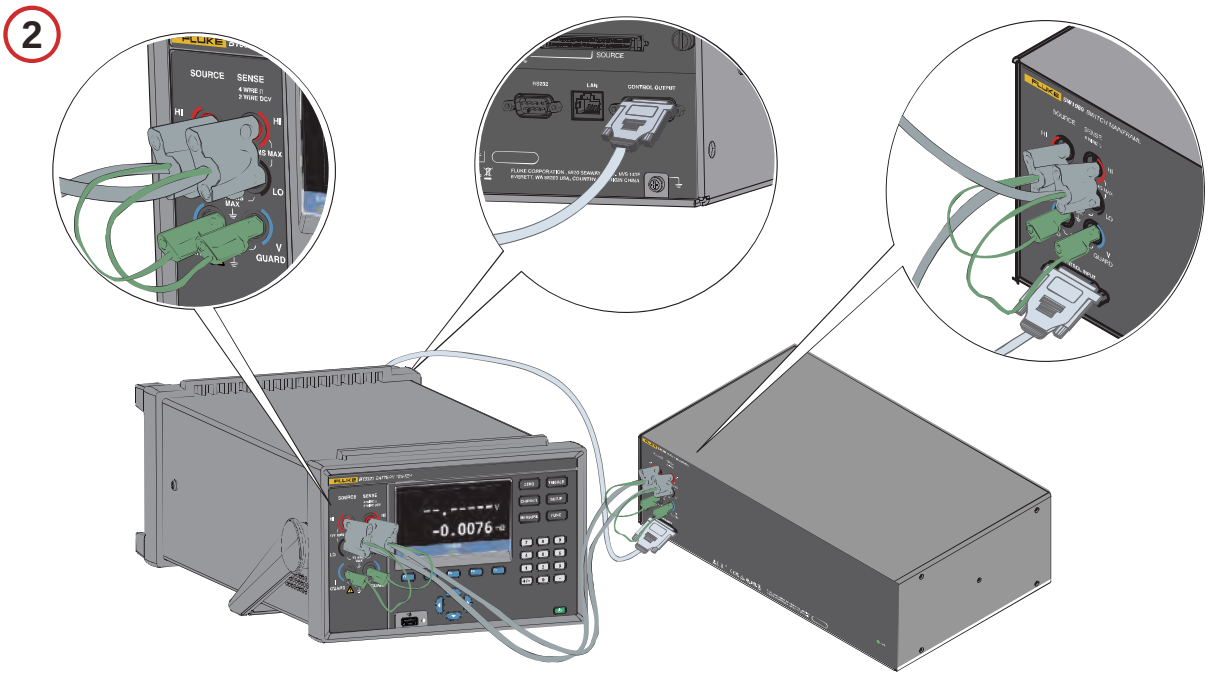
1. To measure through Multiplexer Card, one or more Multiplexer cards must be installed into the Product and/or into the Switch Mainframe.

   Please see the section *Built-in Multiplexer Cards* and *External Multiplexer Cards*, respectively.



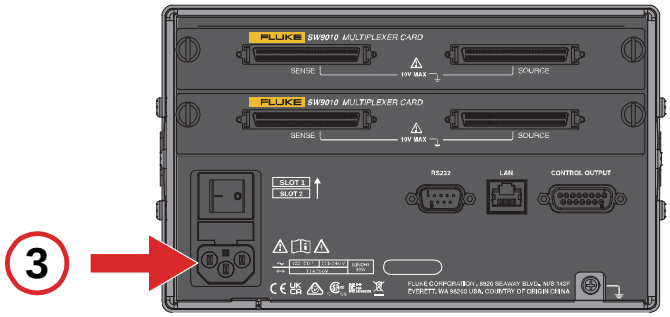
Connect the Product to the Switch Mainframe

2. If a Switch Mainframe is used, connect the Control Input connector on the front panel of the Switch Mainframe to the Control Output connector on the rear panel of the Product using the connection cable provided with SW1080 Switch Mainframe according to the description in the section *Connection Between the Product and the Switch Mainframe*. Connect the signal terminals of the Switch Mainframe to the signal input terminals of the Product using the shield twisted cables provided with the SW1080 Switch Mainframe.



Connect the Power Cord

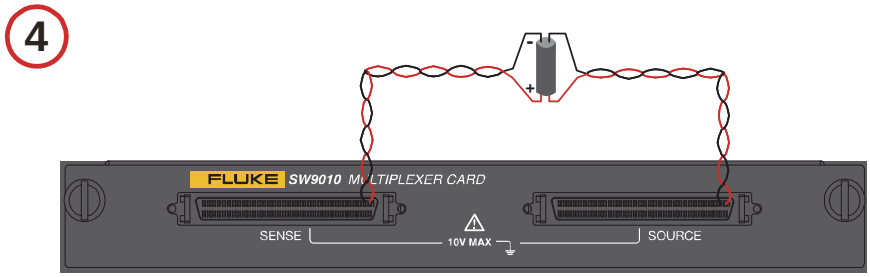
3. Connect the power cord and power on the Product according to th description in the section *Connect to Power and Ground*.



Voltage and Resistance Measurement

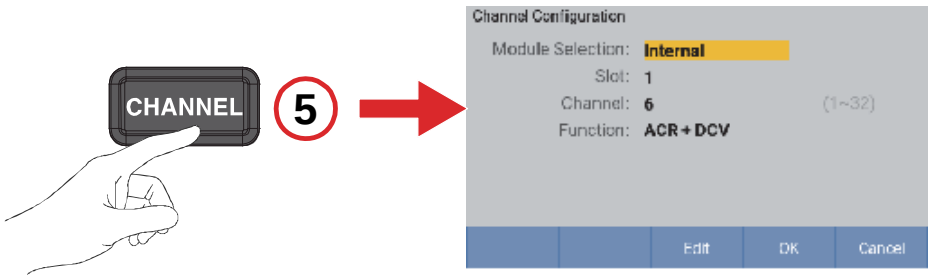
Connect the Cell

4. Connect the test cables to a Multiplexer Card in the Product or Switch Mainframe, and to the cell under test according to the description in the section *Wiring for Voltage and Internal Resistance Measurement*.



Configure the Channel and Function

5. Configure the channel as following according to the description in the section *Configuring Channels*, as well as the wiring method above:
   Module Selection: Internal or External
   Slot: the slot to be used
   Channel: the channel to be used
   Function: ACR + DCV



Select Measurement Range

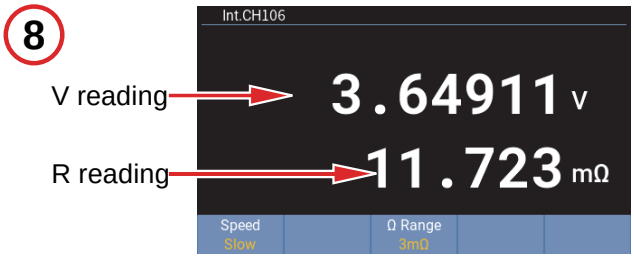
6. Select the appropriate measurement range according to the description in the section *Changing Resistance Range*.

Set Sampling Rate

7. Select the appropriate sampling rate according to the description in the section *Changing Measurement Speed*.

Read the Measured Voltage and Resistance

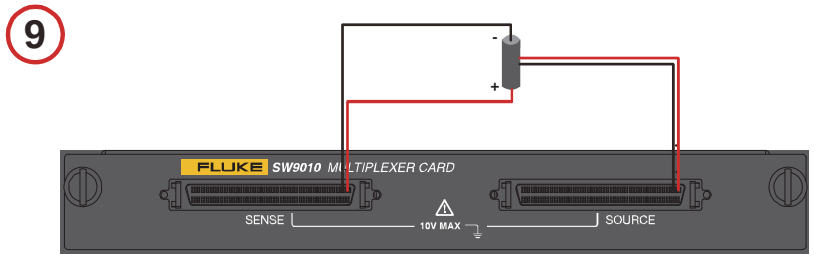
8. Read the measured voltage and internal resistance value. See the section *Display Screen*.



Enclosure Potential Measurement

Connect the Cell

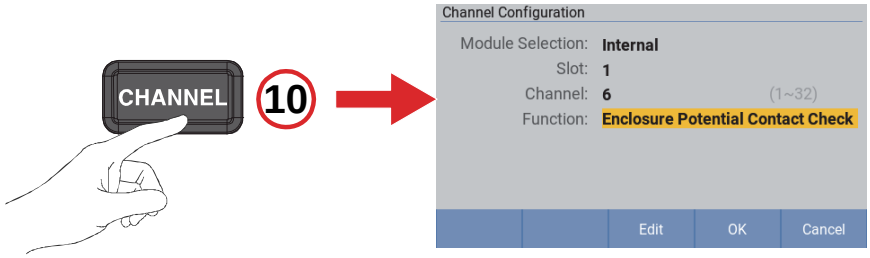
9. Connect the test cables to a Multiplexer Card in the Product or Switch Mainframe, and to the cell under test according to the description in the section *Wiring for Enclosure Potential Measurement*.



Enclosure Potential Contact Check

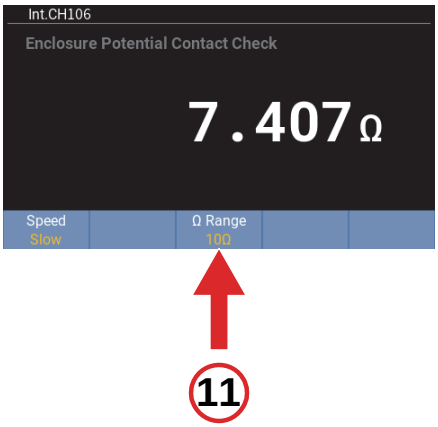
Configure the Channel and Function

10. Configure the channel as following according to the description in the section *Configuring Channels*:
    Module Selection: Internal or External
    Slot: the slot to be used
    Channel: the channel to be used
    Function: Enclosure Potential Contact Check



Select Measurement Range

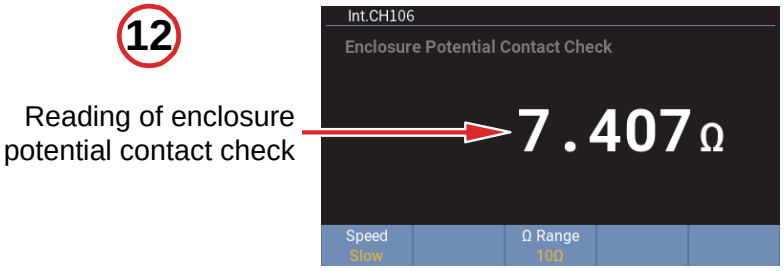
11. Set the impedance measurement range to **10 Ω** according to the description in the section *Changing Resistance Range*.



Read Measurement

12. Read the measured value of the enclosure potential contact check.

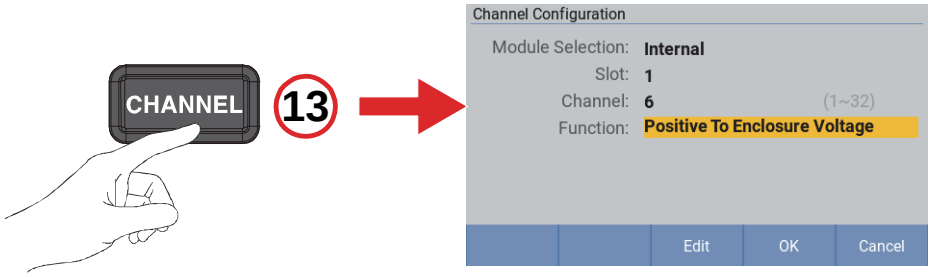
    See the section *Display Screen*.



Positive to Enclosure Voltage

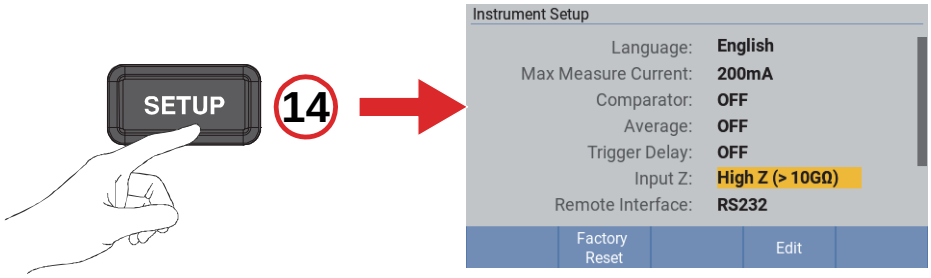
Configure the Channel and Function

13. Configure the channel as following according to the description in the section *Configuring Channels*:
    Module Selection: Internal or External
    Slot: the slot to be used
    Channel: the channel to be used
    Function: Positive To Enclosure Voltage



Set Input Impedance

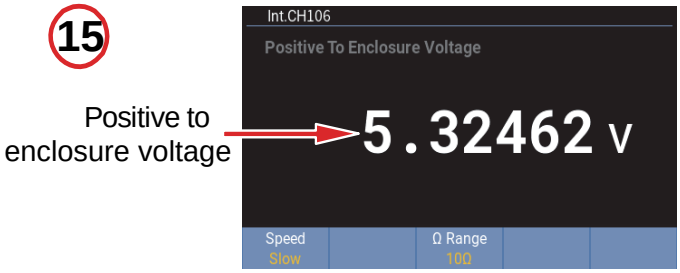
14. Set the Input Z to **High Z (>10Ω)** according to the description in the section *Changing Resistance Range*.



Read Measurement

15. Read the measured value of positive to enclosure voltage.

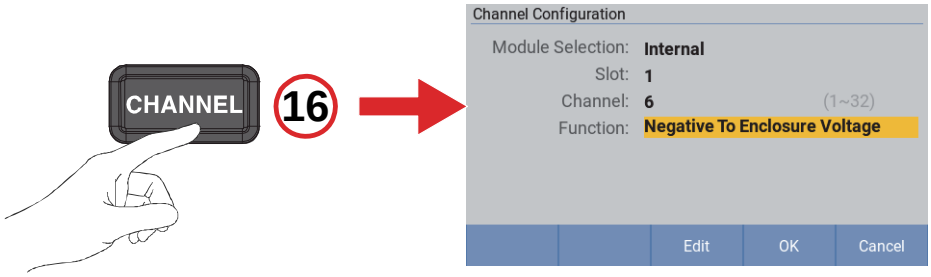
    See the section *Display Screen*.



Negative to Enclosure Voltage

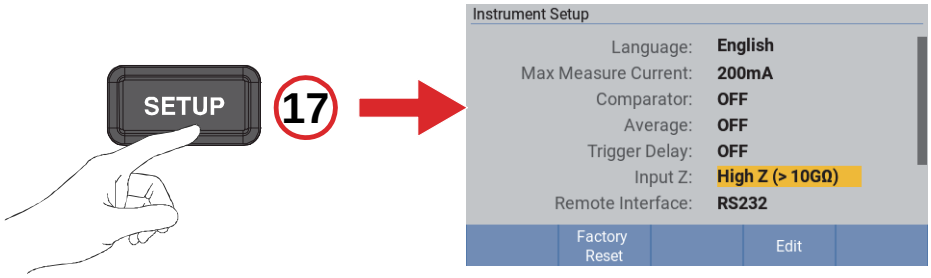
Configure the Channel and Function

16. Configure the channel as following according to the description in the section *Configuring Channels*:
    Module Selection: Internal or External
    Slot: the slot to be used
    Channel: the channel to be used
    Function: Negative to Enclosure Voltage



Set Input Impedance

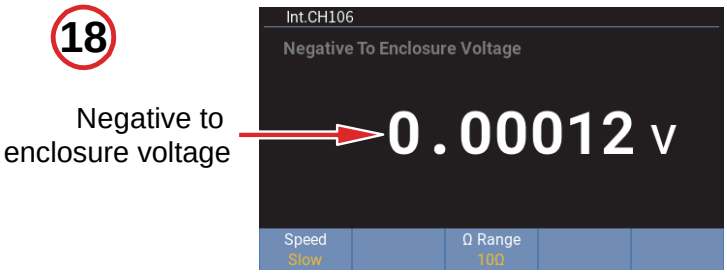
17. Set the Input Z to **High Z (>10Ω)** according to the description in the section *Changing Resistance Range*.



Read Measurement

18. Read the measured value of negative positive to enclosure voltage.

    See the section *Display Screen*.



Input and Channel Configuration

In addition to a set of inputs on the front panel, the Product can also accommodate up to 2 built-in Multiplexer Cards and support up to 8 external Multiplexer Cards. Each Multiplexer Card provides 32 channels, so that the total count of channels reaches 320.

Front Inputs

See the section *Front Panel* and *Appendix 1. AC Four-terminal Method* for more information.

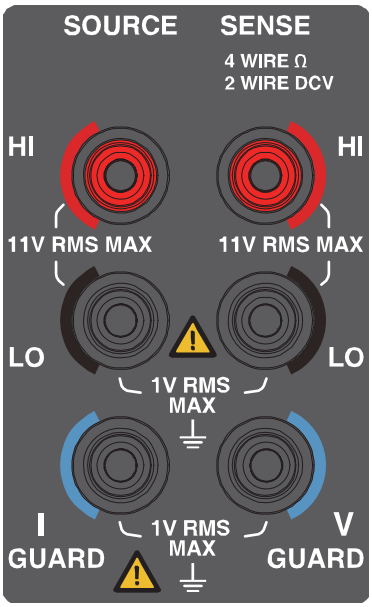


Figure 8. Front inputs

Test leads and cables are not the standard accessories. Please purchase test cables and optional leads (see *Table 7*) according to the specific situation or make your own test cables. Please refer to the section *Appendix 2. Precautions for Making Custom Test Cables* when making test leads by yourself.

To connect test leads:

1. Confirm that the mains power switch of the Product is off.
2. Confirm that the test leads are not connected to any circuit.
3. Plug the connectors of the 4-wire test leads to the front panel input terminals of the Product, as shown in *Figure 9*.

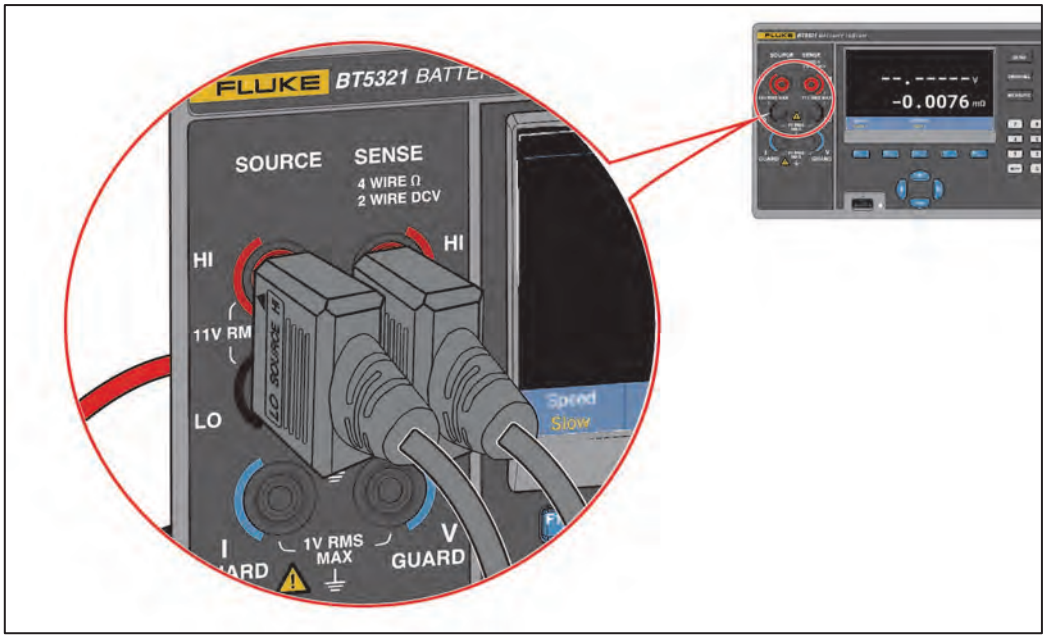


Figure 9. Connecting test leads

Multiplexer cards

Built-in Multiplexer Cards

The BT5311/BT5321 Battery Tester provides 2 slots used to install up to 2 SW9010 Multiplexer Cards. Each Multiplexer Cards provides 32 channels, so that the total count of channel reaches 64.

To install Multiplexer Cards and refer to *Figure 10*:

1. Power off the Product using the mains power switch on the back of the Product. See the section *Power on and Standby*.
2. Loosen the two screws on the left and right of the slot baffle, remove the protective cover of the corresponding slot on the rear panel of the instrument, and keep is in a suitable place. The upper slot is number 1 and the lower slot is number 2.
3. Carefully align the slide rails of the Multiplexer Card with the guide grooves in the slot. Please pay attention to the label on the front panel of the Multiplexer Card to ensure that it faces upwards.
4. Push the Multiplexer Card slowly into the Product until it is fully seated.
5. Tighten the two screws on the left and right sides of the Multiplexer Card. Do not use excessive force.
6. Connect the power cord and power on the Product and confirm that the Multiplexer Card is installed correctly according to the description in the section *Channel Configuration*.

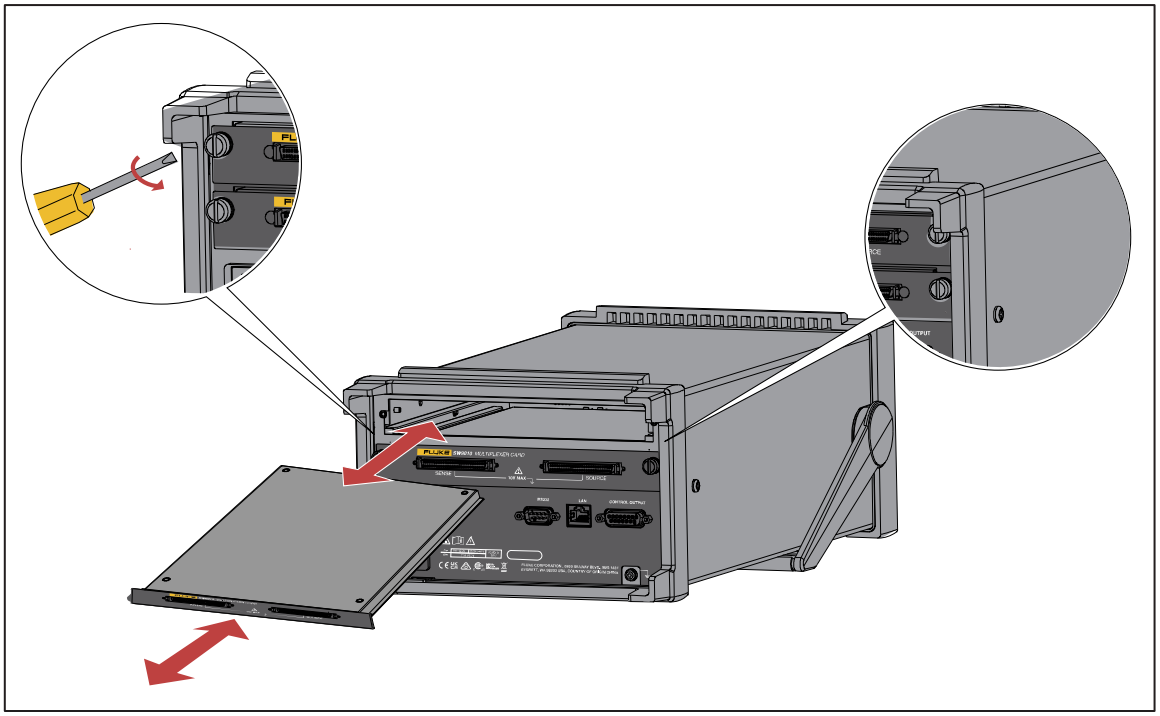


Figure 10. Installation of Multiplexer Cards

External Multiplexer Cards

If more than 64 channels are required, the system can be extended to up to 320 channels by using a SW1080 Switch Mainframe.

The SW1080 Switch Mainframe provide the Product with the capacity of additional 8 Multiplexer Cards as the external channel. The Switch Mainframe connect from the front panel Control Input connector to the Control Ouput connector on the rear panel of the BT5300 Series Battery Tester.

SW1080 Switch Mainframe

The arrangement of 8 SW9010 Multiplexer Cards in the SW1080 Switch Mainframe is shown in *Figure 12*.

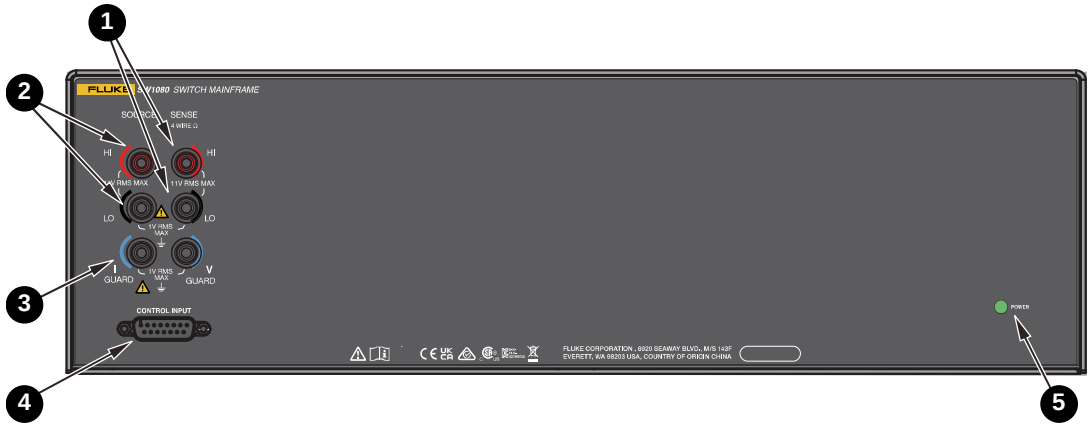


Figure 11. Front panel of the Switch Mainframe

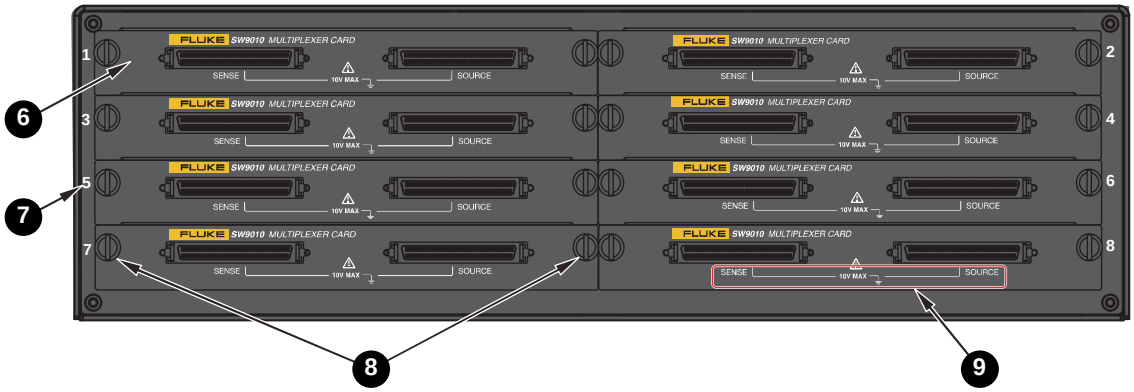
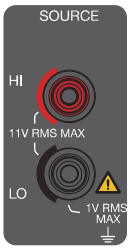
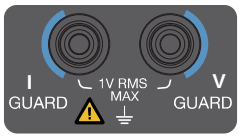
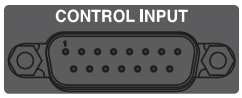


Figure 12. Rear pannel of the Switch Mainframe

Table 9. Switch Mainframe

Item	Description
1	 **Sense terminals** Sense terminals for 4-wire measurement method used to measure induced voltage drop by AC excitation current. These terminals are connected to the Sense terminals on the front panel of the BT5300 Battery Tester.

Item	Description
❷	 **Source terminals** Source terminals for 4-wire measurement method, used to receive AC excitation current. These terminals are connected to the Source terminals on the front panel of the BT5300 Battery Tester.
❸	 **Ground/Guard terminals** Guard connection can provide better shielding effect. These terminals are connected to the Ground/Guard terminals on the front panel of the BT5300 Battery Tester.
❹	 **Control Input connector** Connect to the Control Output connector on the rear panel of the Battery Tester.
❺	 **Status LED** When the Battery Tester is connected and powered on, the green Status LED is on.
❻	**Multiplexer cards** Up to 8 Multiplexer Cards are supported.
❼	 **Slot number** See the section *Channel Number* for details.
❽	 **Locking screw** Each Multiple Card is fastening to the Product or the SW1080 Switch Mainframe though the two screws on the left and right respectively.

Item	Description
❾	 **Connecter label** There are 2 DB-68 connector, Sense and Source, on each of Multiplexer Cards. See the section *Connect the Cell* for more details.

Connection Between the Product and the Switch Mainframe

To extend the measurement channel count through the SW1080 Switch Mainframe, please refer to *Figure 13*, connect the SW1080 to the BT5300 Battery Tester as the following:

1. Connect a shield twisted cable (❻ in the *Figure 4*) provided with the Switch Mainframe from the SENSE terminals (❶ in) on the front panel of the Switch Mainframe to the SENSE terminals (❼ in *Figure 1*) on the front panel of the Product. And plug the green plug into the corresponding V-GUARD terminals below the SENSE terminals.

   Please pay attention to the direction of the SENSE plug, so that the lug marked “GND” on the plug faces downward.

2. Connect another shield twisted cable from the SOURCE terminals (❷ in) on the front panel of the Switch Mainframe to the SOURCE terminals (❻ in *Figure 1*) on the front panel of the Product. And plug the green plug into the I-GUARD terminals below the SOURCE terminals.

   Again, pay attention to the direction of the SOURCE plug, so that the lug marked “GND” on the plug faces downward.

3. Connect the control cable (❼ in the *Figure 4*) provided with the Switch Mainframe from the Control Input connector (❹ in) on the front panel of the Switch Mainframe to the Control Output connector (❽ in *Figure 3*) on the rear panel of the Product.

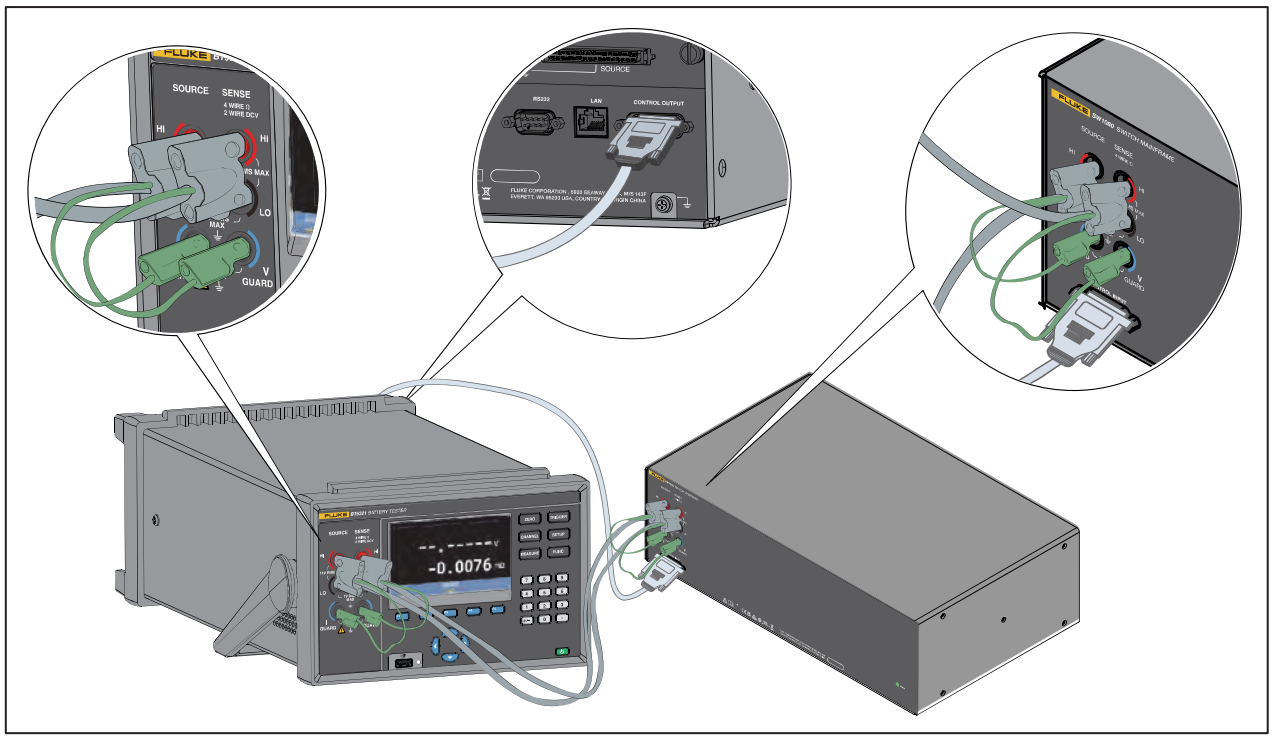


Figure 13. Connecting the Switch Mainframe

Connect the Cell

The SW9010 Multiplexer Card is used to select from and switch between cells to be tested. Each Multiplexer Card provides total 32 channels (01-32) through two DB-68 connectors. These channels can be configured to measure cell's voltage and resistance.

The two DB-68 connectors on the Multiplexer Card are identical with the model of TE 5787082-7, and their pinout is shown in *Figure 14*.

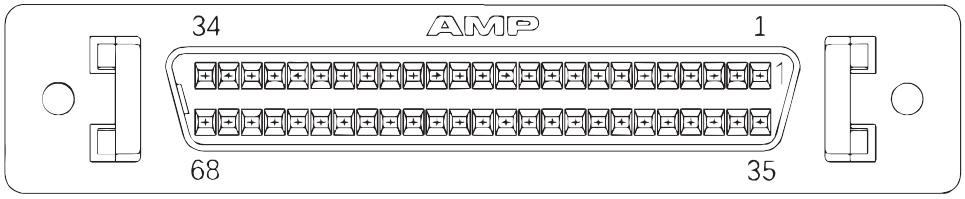


Figure 14. Multiplexer Card connectors

Wiring for Voltage and Internal Resistance Measurement

As shown in *Figure 15*, the left one of two DB-68 connectors on the Multiplexer Cards is SENSE connector, and the right one is SOURCE connector. Each pair of pins (SENSE + / -) on the SENSE connector and the corresponding pair of pins (SOURCE + / -) on the SOURCE connector form a 4-wire measurement connection. See the section *Appendix 1. AC Four-terminal Method* for more information about 4-wire measurement method.

To connect each channel to a cell, connect the SOURCE CH+ and SENSE CH+ to the positive electrode (+), and connect the SOURCE CH- and SENSE CH- to the negative electrode (-) of the cell. As shown in *Figure 15*.

The channel assignment on each connector of the Multiplexer Card is shown in *Table 10*.

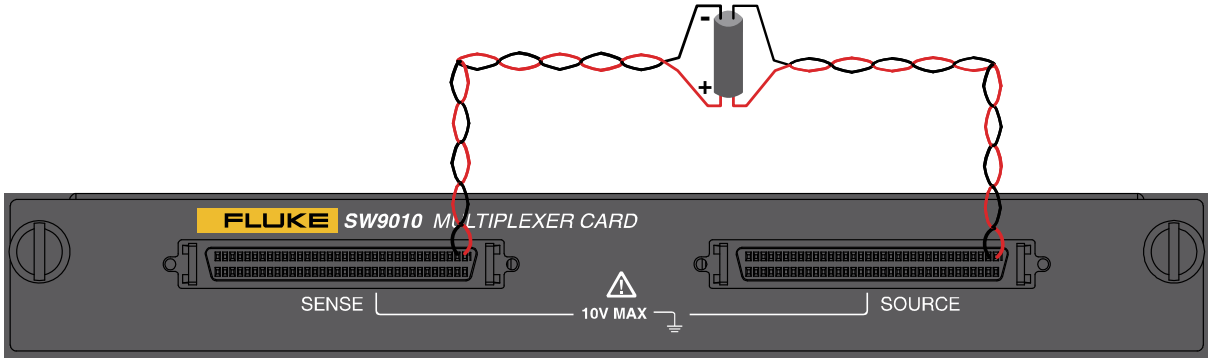


Figure 15. Schematic diagram of cell connection - voltage and resistance measurement

Note

- **The pin definitions of SENSE and SOURCE connectors are the same.**
- **It is recommended to connect to cells using flat twisted pair, shield twisted pair or coaxial cables.**
- **If a shield twisted pair of shield harness is used, it is recommended to short the GUARD+ and GUARD- terminals, then connect them to the shield layer.**
- **If a coaxial cable is used, it is recommended to connect the GUARD+ terminal to shield layers of all signal+'s, and GUARD- to all shield layers of all signal-'s. The +/- lines of each pair signal of the coaxial should be twisted.**
- **Minimize the length of the non-twisted part.**

Wiring for Enclosure Potential Measurement

To connect each channel to a cell, connect the SOURCE CH+ and SOURCE CH- to the positive and negative electrodes of the cell respectively, connect the both corresponding SENSE CH+ and SOURCE CH- to battery enclosure. As shown in the *Figure 16*.

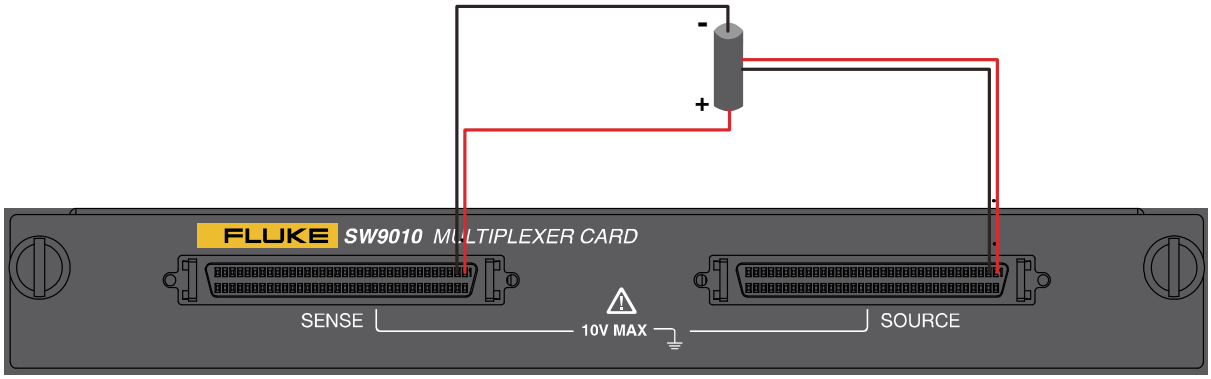


Figure 16. Schematic diagram of cell connection - enclosure potential contact check

The enclosure potential contact check can achieve the following tests:

- Enclosure potential contact check: detect whether the probe tips connected to the SOURCE terminals are well connected to the battery enclosure by measuring the resistance.
- Positive to enclosure voltage: to measure the voltage between the SENSE CH+ and SOURCE CH– terminal.
- Negative to enclosure voltage: to measure the voltage between the SOURCE CH+ and SENSE CH– terminal.

Note

- **The pin definitions of SENSE and SOURCE connectors are the same.**
- **If the Enclosure Potential Contact Check is not needed, and only the the Positeve/Negative to Enclosure Voltage is measured, the SOURCE CH+ and SOURCE CH– can be shorted and connected to the battery enclosure.**

Table 10. Pinout configuration of the connectors on the Multiplexer Card

Pin	Signal	Description		Pin	Signal	Description
1	CH01+	Channel 01 +		**35**	CH17+	Channel 17 +
2	CH01-	Channel 01 -		**36**	CH17-	Channel 17 -
3	CH02+	Channel 02 +		**37**	CH18+	Channel 18 +
4	CH02-	Channel 02 -		**38**	CH18-	Channel 18 -
5	CH03+	Channel 03 +		**39**	CH19+	Channel 19 +
6	CH03-	Channel 03 -		**40**	CH19-	Channel 19 -
…	…	…		**41**	…	…

Pin	Signal	Description		Pin	Signal	Description
…	…	…		**42**	…	…
29	CH15+	Channel 15 +		**63**	CH31+	Channel 31 +
30	CH15-	Channel 15 -		**64**	CH31-	Channel 31 -
31	CH16+	Channel 16 +		**65**	CH32+	Channel 32 +
32	CH16-	Channel 16 -		**66**	CH32-	Channel 32 -
33	GUARD+	Shield/Guard +		**67**	GUARD+	Shield/Guard +
34	GUARD-	Shield/Guard -		**68**	GUARD-	Shield/guard -

⚠⚠ WARNING

To prevent possible electrical shock, fire, or personal injury:

- **Consider all accessible channels to be hazardous live and an electric shock hazard if any channel is connected to a hazardous voltage source.**
- **Do not remove, touch, or change the internal wiring of hazardous inputs until the input source is turned off.**
- **Remove inputs from hazardous voltage sources before removing/installing a Multiple Card.**
- **Use the correct terminals, function, and range for measurements.**
- **Make sure proper insulation is maintained between channel wiring terminations and that no loose strands are outside of the terminal block connections.**

⚠ Caution

To prevent damage to the Product, do not exceed the specified input voltage levels.

Note

To order a Multiplexer Card, see *Table 6*.

Channel Configuration

Channel Number

Up to 2 built-in Multiplexer Cards and up to 8 external Multiplexer Cards are numbered separately, which are called internal and external channels, respectively. As shown in the *Figure 17*.

A channel number is a numerical identification associated with a set of terminals on the Multiplexer Card. The channel number of the input is determined by the slot number the Multiplexer Card is in (1 or 2 or internal cards, 1 to 8 for external cards) followed by the number of the terminal the input is connected to (1 to 32).

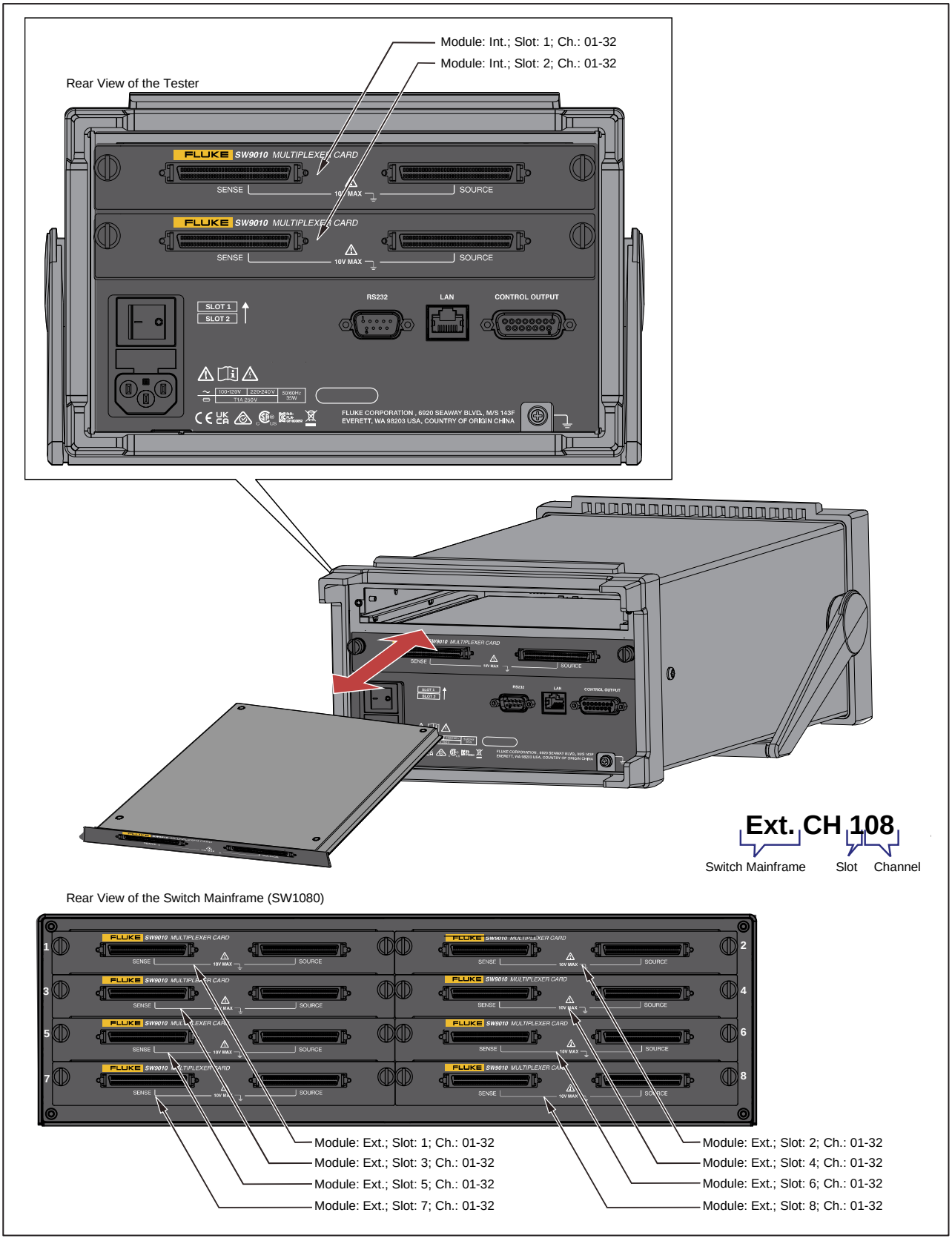


Figure 17. Example channel assignment

Configuring Channels

1. The Instrument front panel —> CHANNEL.
2. The UI for configuring channels is shown in _Figure 18_, and the meaning of each option is shown in _Table 11_.

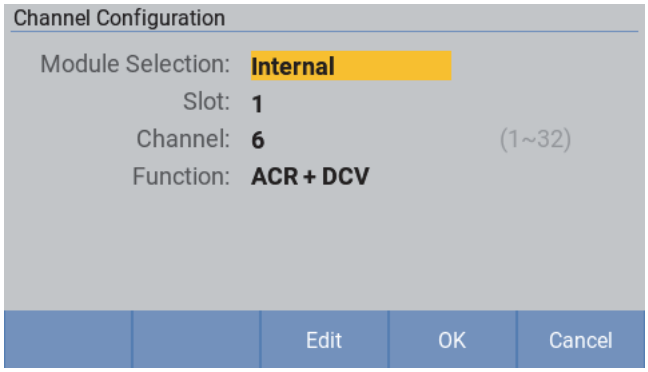


Figure 18. Channel configuration

3. Press F3 (Edit) softkey, and then move the cursor to **Module Selection** option (the option is highlighted in yellow) using the up/down arrow buttons (▼▲).
4. Press F3 (Edit) softkey, and then select the corresponding option using the up/down arrow buttons (▼ ▲). And press F4 (OK) softkey to return.
5. Move the cursor to **Slot** option (the option is highlighted in yellow) using the up/down arrow button (▼ ▲).
6. Press F3 (Edit) softkey, and then select the corresponding option us the up/down arrow buttons (▼ ▲). And press F4 (OK) softkey to return.
7. Move the cursor to **Channel** option (the option is highlighted in yellow) using the up/down arrow button (▼ ▲).
8. Enter the number of the corresponding channel through the keyboard, then press F4 (OK) to return.
9. Move the cursor to **Function** option (the option is highlighted in yellow) using the up/down arrow button (▼ ▲).
10. Press F3 (Edit) softkey, and then select the corresponding option us the up/down arrow buttons (▼ ▲). And press F4 (OK) softkey to return.
11. Press F4 (OK) softkey to confirm the options.

Table 11. Channel configuration

Item	Description
Module Selection	Select whether to use Multiplexer Cards. - **Disable.** Not to use any Multiplexer Card, and to measure directly use the connections on the front panel of the Product. - **Internal.** To use the built-in Multiplexer Cards inside the Product. - **External**. To use the Multiplexer cards inside the SW1080 Switch Mainframe.
Slot	If any Multiplexer Card is selected to be used, this option becomes available, and the slot where the internal or external Multiplexer Card to be used is in can be selected. Options include: - **None**. No slot is selected. - **1 to 8**. 1 to 2 if the Internal module is selected.
Channel	Select the channel number of the corresponding Multiplexer Card, from 01 to 32. This option is unavailable if no slot is selected.
Function	Select a measurement function - **ACR+DCV** - **ACR** (only available when Module Selection is Disable) - **DCV** (only available when Module Selection is Disable) - **Enclosure Potential Contact Check** - **Positive to Enclosure Voltage** - **Negative to Enclosure Voltage** For more details to see the section *Measurement Function*.

Measurement Function

As the Product powers on, it will enter the measurement screen by default, as shown in *Figure 19*.

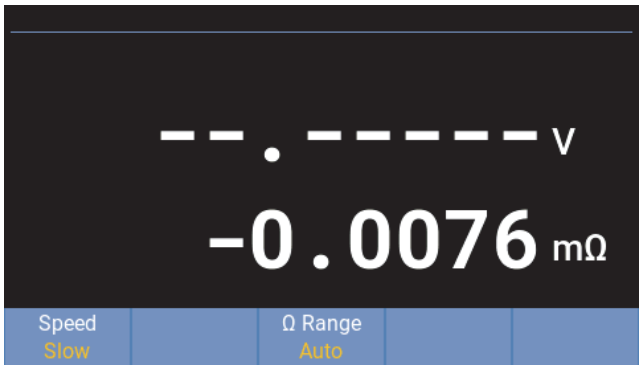


Figure 19. Measurement screen

The Product provides DCV and ACR measurement values. The Product measure through the internal or external Multiplexer Card if any channel is selected; and the Product measure through the front panel terminals if no channel is selected.

For measurement using the front panel terminals, FUNC button can be used to switch among " **ACR+DCV**, "**ACR**", and "**DCV**". If any channel is selected, "**ACR+DCV**", **Enclosure Potential Contact Check**", "**Positive to Enclosure Voltage**" and "**Negative to Enclosure Voltage**" measurement functions can be selected, and the **FUNC** button on the front panel will be disabled.

By default, the measurement function is ACR+DCV, the DCV and ACR measurement values are provided (with other function setting, only ACR **OR** DCV is provided). The DCV value is displayed at the upper of the main display area, and the ACR values is at the lower.

DCV

DCV measurement function features the following:

- User configurable input impedance: the default setting is 10 MΩ, and it can be changed to High Z (>10 GΩ). See the section *Input Impedance*.
- Range: 10 V and cannot be changed. Range information won't be displayed on the screen.
- The readings that can be displayed are -11.000000 V to 11.000000 V(BT5320/BT5321) or -11.00000 V 11.00000(BT5310/BT5311). "- OL" is displayed if the measured value <-11 V; "+ OL" is displayed if the measured value > 11 V; "----" is displayed if the measured is <-12 V or >12 V.

ACR

For ACR function, only 4-wire connection is supported. The default is AUTO Range mode. User can configure measurement range.

User selectable measurement range

Range	Reading	Resolution	Overflow
3 mΩ [1]	0 to 5 mΩ	0.0001 mΩ	>5 mΩ
30 mΩ	0 to 50 mΩ	0.001 mΩ	>50 mΩ
300 mΩ	0 to 500 mΩ	0.01 mΩ	>500 mΩ
3 Ω	0 to 5 Ω	0.0001 Ω	>5 Ω
10 Ω	0 to 15 Ω	0.001 Ω	>15 Ω

1 5 mΩ Max. reading @ test current = 300 mA
7.5 mΩ Max. reading @ test current = 200 mA
15 mΩ Max. reading @ test current = 100 mA

Auto range:

Range	Reading	Resolution	Upper limit	Lower limit
3 mΩ	0 to 3.3 mΩ	0.0001 mΩ	>3.3 mΩ	
30 mΩ	3 to 33 mΩ	0.001 mΩ	>33 mΩ	<3 mΩ
300 mΩ	30 to 330 mΩ	0.01 mΩ	>330 mΩ	<30 mΩ
3 Ω	0.3 to 3.3 Ω	0.0001 Ω	>3.3 Ω	<0.3 Ω
10 Ω	3 to 15 Ω	0.001 Ω	>15 Ω	<3 Ω

Enclosure Potential Contact Check

The measurement range/resolution is same with ACR measurement, but the 10 Ω range is recommended. "**Enclosure Potential Contact Check**" is displayed at the upper left of the screen, as shown in *Figure 20*.

See the section *Enclosure Potential Measurement*.

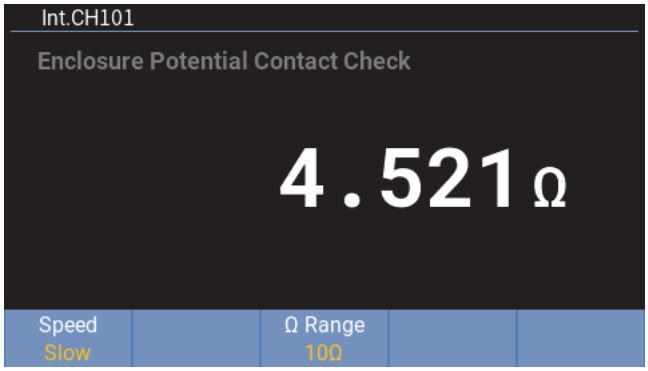


Figure 20. Enclosure potential contact check

Positive to Enclosure Voltage

The measurement range/resolution is same with DCV measurement. "**Positive to Enclosure Voltage**" is displayed at the upper left of the screen, as shown in *Figure 21*.

See the section *Enclosure Potential Measurement*.

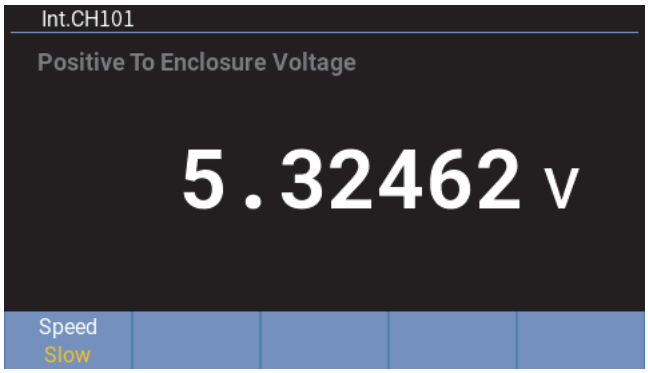


Figure 21. Positive to enclosure voltage

Negative to Enclosure Voltage

The measurement range/resolution is same with DCV measurement. "**Negative to Enclosure Voltage**" is displayed at the upper left of the screen, as shown in *Figure 22*.

See the section *Enclosure Potential Measurement*.

Figure 22. Negative to enclosure voltage

Changing Measurement Speed

In the measurement screen, press F1 (Speed) softkey to switch between different speeds: Ex-Fast, Fast, Medium, and Slow.

Changing Resistance Range

In the measurement screen, press F3 (Ω Range) softkey to switch between different ranges: AUTO, 3 mΩ, 30 mΩ, 300 mΩ, 3 Ω, and 10 Ω.

Instrument Setup

The **Instrument Setup** screen contains general instrument settings, such as UI language, device information, factory reset, and the line frequency, test current, input impedance and trigger delay can be set; the communication settings of remote interfaces are also provided.

This section explains in detail the functions and operation of the **Instrument Setup** menu, which will be used directly in the subsequent sections and will not be repeated.

*Enter **Instrument Setup** screen:*

- The front panel —> 

(**Setup**) button.

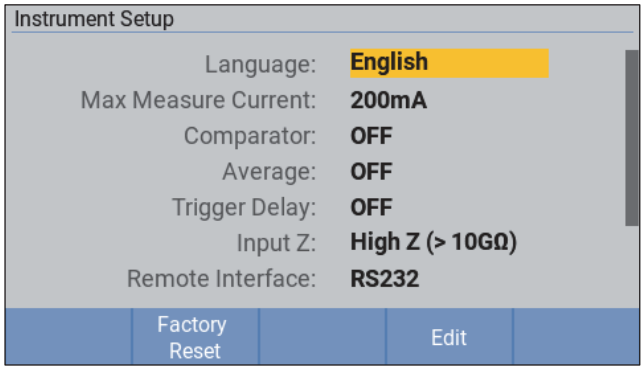


Figure 23. Instrument Setup screen

The options listed on the **Instrument Setup** screen include:

- Language
- Max Measure Current
- Comparator
- Average
- Trigger Delay
- Input Z
- Remote Interface
- Power Frequency
- Self-Calibration
- Device Info.

Language Settings

Users can select the language supported by this unit. The Product now support **English** and **Chinese** UI language.

To change UI language:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Language** option (the option is highlighted in yellow).
2. Press F4 (**Edit**) on the front panel and select the corresponding option using the up/down arrow buttons (▼ ▲).
3. Press F4 (**OK**) to confirm the selection and return to **Instrument Setup** screen.
   If you press F5 (**Cancel**), the Instrument returns to the **Instrument Setup** screen and does not save any change.

Max Measure Current

To measure ACR, the Instrument will output the measurement current. This option is used to set the Maximum measurement current for 3 mΩ measurement range. A higher measurement current can improve the signal-to-noise ratio in the measurement and obtain a higher accuracy and stable ACR measurement value. Please see the section *Measurement Function*.

To setup the maximum measurement current:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Max Measure Current** option (the option is highlighted in yellow). Press F4 (**Edit**) button on the front panel to enter the maximum current setting screen. As shown in *Figure 24*.

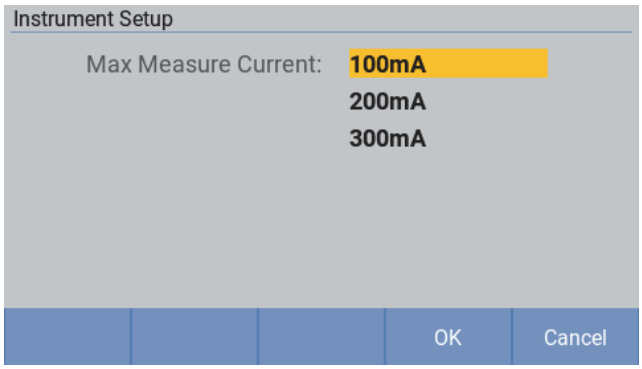


Figure 24. Setting the max measurement current

   The Product provides three options for the maximum measurement current: 100 mA, 200 mA, and 300 mA.

2. Use the up/down arrow (▼ ▲) buttons to select the appropriate option and press F4 (**OK**) softkey to return to the **Instrument Setup** screen.

Note

If the 300 mA measurement current is used, the Instrument will be more sensitive to the eddy current of the measuring loop circuit. If the test can't be completed with a large measurement current, you can reduce the effects of eddy current on test cables, or the system refer to *Appendix 3. Effect of Eddy Currents and Suggested Solution*, or reduce the measurement current, to complete the test.

Comparator

The Product provide a comparator function which compares measured values to user definable upper and lower thresholds, and then display a prompt on the screen, and can also give audio prompt.

To set the comparator function:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) on the front panel to move the cursor to the **Comparator** option (the option is highlighted in yellow). Press F4 (**Edit**) to enter the **Comparator** screen.
2. Use the up and down arrow (▼ ▲) keys to select the **Comparator** option. Press F4 (**Edit**) button on the front panel.

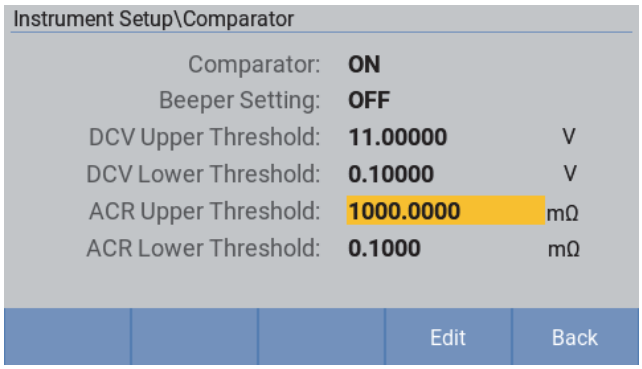


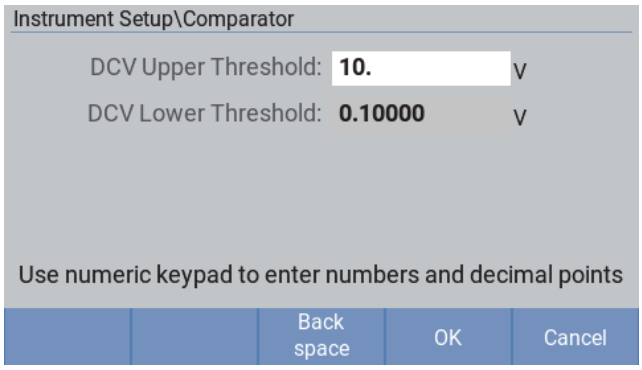
Figure 25. Comparator setting

3. Use the up/down arrow (▼ ▲) buttons on the front panel to select **ON**, then press F4 (**OK**); to switch the comparator off, use the up/down arrow (▼ ▲) buttons on the front panel to select **OFF**, then press F4 (**OK**).
4. Use the up/down arrow (▼ ▲) buttons on the front panel to move the cursor to **DCV Upper Threshold** or **DCV Lower Threshold** (the option is highlighted in yellow), then press F4 (**Edit**).
5. Use the up/down arrow (▼ ▲) buttons on the front panel to select **DCV Upper Threshold** option, then use the numeric keypad to enter a voltage value, in V, in the **DCV Upper Threshold** editbox, which can include a decimal point. As shown in the *Figrue 26*.

Note

When entering a number in the editbox, press F3 (Backspace**) to delete the last digit and move the cursor to the lass position.**

6. Use the up/down arrow (▼ ▲) buttons on the front panel to select **DCV Lower Threshold** option, then use the numeric keypad to enter a voltage, in V, in the **DCV Lower Threshold** editbox, which can include a decimal point.



Figrue 26. Setting the comparator thresholds

7. Press F4 (**OK**) return to the previous screen.
   If you press F5 (**Cancel**), the Product discards all changes and returns to the previous screen.

Note

The upper threshold entered must be greater than or equal to the lower threshold, otherwise the screen will show "Upper threshold can't be less then lower threshold". In this case, upper and/or lower threshold must be re-set before continuing.

8. Use the up/down arrow (▼ ▲) buttons on the front panel to move the cursor to **ACR Upper Threshold** or **ACR Lower Threshold** (the option is highlighted in yellow), then press F4 (**Edit**).
9. Use the up/down arrow (▼ ▲) buttons on the front panel to select **ACR Upper Threshold** option, then use the numeric keypad to enter a resistance value, in mΩ, in the **ACR Upper Threshold** edit box, which can include a decimal point.
10. Use the up/down arrow (▼ ▲) buttons on the front panel to select the **ACR Lower Threshold** option, then use the numeric keypad to enter a voltage, in mΩ, in the **ACR Lower Threshold** editbox, which can include a decimal point.
11. Press F4 (**OK**) button return to the previous screen.
    If you press F5 (**Cancel**), the Product discards all changes and returns to the previous screen.

Note

The upper threshold entered must be greater than or equal to the lower threshold, otherwise the screen will show "Upper threshold can't be less then lower threshold". In this case, upper and/or lower threshold must be re-set before continuing.

12. Use the up and down arrow (▼ ▲) keys to move the cursor to **Beeper Setting** option (the option is highlighted in yellow), press then F4 (**Edit**).

13. The Beeper Setting screen is shown in *Figure 27*, And the meaning of each option is listed in *Table 12*.

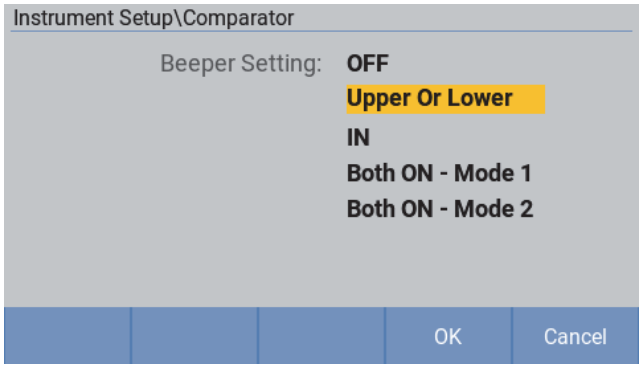


Figure 27. Beeper setting

Table 12. Beeper setting

Item	Both DCV and ACR are within thresholds	Any one of DCV and ACR are out of the threshold
OFF	No beeps sound	No beeps sound
Upper or Lower	No beeps sound	Tick sound
IN	Continuous sound	No beeps sound
Both ON - Mode 1	Continuous sound	Tick sound
Both ON - Mode 2	One beeper only	Tick sound

14. Use the up/down arrow (▼ ▲) buttons on the front panel to select the appropriate option and press F4 (**OK**) to return to the **Comparator** screen.

15. Press F5 (**Back**) on the front panel to return to the **Instrument Setup** home screen.

Average

The average function outputs the averaged measured value. This function can effectively reduce the instability of the display value. The average number of samples can be set from 2 to 16.

- In the case of internal triggering, if the continuous measurement is enabled, moving average values are shown on the UI. Otherwise, simple average values are shown.
- Once one invalid value is detected during one average period, the averaged measured value is an invalid value.
- During one average period, only when all measured values are OL, the average result is OL. Only when all measured values are -OL, the average result is -OL. For ACR, only when all measured values are normal and the measured values are under the same range, the average result is a normal value. For other cases, the average result is invalid.
- The new moving average process starts only when both the internal trigger (IMMediate) and continuous measurement (INITiate:CONTinuous ON) are satisfied.

To set the average function:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Average** option (the option is highlighted in yellow), then press F4 (**Edit**) on the front panel to enter the **Average** screen.
2. Use the up and down arrow (▼ ▲) keys to select the **Average** option. Press F4 (**Edit**) on the front panel.

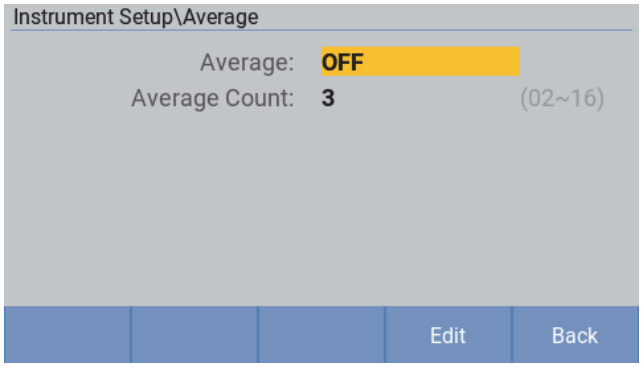


Figure 28. Average screen

3. Use the up/down arrow (▼ ▲) buttons on the front panel to select **ON**, then press F4 (**OK**); to switch the average function off, use the up/down arrow (▼ ▲) buttons on the front panel to select **OFF**, then press F4 (**OK**).

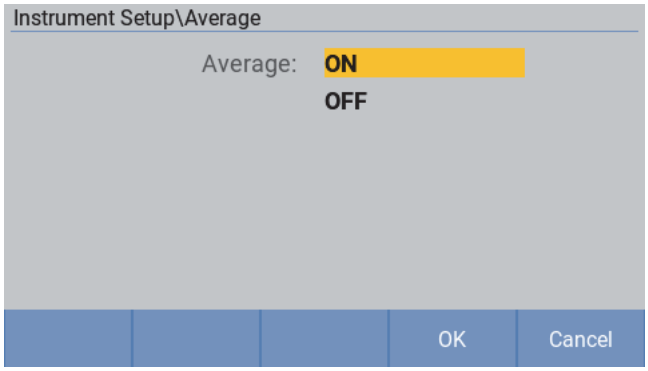


Figure 29. Switch the average function On or off

4. Use the up and down arrow (▼ ▲) buttons to select the **Average Count** option (the option is highlighted in yellow), press then F4 (**Edit**).
5. Enter a number from 02 to 16 in the **Average Count** editbox using the numeric keypad on the front panel.

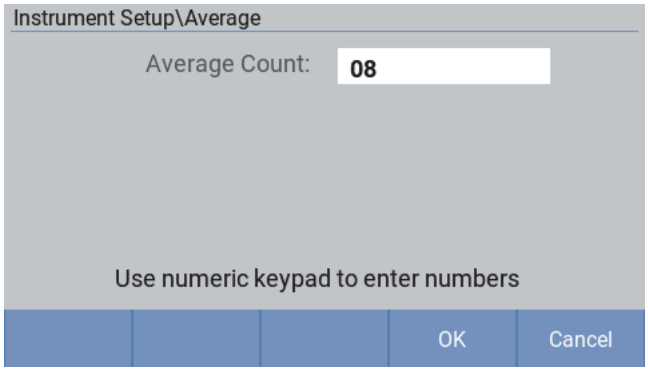
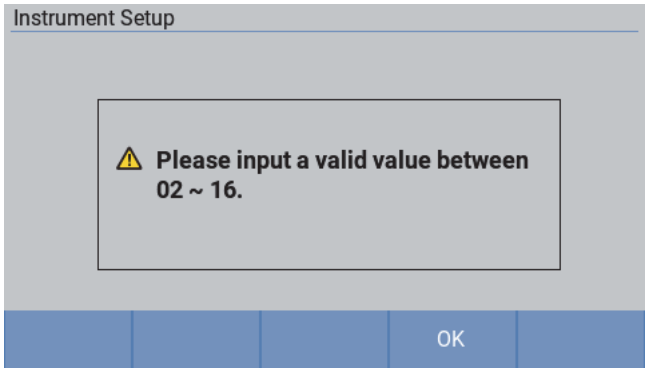


Figure 30. Setting average count

6. Press F4 (**OK**) to return to the previous screen.
   If you press F5 (**Cancel**), the Product discards all changes and returns to the previous screen.

Note

If the number entered is out of the range of 02 to 16, an error message is shown on the screen, as shown in the following figure. At this point, press F4 (OK) to re-set the average count.



7. Press F5 (**Back**) on the front panel to return to the **Instrument Setup** home screen.

Trigger

Trigger Mode

The Product provides two types of Triggers:

- **Internal trigger**: the instrument is in immediate trigger mode by default and performs measurements continuously.
- **External trigger**: the Instrument performs one measurement once received the trigger signal. In this case, measurement result will not update automatically until the user presses TRIGGER on the front panel or the Instrument received a SCPI command to perform measurement.

During measuring, press TRIGGER on the front panel to put the Instrument in the external trigger mode, the label of the button F4 changes to **Exit Ext. Trigger**.

In the measurement screen, press F4 (Exit Ext. Trigger) to switch to the internal trigger.

Trigger Delay

A certain time value can be specified through the **Trigger Delay** setting, which allows the Instrument to delay the measurement by the specified time after receiving the trigger signal or a trigger command.

Trigger delay range is from 0 ms to 9999 ms, with default of 0 ms. The trigger delay applies to internal trigger and external trigger.

- In the **internal trigger** mode, the Product inserts the Trigger Delay time after one measurement, then begins the next measurement.
- In the **external trigger** mode, the Product will not do the measurement after the user presses TRIGGER buttons or receives a SCPI command to do the measurement, until the delay time runs out.

To Set the trigger delay:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Trigger Delay** option (the option is highlighted in yellow), then press F4 (**Edit**) on the front panel to enter **Trigger Delay** screen.
2. Use the up and down arrow (▼ ▲) buttons on the front panel to select the **Trigger Delay Switch** option. Press F4 (**Edit**) on the front panel.

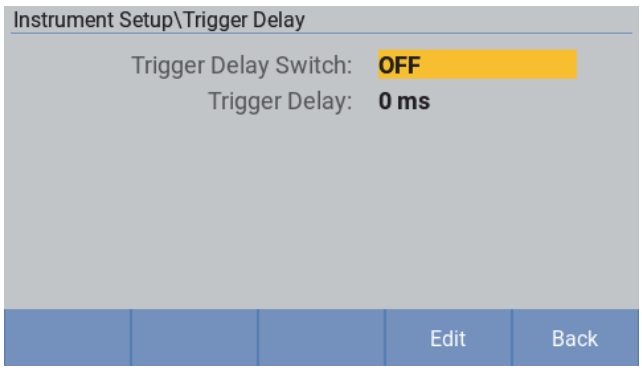


Figure 31. Selecting trigger delay switch

3. Use the up/down arrow (▼ ▲) buttons on the front panel to select **ON**, then press F4 (**OK**); to switch Trigger Delay function off, use the up/down arrow (▼ ▲) buttons on the front panel to select **OFF**, then press F4 (**OK**).

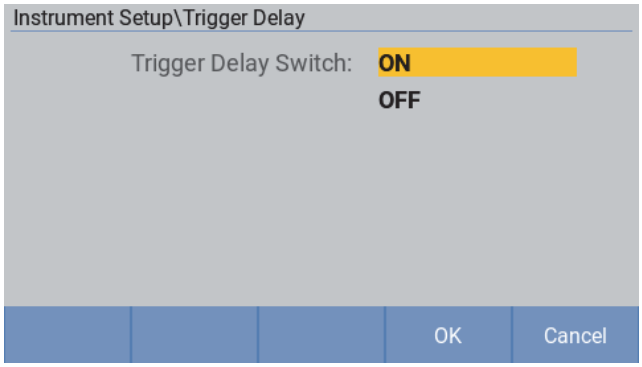


Figure 32. Switch trigger delay ON or OFF

4. Use the up and down arrow (▼ ▲) buttons to select the **Trigger Delay** option (the option is highlighted in yellow), then press F4 (**Edit**).
5. Enter a number from 0 to 9999, in the **Set trigger Delay to** editbox using the numeric keypad on the front panel. Trigger delay time is in ms.

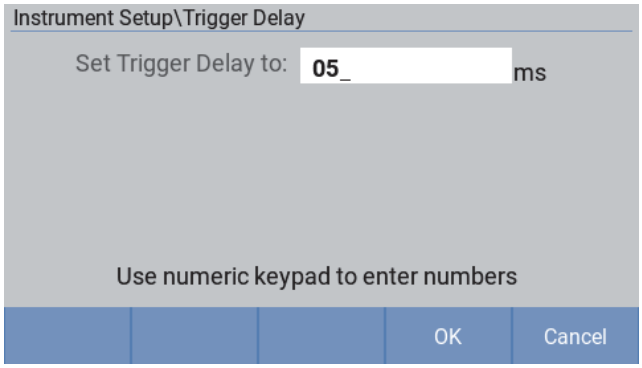


Figure 33. Setting trigger delay time

6. Press F4 (**OK**) button to return to the previous screen.
   If you press F5 (**Cancel**), the Product discards all changes and returns to the previous screen.
7. Press F5 (**Back**) on the front panel to return to the **Instrument Setup** home screen.

Input Impedance

Input impedance affects the DCV measurement only and it is 10 MΩ by default.

To set the input impedance:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Input Z** option (the option is highlighted in yellow).
2. Press F4 (**Edit**) on the front panel, and select the corresponding option, **High Z(>10GΩ)** or **10MΩ**, using the up/down arrow buttons (▼ ▲).

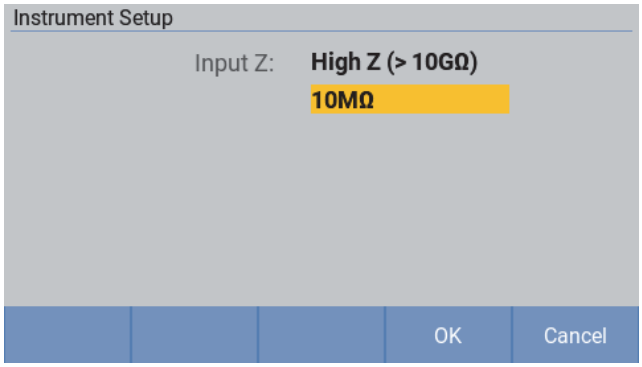


Figure 34. Selecting input impedance

Note

The default input impedance is 10 MΩ. It is recommended to use High-Z (>10GΩ) option for high impedance device under test, such as enclosure potential measurement.

3. Press F4 (**OK**) to confirm the selection and return to the **Instrument Setup** screen.
   Press F5 (**Cancel**), to return to the **Instrument Setup** screen and not save any change.

Remote Interface

The Product provides RS-232 interface and an Ethernet interface on the rear panel, users can use these interface through a PC to change settings, obtain readings, and control the Instrument.

Command syntax and names follow the IEEE-488.2 and SCPI standards. See the section *Remote Control* for details.

To ensure normal communication, the communication port of the Product needs to be set up correctly.

To set remote Interface:

- In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Remote Interface** option (the option is highlighted in yellow).

The **Remote Interface** screen is as shown in *Figure 35*. The options for RS-232 and Ethernet interface are shown in *Table 13*.

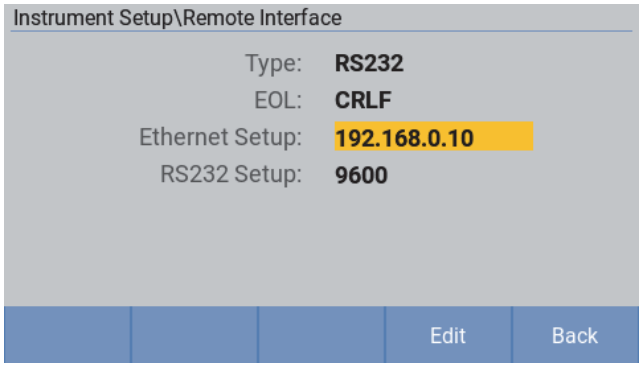


Figure 35. Remote interface setting

Table 13. Remote interface parameters

Item	Options
Type	**RS232** **Ethernet**
EOL	**CR (Carriage Return)** **LF (Line Feed)** **CRLF (Carriage Return & Line Feed)**

Item	Options
Ethernet Setup	**DHCP** Options include: - ON - OFF To communicate using the Ethernet interface, the user can choose to trun on the DHCP function. If set DHCP to be ON but failed due to network connection, DHCP will change to **OFF** automatically and all other parameters, such as IP address, subnet mask, default gateway, etc., will be set to the last static address. **IP Address** The user can set manually the IP address of the Instrument when the DHCP is set to OFF. The IP address is in “dotted decimal” notation and consists of 4 segment of numbers, each with a value of 0 to 255. The IP address must follow the network address setting specifications and must not be 000.000.000.000. To set the IP address, use left and right buttons (▶ ◀) to select the number segment to be edited, and then enter a number from 0 to 255 using the numeric keypad on the front panel. After completing the input, press F4 (**OK**) to confirm, or F5 (**Cancel**) to discard the modification. If the number entered is greater than 255, the screen will display “LAN address is invalid”. At this point, press F4 (**OK**) to return and repeat the process above to enter a correct IP address. **Subnet Mask** The user can set manually the IP address of the Instrument when the DHCP is set to OFF. At this time, the subnet mask must be set too. The setting process of subnet mask is the same as that of IP address, see above. **Default Gateway:** Please refer to the setting process of IP address or subnet mask. **Port** Set the network port number of the PC used for LAN communication. The default is 1500. Check the setting on the PC and change the firewall setting if necessary to allow communication through this port. Consult your system administrator for more details. **MAC Address** The unique address number of the network card of the Instrument, for reference only and cannot be modified.

Item	Options
RS232 Setup	RS-232 communication settings are as follows: **Baud Rate** Baud rate that the Instrument support: - 9600 - 19200 - 38400 - 57600 - 115200 **Data Bits** The number of data bits supported by the instrument includes: - 7 Bits - 8 Bits **Stop Bits** Users can select: - 1 Bit - 1.5 Bits - 2 Bits **Parity** The Instrument support: - Odd - Even None To communicate through RS-232 interface, make sure that the setting of the Instrument and that of the computer are matched.

Power Frequency

Power frequency is 50 Hz by default, and it can be switched to 60 Hz.

Power frequency will affect Instrument's DCV measurement accuracy. The accuracy of the instrument is only promised when selected power frequency is same with mains power frequency. For example, the mains power frequency in China is 50 Hz, customer need set instruments' power frequency to be 50 Hz when using in China so that the DCV accuracy can be met.

To set the power frequency:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Power Frequency** option (the option is highlighted in yellow).
2. Press F4 (**Edit**) on the front panel, and select the corresponding option, **50 Hz** or **60 Hz**, using the up/down arrow buttons (▼ ▲).

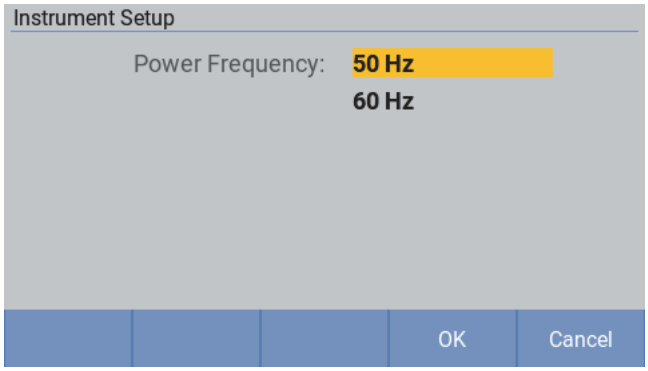


Figure 36. Select power frequency

3. Press F4 (**OK**) to confirm the selection and return to the **Instrument Setup** screen.
   If you press F5 (**Cancel**), the Instrument returns to the **Instrument Setup** screen and not save any change.

Self-Calibraion

The self-calibration function adjusts offset voltage and gain drift of the instrument's internal circuitry to improve measurement accuracy. The instrument's measurement accuracy specifications depend on self-calibration. Always do self-calibration after warm-up and when the ambient temperature changes by more than 2 °C.

To execute self-calibration:

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Self-Calibration** option (the option is highlighted in yellow).
2. Press F4 (**Edit**) on the front panel to execute self-calibration.

   The **Self-Calibration** screen is shown in *Figure 37*.

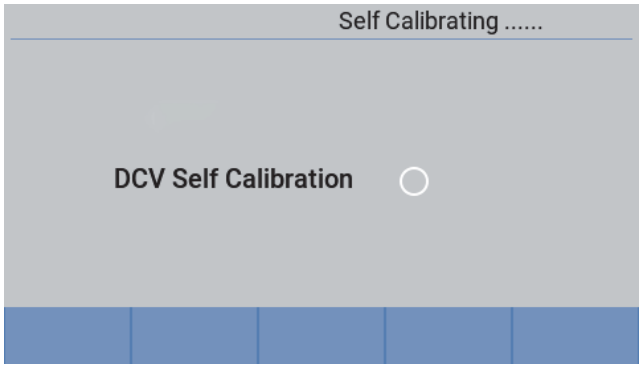


Figure 37. Self-Calibration

After completing the self-calibration, the Instrument will return to the **Instrument Setup**" screen.

Note

Executing self-calibraion under the Zeroed state will clear the zero-adjust value.

Device Information

The **Device Info.** screen shows reference information about the Product, including serial number, firmware version, FPGA and DSP version, and the version and serial number of the connected Switch Mainframe.

To enter the Device Info. secreen

1. In the **Instrument Setup** screen, use the up and down arrow (▼ ▲) buttons on the front panel to move the cursor to the **Device Inf.** option (the option is highlighted in yellow).
2. Press F4 (**Edit**) on the front panel. The **Device Info.** screen is shown as *Figure 38*.

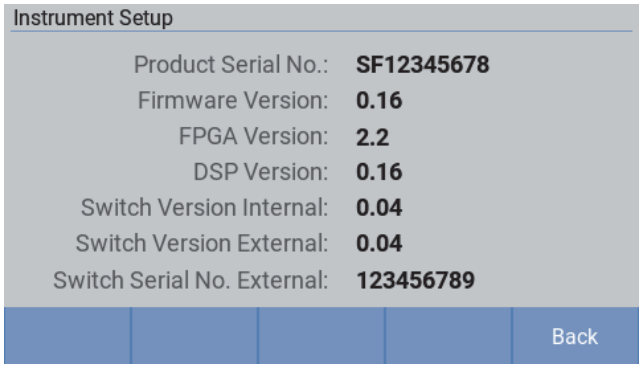


Figure 38. Device Info. screen

All information listed in the **Device Info.** screen is reference information and cannot be changed. This information is useful for troubleshooting and maintenance.

Note

Please have this information ready when contacting Fluke for technical support.

Table 14. System Information

Item	Description
Product Serial No.	The unique serial number of the Product, which may be requested when contacting Fluke Customer Service.
Firmware Version	The version number of the internal firmware of the Product.
FPGA Version	The version number of the FPGA in the Product.
DSP Version	The version numbers of the Digital Signal Processing (DSP) device in the Product.
Switch Version Internal	The version number of the built-in core board.
Switch Version External	The version number of the external Switch Mainframe.

Item	Description
Switch Serial No. External	The serial number of the external Switch Mainframe.

Restore to Factory Defaults

To reset the Instrument to the factory defaults:

1. In the **Instrument Setup** screen, press F2 (**Factory Reset**).
2. The Instrument will pop up a dialog, prompting the user to confirm "**Whether start a Factory Reset?**".
3. Press F4 (**OK**) to confirm. The Instrument will restore its factory default setting and return to the measurement screen. Press F5 (**Cancel**) if you do not want to restore the factory settings.
4. The factory defaults are shown in *Table 15*.

Table 15. Factory defaults

Screen	Setup			Default Value
Measure Screen	Speed			Slow
	Resistance Range			Auto Range
	Trigger Mode			Internal trigger
Zero				OFF
Switch Configuration	Module Selection			Disable
	Slot			None
	Channel			1
	Function			ACR+DCV
Instrument Setup	Trigger Delay	Trigger Delay Switch		OFF
		Trigger Delay		0ms
	Input Z			10 MΩ
	Power Frequency			50 Hz
	Max Measure Current			200 mA
	Average	Average		OFF
		Average Count		2
	Comparator	Comparator		OFF
		DCV Comparator Mode		**BT5320, BT5321**
				Upper Threshold: 11.000000 V

Screen	Setup			Default Value
				Lower Threshold: 0.100000 V
				BT5310, BT5311
				Upper Threshold: 11.00000 V
				Lower Threshold: 0.10000 V
		ACR Comparator Mode		Upper Threshold: 1000.0000 mΩ
				Lower Threshold: 0.1000 mΩ
		Beeper Setting		OFF
	Remote Interface	Type		RS232
		EOL		CRLF
		Ethernet Setup	DHCP	OFF
			IP Address	192.168.0.10
			Subnet Mask	255.255.255.0
			Default Gateway	192.168.0.1
			Port	1500
		RS232 Setup	Baud Rate	9600
			Data Bits	8
			Stop Bits	1
			Parity	None
Not shown in screen		Customer defined manufacturer		FLUKE
		Customer defined model		BUND
		SCPI command header		OFF
		Memory		OFF
		INIT	Continuous	ON

Zero-Adjust

Execute zero adjustment before measuring to nullify any residual offset voltage from the instrument or measurement environment.

Zeroing is not supported if the Module Selection in not set to **Disable**.

For more information about zeroing and zero-adjust board, see the section *Appendix 4. Zero Adjustment*.

To do the zero adjustment:

1. Connect the testing leads to the zero-adjust board to create the close to 0 Ω status. See the section *Appendix 4. Zero Adjustment*.
2. Press MEASURE on the font panel to enter measurement screen.
3. In the measurement screen, if the measurement range is not in **Auto**, the following zeroing operation will zero a single range. Press ZERO on the front panel. The Instrument starts to execute zeroing, and "**Zero Adjusting…**" shows at the top right of the screen. As shown in *Figure 39*.
4. Once it succeeds, "**Zero Adjusted**" shows at the top right of the screen. As shown in *Figure 40*.

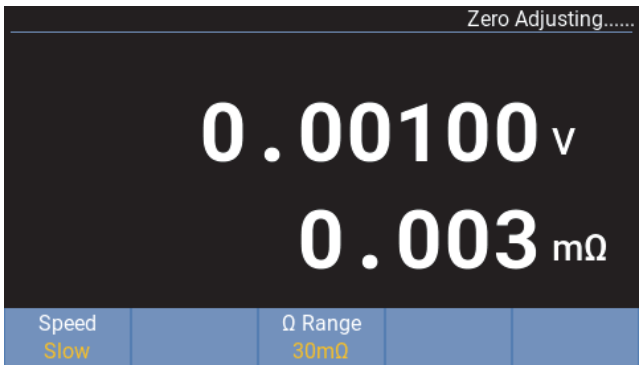


Figure 39. Zeroing process

Figure 40. Zeroed

If the Instrument zeroed failed, the Instrument briefly prompts **Zero adjustment failed**, as shown in *Figure 41*, and then return to normal measurement.

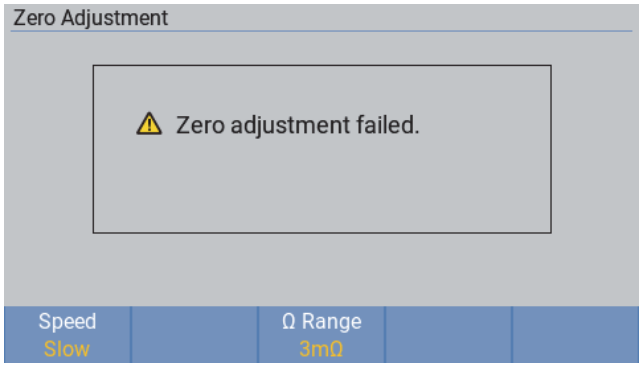


Figure 41. Zero adjustment failure prompt

In the Auto range mode (see the section *Changing Resistance Range*), when the user presses ZERO, the Instrument will try to zero all measurement ranges. As shown in *Figure 42*.

Figure 42. Zeroing all ranges

Note

Zero adjustment can only remove the offset of 1000 digits for ACR and 1 mV for DCV measurement. For example, in 3 mΩ range, zero adjustment can only remove 0.1 mΩ drift. If the drift is more than 1000 digits, for example, 0.2 mΩ in 3 mΩ range, "Zero Adjustment failed" message will be displayed during zero adjustment.

If the zero adjustment is completed successfully under the ACR+DCV measurement function, the zeroed state will be retained when switching to the ACR or DCV measurement function.

If the zero adjustment is completed successfully under the ACR or DCV measurement function, the zeroed state will be cleared when switching to other measurement functions.

For zero adjustment under Auto range, once the zero adjustment for all range is completed successfully, "Zero Adjusted" is shown when the Product switches to any range; for zero adjustment under a certain range, "Zero Adjusted" is shown only under this range.

Clearing Zero-Adjustment

In the **Instrument Setup** screen, press F1 (**Clear Zero-adjust**), the zero-adjust value will be cleared.

The **Clear Zero-adjust** softkey is available only after that the Product is zeroed. After clearing, the screen will not display “Zero Adjusted” indicator.

For more information on the zero-adjustment, please see the section *Zero-Adjust*.

Memory Function

The Memory function is only available via communication commands. When the Memory function is **ON**, measurement values are stored in the Instrument’s internal memory according to trigger input sequence. Stored data (up to 512 values) can be read by using commands. Test cycle time can be minimized by using this function to store measurement values internally until multiple measurements are finished, at which time the stored values are downloaded together during the next idle period. MEM is shown on the measurement screen when the memory function is enabled.

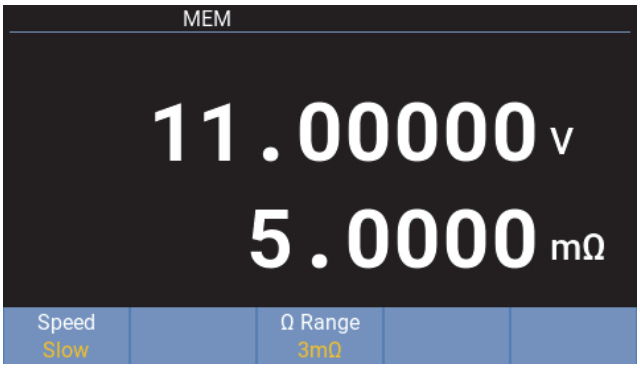


Figure 43. Memroy function UI

See the section *Memory Commands* for more information about memory function.

Remote Control

Connect the Computer

The product has a RS-232 interface and a Ethernet interface, and can connect to a computer through any interface.

For the procedure to connect the Product to the Switch Mainframe, see the section *Connection Between the Product and the Switch Mainframe*.

To connect through the RS-232 interface:

As shown in method A of *Figure 44*, connect a RS-232 to USB adapter cable from the RS-232 port (❺ *Figure 3*) on the rear panel of the Product to a USB port on the computer, or connect a standard RS-232 communication cable to a standard RS-232 port on the computer.

To order a RS-232 to USB adapter cable, see *Table 6* and the section *How to Contact Fluke*.

To connect through the Ethernet interface:

As shown in method B of *Figure 44*, connect a Ethernet cable from the Ethernet port (❻ in *Figure 3*) on the rear panel of the Product to a Ethernet port on the computer.

To order a Ethernet cable, see *Table 7* and the section *How to Contact Fluke*.

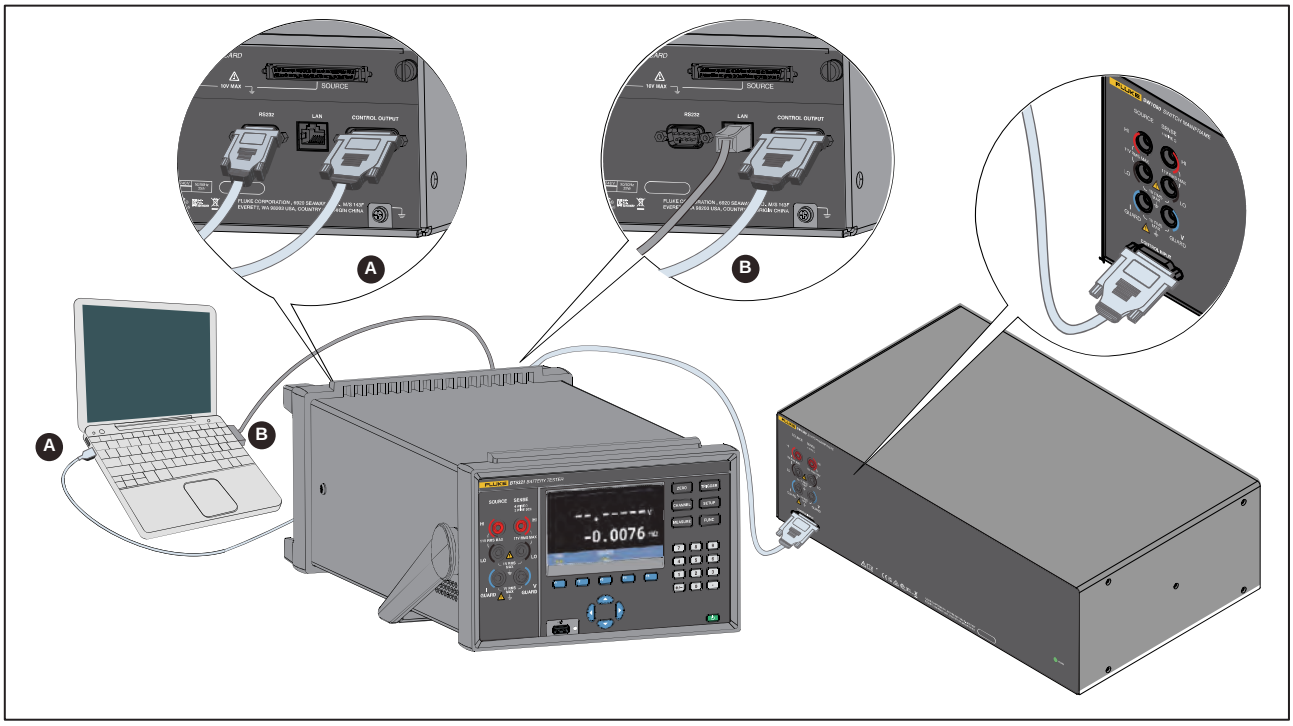


Figure 44. Connecting to the computer

Remote Control UI

When the Instrument is connected to a computer and communicates, the Product will enter the remote state. The screen under remote control is as shown in *Figure 45*.

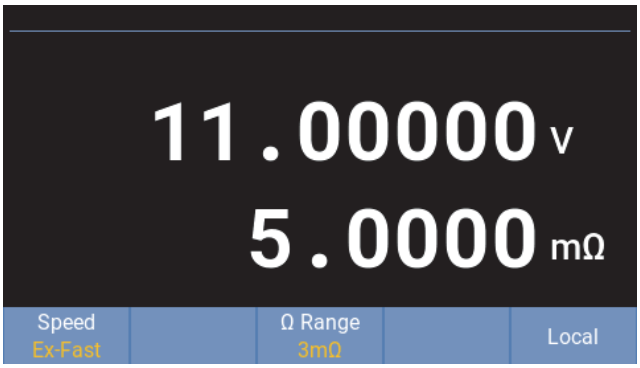


Figure 45. Remote control UI

In the remote-control mode, all buttons except F5 and Trigger on the front panel are locked. The measurement screen of the Product will change according to the remote setting parameters.

The remote control can be unlocked through the following two methods:

- Press F5 (Local) to switch to local mode.
- Send a SYSTem:LOCal command through the computer

Remote Control Commands

A computer can set the Product, execute functions, or command the Product to responds with the request data through the RS-232 or Ethernet port of the Product using the commands supported by the Product. Command syntax and names follow the IEEE-488.2 and SCPI standards.

Commands consist of a command header and, if necessary, parameter data. All commands must be terminated with a carriage return (0D hex or 13 decimal), or a new line character (0A hex or 10 decimal), or both.

The Instrument can parse <compound command program header> and <compound query program header>, which consists of multiple mnemonics separated by colons ":", The Instrument supports to traversal the tree structured commands described in SCPI. Multiple <PROGRAM MESSAGE UNIT> elements may be sent in a <PROGRAM MESSAGE>. The first command is always referenced to the root node. subsequent commands, however, are referenced to the same tree level as the previous command in a message unit. See the section *Compound Headers Using a Tree – Usage and Examples* for examples.

Mnemonics may use letter characters, the underscore character (_), and possibly numeric digits as well. Commands are not case sensitive. Most mnemonics have a long form that is more readable and a short form consisting of three or four characters that is more efficient. The Instrument can accept only the exact short and the exact long forms.

Query commands are commands that request data in response. Query commands have a question mark (?) immediately following the command header. Responses to query commands are generated immediately and placed in the output buffer. Responses are then transmitted automatically to the PC.

Some commands require parameter data to specify values for one or more parameters. The command header is separated from the parameter data by a space (20 hex or 32 decimal). Multiple parameters are separated by a comma (,).

The Instrument's input buffer capacity is 512 bytes. The remote interface will not accept data beyond 512 bytes.

Table 16. Data type abbreviation (parameter and response)

Data type (parameter and response)	Description
NRf	Numeric data, number format may be any of NR1, NR2 and NR3
NR1	Numeric data, integer data (e.g.: 4, +4, -4)
NR2	Numeric data, fixed-point data (e.g.: 4.5, +4.5, -4.5)
NR3	Numeric data, floating-point exponential representation data (e.g.: 4.0E+1, +4.0E+1, -4.0E+1)
Boolean	Boolean data (e.g.: OFF, ON, 0, 1)
Character	Character parameters supported (e.g., FLUKE_DEFINED, FLUKE_DEFINED', FLUKE_DEFINED") Character parameters can be be set with/without single quote/double quote. The returned parameter is without single quote/double quote.
Channel_list	Channel numbers of the Multiplex Cards, 3-digit format, the 1st digit represents slot ID (1 to 8), the last 2 digits represents channel ID (01 to 32) (e.g., (@101), (@101:104)).

System Status Diagram

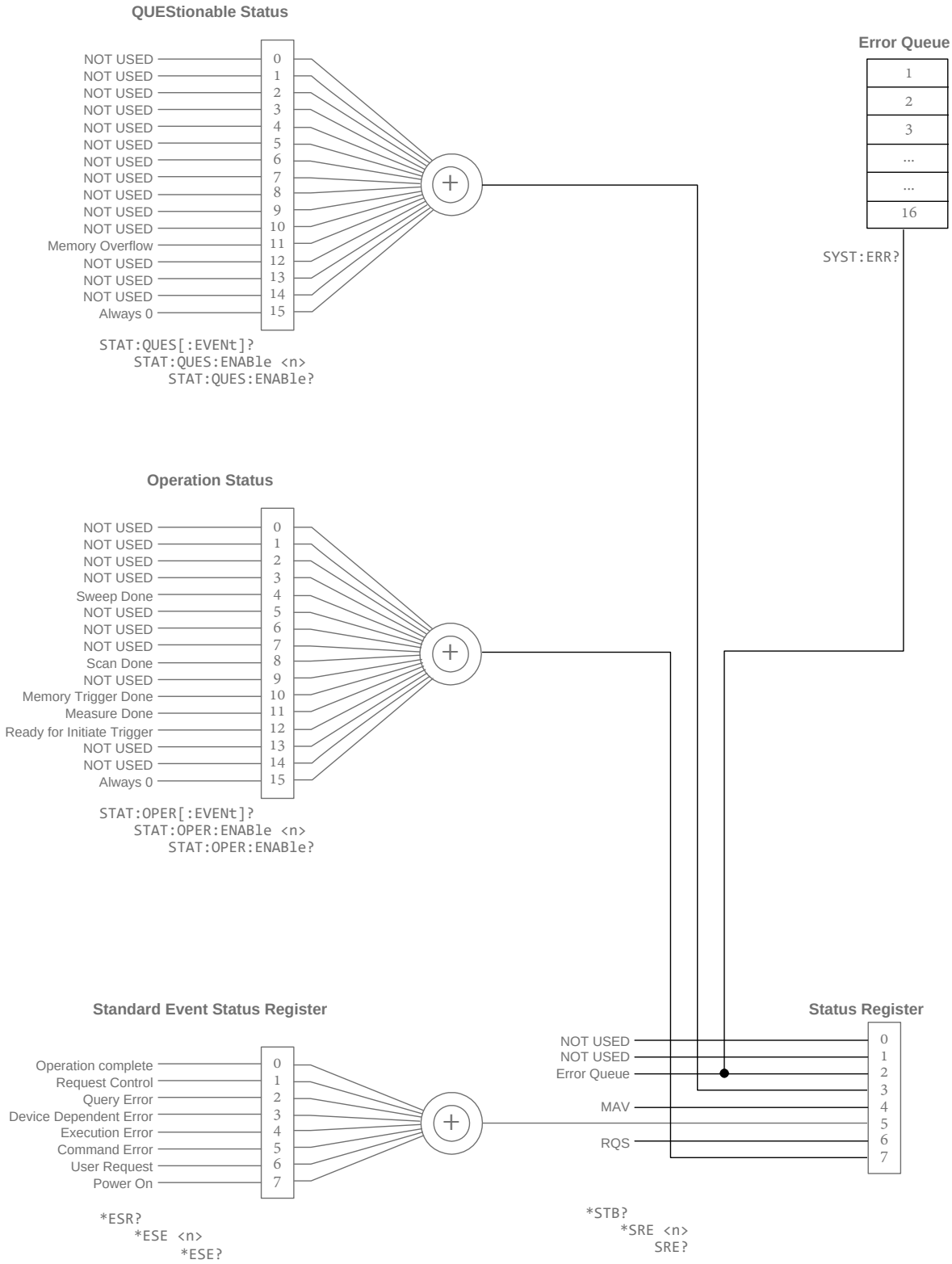


Figure 46. System Status diagram

Table 17. QUEStionable Status registor

Bit No.	Bit Name	Description
Bit 0	NOT USED	Not used
Bit 1	NOT USED	Not used
Bit 2	NOT USED	Not used
Bit 3	NOT USED	Not used
Bit 4	NOT USED	Not used
Bit 5	NOT USED	Not used
Bit 6	NOT USED	Not used
Bit 7	NOT USED	Not used
Bit 8	NOT USED	Not used
Bit 9	NOT USED	Not used
Bit 10	NOT USED	Not used
Bit 11	Memory Full	Memory storage is full (max capacity is 512 measurements)
Bit 12	NOT USED	Not used
Bit 13	NOT USED	Not used
Bit 14	NOT USED	Not used
Bit 15	Always 0	The use of Bit 15 is not allowed since some controllers may have difficulty reading a 16-bit unsigned integer

Table 18. OPERation Status registor

Bit No.	Bit Name	Description
Bit 0	NOT USED	Not used
Bit 1	NOT USED	Not used
Bit 2	NOT USED	Not used
Bit 3	NOT USED	Not used
Bit 4	Sweep Done	One scan sweep is done
Bit 5	NOT USED	Not used
Bit 6	NOT USED	Not used
Bit 7	NOT USED	Not used
Bit 8	Scan Done	All scan sweeps are done (The Instrument only supports 1 scan sweep, so this bit is set at the same time as Bit 4.)
Bit 9	NOT USED	Not used
Bit 10	Memory Trigger Done	One memory storage triggered by *TRG or Trigger key is done when Memory function is enabled.

Bit No.	Bit Name	Description
Bit 11	Measure Done	One measurement is done.
Bit 12	Ready for Initiate Trigger	Ready for Initiate Trigger (*TRG or Trigger key) when INIT:CONT OFF and TRIG:SOUR EXT.
Bit 13	NOT USED	Not used
Bit 14	NOT USED	Not used
Bit 15	Always 0	The use of Bit 15 is not allowed since some controllers may have difficulty reading a 16 bit unsigned integer.

Table 19. Standard Event Status registor

Bit No.	Bit Name	Description
Bit 0	Operation Complete	Set when error code* is between -800 and -899.
Bit 1	Request Control	Set when error code* is between -700 and -799.
Bit 2	Query Error	Set when error code* is between -400 and -499.
Bit 3	Device Dependent Error	Set when error code* is between -300 and -399.
Bit 4	Execution Error	Set when error code* is between -200 and -299. For example, range error.
Bit 5	Command Error	Set when error code* is between -100 and -199. For example, syntax error.
Bit 6	User Request	Set when error code* is between -600 and -699.
Bit 7	Power On	Set when error code* is between -500 and -599.

*Note: * See* List of Error Message*.*

Table 20. Status Byte registor

Bit No.	Bit Name	Description
Bit 0	NOT USED	Not used
Bit 1	NOT USED	Not used
Bit 2	Error/Event Queue	Error/Event queue message available.
Bit 3	Questionable Status	Operation Status flag.
Bit 4	MAV	Output queue message available.
Bit 5	Standard Event Status	Standard Event Status flag.
Bit 6	RQS	Service request. The summary based on the logical sum of all other bits of the Service Request Enable Register and Status Byte Register.
Bit 7	Operation Status	Operation Status flag.

List of Commands

Table 21. List of commands

Command Header **[ ]: Omissible**	**Data Format** **[ ]: Omissible** **( ): Response data** **{ }: Customized parameter definition*** **|: Or**	**Description**
IEEE-488.2 Common Commands		
*CLS		Clear the Status Byte Register and all event registers, and clear the Error Queue.
*ESE	<NR1 (0 to 255)>	Set the Standard Event Status Enable register.
*ESE?	(<NR1 (0 to 255)>)	Query Standard Event Status Enable register.
*ESR?	(<NR1 (0 to 255)>)	Query Standard Event Status register.
*IDN?	(<Manufacturer>,<Model>,<Serial number>, Instrument firmware version>,<DSP version>,<FPGA version>,<Internal switch version>, External switch version>)	Query the user defined instrument information.
*OPC		Set the Bit 0 (Operation Complete) in the Standard Event Status register.
*OPC?	(<NR1 (1)>)	Return a “1” to the instrument’s output buffer.
*RST		Reset the Instrument to its power-up configuration, except that the state of IEEE-488 interface is unchanged.
*SRE	<NR1 (0 to 255)>	Set the Service Request Enable register.
*SRE?	(<NR1 (0 to 255)>)	Query the Service Request Enable register.
*STB?	(<NR1 (0 to 255)>)	Query the Status Byte register.
*TRG		Trigger one measurement.
*TST?		Perform self-test and return the result.
*WAI		Wait for previous operations to finish.

Command Header **[ ]: Omissible**	**Data Format** **[ ]: Omissible** **( ): Response data** **{ }: Customized parameter definition*** **|: Or**	**Description**
Status Reporting Commands		
STATus:OPERation[:EVENt]?	(<NR1 (0 to 32767)>)	Query and clear the Operation Status register.
STATus:OPERation:ENABle	<NR1 (0 to 32767)>	Set the Operation Status Enable register.
STATus:OPERation:ENABle?	(<NR1 (0 to 32767)>)	Query the Operation Status Enable register.
STATus:QUEStionable[:EVENt]?	(<NR1 (0 to 32767)>)	Query and clear the Questionable Status register.
STATus:QUEStionable:ENABle	<NR1 (0 to 32767)>	Set the Questionable Status Enable register.
STATus:QUEStionable:ENABle?	(<NR1 (0 to 32767)>)	Query the Questionable Status Enable register.
SYSTem:ERRor[:NEXT]?	(<Error_Code>, "<Error_Description>")	Query and removes the next error in the error queue (FIFO).
SYSTem:ERRor:COUNt?	(NR1 (0 to 16))	Query the count of errors in the Error Queue.
System-Related Commands		
SYSTem:CALibration		Execute one self-calibration.
SYSTem:CUSTom:MANufacturer	<Character>	Set the customized instrument manufacturer.
SYSTem:CUSTom:MANufacturer?	(<Character>)	Query the customized instrument manufacturer.
SYSTem:CUSTom:MODel	<Character>	Set the customized instrument model.
SYSTem:CUSTom:MODel?	(<Character>)	Query the customized instrument model.
SYSTem:HEADer	<Boolean>	Enable or disable the command header to be sent with response message.
SYSTem:HEADer?	(<Boolean>)	Query the state whether the command header to be sent with response message.
SYSTem:LANGuage	{ENG | CHN}	Set the system language.
SYSTem:LANGuage?	({ENG | CHN})	Query the system language.
SYSTem:SERial?	(<Character>)	Query the instrument serial number.

Command Header **[ ]: Omissible**	**Data Format** **[ ]: Omissible** **( ): Response data** **{ }: Customized parameter definition*** **|: Or**	**Description**
Remote Interface Commands		
SYSTem:LOCal		Cancel the communication (remote) state.
Factory Reset Commands		
SYSTem:RESet		Restore factory settings.
Line Power Frequency Commands		
SYSTem:LFReqency	{F50Hz | F60Hz}	Set the power line frequency.
SYSTem:LFReqency?	({F50HZ | F60HZ})	Query the power line frequency.
Measurement Configuration Commands		
ADJust?	<NR1 (0 or 1)>	Execute zero adjustment and return the result (success or fail).
ADJust:CLEar		Clear the zero adjustment value.
AUTorange	<Boolean>	Enable or disable the resistance measurement auto range.
AUTorange?	(<Boolean>)	Query the resistance measurement auto range setting.
INPut:IMPedance:HIGH	<Boolean>	Enable or disable the input high impedance (>10 GΩ).
INPut:IMPedance:HIGH?	(<Boolean>)	Query the input high impedance setting.
[:SENSe]:FUNCtion	{RVOLtage | EPCCheck | PEVoltage | NEVoltage | RV | RESistance | VOLTage }	Set the measurement function.
[:SENSe]:FUNCtion?	({RV | EPCCHECK | PEVOLTAGE | NEVOLTAGE | RESISTANCE | VOLTAGE })	Query the measurement function.
RESistance:RANGe	<NRf (0 to 10)>	Set the resistance measurement range.
RESistance:RANGe?	({AUTO | 3.0000E-03 | 3.0000E-02 | 3.0000E-01 | 3.0000E+00 | 1.0000E+01})	Query the resistance measurement range.
RESistance:CURRent:MAX	{C100 | C200 | C300}	Set the maximum measurement current.
RESistance:CURRent:MAX?	({C100 | C200 | C300})	Query the maximum measurement current.
VOLTage:RANGe	<NRf (-10 to 10)>	Set the voltage measurement range.

Command Header **[ ]: Omissible**	**Data Format** **[ ]: Omissible** **( ): Response data** **{ }: Customized parameter definition*** **|: Or**	**Description**
VOLTage:RANGe?	({1.000000E+01 | 1.0000000E+01})	Query the voltage measurement range.
SAMPle:RATE	{EXFast | FAST | MEDium | SLOW}	Set the sampling speed.
SAMPle:RATE?	({EXFAST | FAST | MEDIUM | SLOW})	Query the sampling speed.
Calculate Commands		
CALCulate:AVERage:STATe	<Boolean>	Enable or disable the average function.
CALCulate:AVERage:STATe?	(<Boolean>)	Query the average function state.
CALCulate:AVERage	<NR1 (2 to 16)>	Set the number of samples to average.
CALCulate:AVERage?	(<NR1 (2 to 16)>)	Query the number of samples to average.
CALCulate:LIMit:STATe	<Boolean>	Enable or disable the comparator function.
CALCulate:LIMit:STATe?	(<Boolean>)	Query the comparator function state.
CALCulate:LIMit:BEEPer	{OFF | HL | IN | BOTH1 | BOTH2}	Set the comparator judgments.
CALCulate:LIMit:BEEPer?	({OFF | HL | IN | BOTH1 | BOTH2})	Query the comparator judgments.
CALCulate:LIMit:RESistance:UPPer	<NRf (0 to 10000)>	Set the comparator resistance upper threshold (in mΩ).
CALCulate:LIMit:RESistance:UPPer?	(<NRf (0 to 10000)>)	Query the comparator resistance upper threshold (in mΩ).
CALCulate:LIMit:VOLTage:UPPer	<NRf (0 to 10000)>	Set the comparator voltage upper threshold (in V).
CALCulate:LIMit:VOLTage:UPPer?	(<NRf (0 to 10000)>)	Query the comparator voltage upper threshold (in V).
CALCulate:LIMit:RESistance:LOWer	<NRf (0 to 10000)>	Set the comparator resistance lower threshold (in mΩ).
CALCulate:LIMit:RESistance:LOWer?	(<NRf (0 to 10000)>)	Query the comparator resistance lower threshold (in mΩ).
CALCulate:LIMit:VOLTage:LOWer	<NRf (0 to 10000)>	Set the comparator voltage lower threshold (in V).
CALCulate:LIMit:VOLTage:LOWer?	(<NRf (0 to 10000)>)	Query the comparator voltage lower threshold (in V).

Command Header **[ ]: Omissible**	**Data Format** **[ ]: Omissible** **( ): Response data** **{ }: Customized parameter definition*** **|: Or**	**Description**
CALCulate:LIMit:RESistance:RESult?	({HI | IN | LO | OFF | ERR})	Query the comparator resistance judgment results.
CALCulate:LIMit:VOLTage:RESult?	({HI | IN | LO | OFF | ERR})	Query the comparator voltage judgment results.
Memory Commands		
MEMory:STATe	<Boolean>	Enable or disable the memory function.
MEMory:STATe?	(<Boolean>)	Query the memory function state.
MEMory:CLEar		Clear the instrument memory.
MEMory:COUNt?	(<NR1 (0 to 512)>)	Query the count of memory data.
MEMory:DATA?	(<NR3>,…,<NR3>)	Query the memory data values.
Triggering Commands		
INITiate:CONTinuous	<Boolean>	Enable or disable the continuous measurement.
INITiate:CONTinuous?	(<Boolean>)	Query the continuous measurement state.
INITiate[:IMMediate]		Transit to the trigger waiting state.
TRIGger:SOURce	{IMMediate | EXTernal}	Set the trigger source.
TRIGger:SOURce?	({IMMEDIATE | EXTERNAL})	Query the trigger source.
TRIGger:DELay:STATe	<Boolean>	Enable or disable the trigger delay.
TRIGger:DELay:STATe?	(<Boolean>)	Query the trigger delay state.
TRIGger:DELay	<NR2 (0 to 9.999)>	Set the trigger delay.
TRIGger:DELay?	(<NR2 (0 to 9.999)>)	Query the trigger delay.
Reading Measured Values Commands		
FETCh?	(<NR3>,…,<NR3>)	Query the latest measurement readings or scanned readings.
READ?	(<NR3>,…,<NR3>)	Initiate one measurement and returns the readings.
Switch Relay Card Commands		
ABORt		Scanning is aborted (forcibly terminated).
ROUTe:CLOSe	<channel_list (1 channel)>	Close one specified channel.
ROUTe:OPEN:ALL		Open all channels.

Command Header **[ ]: Omissible**	**Data Format** **[ ]: Omissible** **( ): Response data** **{ }: Customized parameter definition*** **|: Or**	**Description**
ROUTe:SCAN	<channel_list>	Set the channel scan list.
SWITch:MODule	{DISable | INTernal | EXTernal}	Set the switch module selection.
SWITch:MODule?	({DISABLE | INTERNAL | EXTERNAL})	Query the switch module selection.
SWITch:MODule:STATe?	{INTernal | EXTernal} (<NR1 (0 or 1)>,…,< NR1 (0 or 1)>)	Query the specified switch module's slots state.

*Note: * Characters of customized parameter are returned as all capital letters.*

Message Reference Interpretation

IEEE-488.2 Common Commands

*CLS

Description	Clear the Status Byte Register and all event registers, and clear the Error Queue.	
Examples	`*CLS`	

*ESE

Description	Set the Standard Event Status Enable register.	
Parameters	`< NR1 (0 to 255)>`	Binary-weighted decimal value. Each bit enables or disables the appropriate bit in the Standard Event Status register.
Examples	`*ESE 48`	Set bit 4 and 5 to one and all other bits to zero.

*ESE?

Description	Query Standard Event Status Enable register.	
Response	`<NR1 (0 to 255)>`	
Examples	`*ESE?`	
	`48`	Bit 4 and 5 are one and all other bits are zero.

*ESR?

Description	Query Standard Event Status register.	
Response	`<NR1 (0 to 255)>`	
Examples	`*ESR?`	
	`48`	Bit 4 and 5 are one and all other bits are zero.

*IDN?

Description	Query the user defined instrument information.	
Response	`<Manufacturer>,<Model>,<Serial number>,<Instrument firmware version>,<DSP version>,<FPGA version>,<Internal switch version>,<External switch version>`	
Examples	`*IDN?`	Retrieves the IDN string which is composed by user defined manufacturer, user defined model, user defined serial number, instrument firmware version, DSP version, FPGA version, internal switch version and External switch version.

	FLUKE,BUND,54010008WS,0 .06,0.04,1.8,0.02,0.02	

*OPC

Description	Set the Bit 0 (Operation Complete) in the Standard Event Status register.	
Examples	*OPC	

*OPC?

Description	Return a “1” to the instrument’s output buffer.	
Examples	*OPC?	A “1” is placed in the instrument output buffer.

*RST

Description	Reset the instrument to its power-up configuration, except that the state of IEEE-488 interface is unchanged.	
Examples	*RST	

*SRE

Description	Set the Service Request Enable register.	
Parameters	< NR1 (0 to 255)>	Binary-weighted decimal value. Each bit enables or disables the appropriate bit in the Status Byte register.
Examples	*SRE 12	Set bit 2 and 3 to one and all other bits to zero.

*SRE?

Description	Query the Service Request Enable register.	
Response	<NR1 (0 to 255)>	
Examples	*SRE?	
	12	Bit 2 and 3 are one and all other bits are zero.

*STB?

Description	Query the Status Byte register.	
Response	<NR1 (0 to 255)>	
Examples	*STB?	
	12	Bit 2 and 3 are one and all other bits are zero.

*TRG

Description	Trigger one measurement.	
Examples	*TRG	

*TST?

Description	Perform self-test and return the result. Returns “0” if the test succeeds, “1” if the test fails.	
Examples	*TST?	

*WAI

Description	Wait for previous operations to finish. Command required by IEEE-488.2 standard. Non-operational in this instrument. Command accepted but has no effect.	
Examples	*WAI	

Status Reporting Commands

STATus:OPERation[:EVENt]?

Description	Query and clear the Operation Status register.	
Response	(<NR1 (0 to 32767)>)	Refer to the System Status Diagram.
Examples	SYST:OPER?	
	272	

STATus:OPERation:ENABle

Description	Set the Operation Status Enable register.	
Parameters	<NR1 (0 to 32767)>	Refer to the System Status Diagram.
Examples	SYST:OPER:ENAB 272	

STATus:OPERation:ENABle?

Description	Query the Operation Status Enable register.	
Response	(<NR1 (0 to 32767)>)	Refer to the System Status Diagram.
Examples	SYST:OPER:ENAB?	
	272	

STATus:QUEStionable[:EVENt]?

Description	Query and clear the Questionable Status register.	
Response	(<NR1 (0 to 32767)>)	Refer to the System Status Diagram.
Examples	SYST:QUES?	
	2048	

STATus:QUEStionable:ENABle

Description	Set the Questionable Status Enable register.	
Response	(<NR1 (0 to 32767)>)	Refer to the System Status Diagram.
Examples	SYST:QUES:ENAB 2048	

STATus:QUEStionable:ENABle?

Description	Query the Questionable Status Enable register.	
Response	(<NR1 (0 to 32767)>)	Refer to the System Status Diagram.
Examples	SYST:QUES:ENAB?	
	2048	

SYSTem:ERRor[:NEXT]?

Description	Query and remove the next error in the error queue (FIFO).	
Response	<Error_Code>, "<Error_Description>"	Refer to the chapter “List of Error Message”.
Examples	SYST:ERR?	
	-200,"Execution error"	

SYSTem:ERRor:COUNt?

Description	Query the count of errors in the Error Queue.	
Response	NR1 (0 to 16)	
Examples	SYST:ERR:COUN?	
	1	

System-Related Commands

SYSTem:CALibration

Description	Execute one self-calibration.	
Examples	SYST:CAL	

SYSTem:CUSTom:MANufacturer

Description	Set the customized instrument manufacturer name. Max length of parameter is 15.	
Parameters	<Character>	
Examples	SYST:CUST:MAN "CUSTFLUKE"	

SYSTem:CUSTom:MANufacturer?

Description	Query the customized instrument manufacturer name.	
Response	<Character>	
Examples	SYST:CUST:MAN?	
	CUSTFLUKE	

SYSTem:CUSTom:MODel

Description	Set the customized instrument model. Max length of parameter is 15.	
Parameters	<Character>	
Examples	SYST:CUST:MOD "CUSTB0102"	

SYSTem:CUSTom:MODel?

Description	Query the customized instrument model.	
Response	<Character>	
Examples	SYST:CUST:MOD?	
	CUSTB0102	

SYSTem:HEADer

Description	Enable or disable the command header to be sent with response message. Reset to default value (OFF) when power on.

Parameters	<Boolean>	
	= OFF or 0	Disable the command header to be sent with response message.
	= ON or 1	Enable the command header to be sent with response message.
Examples	SYST:HEAD ON	

SYSTem:HEADer?

Description	Query the state whether the command header to be sent with response message.	
Response	<Boolean>	
Examples	SYST:HEAD?	
	SYSTEM:HEADER ON	

SYSTem:LANGuage

Description	Set the system UI language.	
Parameters	{ENG | CHN}	
	= ENG	Use English language in instrument UI.
	= CHN	Use Chinese language in instrument UI.
Examples	SYST:LANG CHN	

SYSTem:LANGuage?

Description	Query the system UI language.	
Response	{ENG | CHN}	
Examples	SYST:LANG?	
	CHN	

SYSTem:SERial?

Description	Query the instrument serial number.	
Response	<Character>	
Examples	SYST:SER?	
	SH120401	

Remote Interface Commands

SYSTem:LOCal

Description	Cancel the communication (remote) state, and return to the local control mode.	
Examples	SYST:LOC	

Factory Reset Commands

SYSTem:RESet

Description	Restore factory settings. The same as the “Factory Reset” in the instrument UI menu.	
Examples	SYST:RES	

Line Power Frequency Commands

SYSTem:LFReqency

Description	Set the power line frequency.	
Parameters	{F50Hz | F60Hz}	
	= F50Hz	The power line frequency is 50 Hz.
	= F60Hz	The power line frequency is 60 Hz.
Examples	SYST:LFR F60Hz	

SYSTem:LFReqency?

Description	Query the power line frequency.	
Response	{F50HZ | F60HZ}	
Examples	SYST:LFR?	
	F60HZ	

Measurement Configuration Commands

ADJust?

Description	Execute zero adjustment and return the result (success or fail). Valid when switch module selection is DISable. The acceptable range of zero adjustment for both resistance and voltage is ±1000 digits. When using the auto-range function, perform zero adjustment for all ranges.	
Response	<NR1 (0 or 1)>	
	= 0	Zero adjustment succeeded.
	= 1	Zero adjustment failed.
Examples	AUT ON	
	ADJ?	
	1	Zero adjustment under all resistance ranges (3 mΩ to 10 Ω) are executed in turn, and the zero adjustment under at least one range is fail.
	AUT OFF	Disable the resistance measurement auto range and set to 10 Ω resistance range.
	ADJ?	
	0	Zero adjustment under 10 Ω resistance range is executed successfully.

ADJust:CLEar

Description	Clear the zero adjustment value.	
Examples	ADJ:CLE	

AUTorange

Description	Enable or disable the resistance measurement auto range.	
Parameters	<Boolean>	
	= OFF or 0	Disable the resistance measurement auto range, and set to 10 Ω resistance range when switch from ON to OFF.
	= ON or 1	Enable the resistance measurement auto range.
Examples	AUT ON	

AUTorange?

Description	Query the resistance measurement auto range setting.	
Response	<Boolean>	
Examples	AUT?	
	ON	

INPut:IMPedance:HIGH

Description	Enable or disable the input high impedance (>10 GΩ).	
Parameters	<Boolean>	
	= OFF or 0	Disable the input high impedance, and use 10 MΩ as the input impedance.
	= ON or 1	Enable the input high impedance (>10 GΩ).
Examples	INP:IMP:HIGH ON	

INPut:IMPedance:HIGH?

Description	Query the input high impedance setting.	
Response	<Boolean>	
Examples	INP:IMP:HIGH?	
	ON	

[:SENSe]:FUNCtion

Description	Set the measurement function. Reset to default value (RVOLtage) when power on.	
Parameters	{RVOLtage | EPCCheck | PEVoltage | NEVoltage | RV | RESistance | VOLTage}	
	= RVOLtage	Measurement function is ACR+DCV, READ? and FETCh? return readings including ACR and DCV.
	= EPCCheck	Measurement function is Enclosure Potential Contact Check, READ? and FETCh? return readings including ACR.
	= PEVoltage	Measurement function is Positive To Enclosure Voltage, READ? and FETCh? return readings including DCV.
	= NEVoltage	Measurement function is Negative To Enclosure Voltage, READ? and FETCh? return readings including DCV.

	= RV	Measurement function is ACR+DCV, READ? and FETCh? return readings including ACR and DCV.
	= RESistance	Measurement function is ACR, READ? and FETCh? return readings including ACR.
	= VOLTage	Measurement function is DCV, READ? and FETCh? return readings including DCV.
Examples	FUNC EPCCheck	

[:SENSe]:FUNCtion?

Description	Query the measurement function.	
Response	{RVOLtage | EPCCHECK | PEVOLTAGE | NEVOLTAGE | RV | RESISTANCE | VOLTAGE}	
Examples	FUNC?	
	EPCCHECK	

RESistance:RANGe

Description	Set the resistance measurement range.	
Parameters	<NRf (0 to 10)>	
	= [0, 3.0000E-03]	The resistance measurement range is 3 mΩ.
	= (3.0000E-03,3.0000E-02]	The resistance measurement range is 30 mΩ.
	= (3.0000E-02,3.0000E-01]	The resistance measurement range is 300 mΩ.
	= (3.0000E-01,3.0000E+00]	The resistance measurement range is 3 Ω.
	= (3.0000E+00,1.0000E+01]	The resistance measurement range is 10 Ω.
Examples	RES:RANG 3.0000E-03	Select the resistance measurement range for measuring 3 mΩ.

RESistance:RANGe?

Description	Query the resistance measurement range.	
Response	{AUTO | 3.0000E-03 | 3.0000E-02 | 3.0000E-01 | 3.0000E+00 | 1.0000E+01}	
Examples	RES:RANG?	
	3.0000E-03	The current resistance measurement range is 3 mΩ.

RESistance:CURRent:MAX

Description	Set the maximum measurement current. This parameter only applies to the 3 mΩ resistance range.	
Parameters	{ C100 | C200 | C300}	
	= C100	The maximum measurement current is 100 mA.
	= C200	The maximum measurement current is 200 mA.
	= C300	The maximum measurement current is 300 mA.
Examples	RES:CURR:MAX C300	

RESistance:CURRent:MAX?

Description	Query the maximum measurement current.	
Response	{C100 | C200 | C300}	
Examples	RES:CURR:MAX?	
	C300	

VOLTage:RANGe

Description	Set the voltage measurement range.	
Parameters	<NRf (-10 to 10)>	
	= [-10, 10]	The voltage measurement range is 10 V.
Examples	VOLT:RANG 0	Select the voltage measurement range for measuring 10 V.

VOLTage:RANGe?

Description	Query the voltage measurement range.	
Response	{1.000000E+01 | 1.0000000E+01}	
	1.000000E+01	The voltage measurement range is 10 V when the instrument voltage resolution is 6.5-digit.
	1.0000000E+01	The voltage measurement range is 10 V when instrument voltage resolution is 7.5-digit.
Examples	VOLT:RANG?	
	1.000000E+01	Current voltage measurement range is 10 V when instrument voltage resolution is 6.5-digit.

SAMPle:RATE

Description	Set the sampling speed.	
Parameters	{EXFast | FAST | MEDium | SLOW}	
	= EXFast	The sample time is 10 ms.
	= FAST	The sample time is 20 ms.
	= MEDium	The sample time is 100 ms.
	= SLOW	The sample time is 200 ms.
Examples	SAMP:RATE FAST	

SAMPle:RATE?

Description	Query the sampling speed.	
Response	{EXFAST | FAST | MEDIUM | SLOW}	
Examples	SAMP:RATE?	
	FAST	

Calculate Commands

Average

CALCulate:AVERage:STATe

Description	Enable or disable the Average Value function.	
Parameters	<Boolean>	
	= OFF or 0	
	= ON or 1	
Examples	CALC:AVER:STAT ON	

CALCulate:AVERage:STATe?

Description	Query the Average value function state.	
Response	<Boolean>	
Examples	CALC:AVER:STAT?	
	ON	

CALCulate:AVERage

Description	Set the number of samples to be averaged.	
Parameters	<NR1 (2 to 16)>	
Examples	CALC:AVER 2	

CALCulate:AVERage?

Description	Query the number of samples to be averaged.	
Response	<NR1 (2 to 16)>	
Examples	CALC:AVER?	
	2	

Comparator

CALCulate:LIMit:STATe

Description	Enable or disable the comparator function.	
Parameters	<Boolean>	
	= OFF or 0	
	= ON or 1	
Examples	CALC:LIM:STAT ON	

CALCulate:LIMit:STATe?

Description	Query the comparator function state.	
Response	<Boolean>	
Examples	CALC:LIM:STAT?	
	ON	

CALCulate:LIMit:BEEPer

Description	Set the comparator judgments.	
Parameters	{OFF | HL | IN | BOTH1 | BOTH2}	
	= OFF	No beeps sound.
	= HL	The beeper sounds upon Hi and Lo judgments.
	= IN	The beeper sounds upon IN judgments.

	= BOTH1	The beeper sounds continuously upon IN judgments, and repeatedly upon Hi and Lo judgments.
	= BOTH2	The beeper sounds once (briefly) upon IN judgments, and repeatedly upon Hi and Lo judgments.
Examples	CALC:LIM:BEEP HL	

CALCulate:LIMit:BEEPer?

Description	Query the comparator judgments.	
Response	{OFF | HL | IN | BOTH1 | BOTH2}	
Examples	CALC:LIM:BEEP?	
	HL	

CALCulate:LIMit:RESistance:UPPer

Description	Set the comparator resistance upper threshold (in mΩ).	
Parameters	<NRf (0 to 15000)>	
Examples	CALC:LIM:RES:UPP 3	Select the comparator resistance upper threshold to be 3 mΩ.

CALCulate:LIMit:RESistance:UPPer?

Description	Query the comparator resistance upper threshold (in mΩ).	
Response	<NRf (0 to 15000)>	
Examples	CALC:LIM:RES:UPP?	
	3	

CALCulate:LIMit:VOLTage:UPPer

Description	Set the comparator voltage upper threshold (in V).	
Parameters	<NRf (0 to 11)>	
Examples	CALC:LIM:VOLT:UPP 3	Select the comparator voltage upper threshold to be 3 V.

CALCulate:LIMit:VOLTage:UPPer?

Description	Query the comparator voltage upper threshold (in V).	
Response	<NRf (0 to 11)>	
Examples	CALC:LIM:VOLT:UPP?	
	3	

CALCulate:LIMit:RESistance:LOWer

Description	Set the comparator resistance lower threshold (in mΩ).	
Parameters	<NRf (0 to 15000)>	
Examples	CALC:LIM:RES:LOW 3	Select the comparator resistance lower threshold to be 3 mΩ.

CALCulate:LIMit:RESistance:LOWer?

Description	Query the comparator resistance lower threshold (in mΩ).	
Response	<NRf (0 to 15000)>	
Examples	CALC:LIM:RES:LOW?	
	3	

CALCulate:LIMit:VOLTage:LOWer

Description	Set the comparator voltage lower threshold (in V).	
Parameters	<NRf (0 to 11>	
Examples	CALC:LIM:VOLT:LOW 3	Select the comparator voltage lower threshold to be 3 V.

CALCulate:LIMit:VOLTage:LOWer?

Description	Query the comparator voltage lower threshold (in V).	
Response	<NRf (0 to 11)>	
Examples	CALC:LIM:VOLT:LOW?	
	3	

CALCulate:LIMit:RESistance:RESult?

Description	Query the comparator resistance judgment results.	
Response	{HI | IN | LO | OFF | ERR}	

	= HI	The measured value is higher than the upper threshold.
	= IN	The measured value is between the upper and lower threshold.
	= LO	The measured value is lower than the lower threshold.
	= OFF	The Comparator function is disabled or SENSe:FUNCtion is PEVoltage/NEVoltage.
	= ERR	Measurement fault.
Examples	CALC:LIM:RES:RES?	
	HI	

CALCulate:LIMit:VOLTage:RESult?

Description	Query the comparator voltage judgment results.	
Response	{HI | IN | LO | OFF | ERR}	
	= HI	The measured value is higher than the upper threshold.
	= IN	The measured value is between the upper and lower threshold.
	= LO	The measured value is lower than the lower threshold.
	= OFF	The Comparator function is disabled or SENSe:FUNCtion is EPCCheck.
	= ERR	Measurement fault.
Examples	CALC:LIM:VOLT:RES?	
	HI	

Memory Commands

One measurement is stored when a trigger is applied by the Trigger key or *TRG command, and the LCD MEM indicator blinks once.

In the case of external triggering, if the continuous measurement is enabled, one measurement is stored after each trigger event (Trigger key or *TRG command).

In the case of immediate triggering, if the continuous measurement is enabled, a trigger event (**Trigger** key or *TRG command) does not trigger measurements, and measurement values are still generated through the immediate triggering according to the existing beat, but the first measurement value after the triggering event is stored.

Note

- **The continuous measurement needs to be enabled to use the storage function.**
- **Maximum memory storage capacity is 512 measurements. Be aware that attempting to store more data (by applying a trigger) results in nothing further being stored.**
- **When the Memory function is enabled, auto-range is not available.**
- **Memory contents are cleared when performing the following operations:**
  - **Enabling the Memory function (OFF to ON)**
  - **Changing measurement ranges (ensure all stored measurements in one memory data are in the same range)**
  - **Sending the `MEMory:CLEar` command**
  - **Sending the `*RST` command**
  - **Sending the `SYSTem:RESet` command**
  - **Factory Reset is executed from the UI menu**
  - **Power cycling**

MEMory:STATe

Description	Enable or disable the Memory function. Reset to default value (OFF) when power on.	
Parameters	`<Boolean>`	
	`= OFF or 0`	
	`= ON or 1`	
Examples	`MEM:STAT ON`	

MEMory:STATe?

Description	Query the Memory function state.	
Response	`<Boolean>`	
Examples	`MEM:STAT?`	
	`ON`	

MEMory:CLEar

Description	Clear the memory data.	
Examples	`MEM:CLE`	

MEMory:COUNt?

Description	Query the count of memory data.	
Response	<NR1 (0 to 512)>	
Examples	MEM:COUN?	
	2	

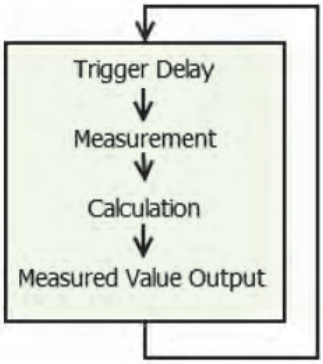
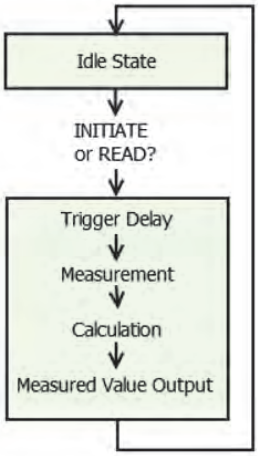
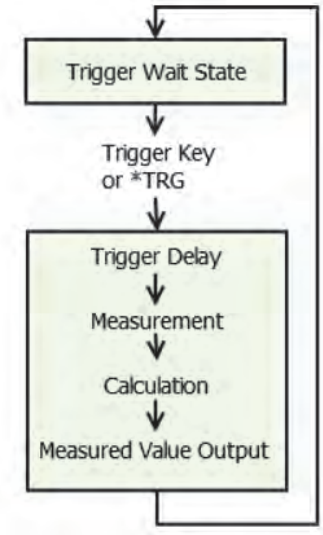
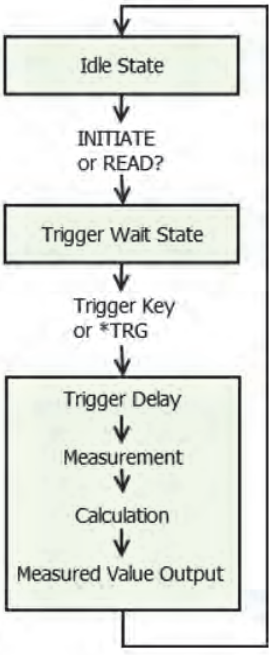
MEMory:DATA?

Description	Query the memory data. Ended with the string “END”.	
Response	For FUNCtion = RVOLtage: <NR1>,<NR3>,<NR3> … <NR1>,<NR3>,<NR3> END	Return pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).
	For FUNCtion = EPCCheck: <NR1>,<NR3>,<NR3> … <NR1>,<NR3>,<NR3> END	Return pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is reserved for the voltage value (DCV) which is filled with an invalid value (+2.000000E+09/+2.0000000E+09).
	For FUNCtion = PEVoltage: <NR1>,<NR3>,<NR3> … <NR1>,<NR3>,<NR3> END	Return pairs of value. In each pair of data, the 1st value is reserved for the the resistance value (ACR), which is filled with an invalid value (+2.000000E+09/+2.0000000E+09); and the 2nd value is the voltage value (DCV).
	For FUNCtion = NEVoltage: <NR1>,<NR3>,<NR3> … <NR1>,<NR3>,<NR3> END	Return pairs of value. In each pair of data, the 1st value is reserved for the the resistance value (ACR), which is filled with an invalid value (+2.000000E+09/+2.0000000E+09); and the 2nd value is the voltage value (DCV).
	For FUNCtion = RV: <NR1>,<NR3>,<NR3> … <NR1>,<NR3>,<NR3> END	Return pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).

	For FUNCtion = RESistance: <NR1>,<NR3>,<NR3> … <NR1>,<NR3>,<NR3> END	Return pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).
	For FUNCtion = VOLTage: <NR1>,<NR3>,<NR3> … <NR1>,<NR3>,<NR3> END	Return pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).
Examples	MEM:DATA?	
	1,1.9896E-02, -0.000001E+01 2,1.9896E-02, -0.000001E+01 END	

Trigger Commands

Table 22. Trigger mode table

Measurement flow		Continuous Measurement Command-Specific Settings	
		`INITiate:CONTinuous ON`	`INITiate:CONTinuous OFF`
Trigger Source	`TRIGger:SOURce IMMediate`	Free-Run state. Measurement continues automatically. 	Start measurement by `INITiate` (or `READ?`) command. 
	`TRIGger:SOURce EXTernal`	Triggered by TRIG Key or `*TRG` command. After measurement, enters the trigger wait state. 	`INITiate` (or `READ?`) command to wait for trigger. Triggered by TRIG key (`INITiate` or `READ?`) or `*TRG (INITiate)`. After measurement, enter the idle State. 

INITiate:CONTinuous

Description	Enable or disable the continuous measurement. Continuous measurement can only be set by Remote command. Continuous measurement is enabled when operation is returned to the Local state or power is ON.	
Parameters	<Boolean>	
	= OFF or 0	Disable continuous measurement. After measurement, enter the Idle State. Triggering is ignored in the Idle State. Executing INITiate or READ? enable the Trigger Wait State.
	= ON or 1	Enable continuous measurement. After measurement, enter the Trigger Wait State. When there is an internal trigger (trigger source is <IMMediate>), the next trigger is promptly generated and enters a free run state.
Examples	INIT:CONT OFF	Disable continuous measurement.

INITiate:CONTinuous?

Description	Query the continuous measurement state.	
Response	<Boolean>	
Examples	INIT:CONT?	
	ON	

INITiate[:IMMediate]

Description	Transit to the Trigger Wait State. Once the instrument has been configured to not use continuous measurement (INITiate:CONTinuous OFF), the INITiate command causes the instrument to take a measurement when the trigger conditions are met. The last reading can be read by using FETCh? command.	
Examples	INIT:CONT OFF	
	INIT	

TRIGger:SOURce

Description	Set the trigger source.	
Parameters	{IMMediate | EXTernal}	
	= IMMediate	Sets the instrument to be triggered by the internal triggering system.
	= EXTernal	Sets the instrument to sense triggers through the trigger key on the front panel of the instrument or upon on execution of a *TRG command.
Examples	TRIG:SOUR EXT	

TRIGger:SOURce?

Description	Query the trigger source.	
Response	{IMMEDIATE | EXTERNAL}	
Examples	TRIG:SOUR?	
	IMMEDIATE	

TRIGger:DELay:STATe

Description	Enable or disable the trigger delay.	
Parameters	<Boolean>	
	= OFF or 0	
	= ON or 1	
Examples	TRIG:DEL:STAT ON	

TRIGger:DELay:STATe?

Description	Query the trigger delay state.	
Response	<Boolean>	
Examples	TRIG:DEL:STAT?	
	ON	

TRIGger:DELay

Description	Set the trigger delay.	
Parameters	<NR2 (0 to 9.999)>	Delay specified in seconds.
Examples	TRIG:DEL 2	Trigger delay is 2 seconds.

TRIGger:DELay?

Description	Query the trigger delay.	
Response	<NR2 (0 to 9.999)>	
Examples	TRIG:DEL?	
	2	

Reading Measured Values Commands

Measurement Value Formats

- Resistance **(in Ω)**

Resistance range	Remote returned value		Measurement fault
	6.5-digit resolution	7.5-digit resolution	
3 mΩ	±□□✱.✱✱✱✱E-03	±□□□✱.✱✱✱✱E-03	See *Table 23. Measurement value formats (measurement fault)*.
30 mΩ	±□□✱.✱✱✱✱E-02	±□□□✱.✱✱✱✱E-02	
300 mΩ	±□□✱.✱✱✱✱E-01	±□□□✱.✱✱✱✱E-01	
3 Ω	±□□✱.✱✱✱✱E+00	±□□□✱.✱✱✱✱E+00	
10 Ω	±□□✱.✱✱✱✱E+01	±□□□✱.✱✱✱✱E+01	

- **Voltage (in V)**

Voltage Range	Remote returned value		Measurement fault
	6.5-digit resolution	7.5-digit resolution	
	±✱.✱✱✱✱✱✱E+01	±✱.✱✱✱✱✱✱✱E+01	See *Table 23. Measurement value formats (measurement fault)*.

Note “±” is a symbol placeholder. When the value is positive, replace the symbol with a space, otherwise use "-" instead.

Table 23. Measurement value formats (measurement fault)

Measurement fault	Display	Remote returned value	
		6.5-digit resolution	7.5-digit resolution
Out of R range	±OL	+1.000000E+08	+1.0000000E+08
Out of V range	±OL	+7.000000E+08	+7.0000000E+08
Invalid value	------	+2.000000E+09	+2.0000000E+09

FETCh?

Description	Query the readings from the measurement/scan memory. If FETCh? is send following one scan is done, every channel’s readings will be returned in turn.	
Response	For FUNCtion = RVOLtage: <NR3>,<NR3>,…,<NR3>,<NR3>	Returns pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).
	For FUNCtion = EPCCheck: <NR3>,…,<NR3>	Returns the resistance value (ACR).

	For FUNCtion = PEVoltage, <NR3>,…,<NR3>	Returns the voltage value (DCV).
	For FUNCtion = NEVoltage, <NR3>,…,<NR3>	Returns the voltage value (DCV).
	For FUNCtion = RV: <NR3>,<NR3>,…,<NR3>, <NR3>	Returns pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).
	For FUNCtion = RESistance: <NR3>,…,<NR3>	Returns the resistance value (ACR).
	For FUNCtion = VOLTage: <NR3>,…,<NR3>	Returns the voltage value (DCV).
Examples	FETC?	
	+0.123827E+01, +1.000000E+08	

READ?

Description	Initiates one measurement and returns the readings.	
Response	For FUNCtion = RVOLtage: <NR3>,<NR3>	Returns pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).
	For FUNCtion = EPCCheck, <NR3>	Returns the resistance value (ACR).
	For FUNCtion = PEVoltage, <NR3>	Returns the voltage value (DCV).
	For FUNCtion = NEVoltage, <NR3>	Returns the voltage value (DCV).
	For FUNCtion = RV: <NR3>,<NR3>	Returns pairs of value. In each pair of data, the 1st value is the resistance value (ACR), and the 2nd value is the voltage value (DCV).
	For FUNCtion = RESistance: <NR3>	Returns the resistance value (ACR).
	For FUNCtion = VOLTage: <NR3>	Returns the voltage value (DCV).
Examples	READ?	
	0.1996E-01, -0.000001E+01	

Switch Relay Card Commands

ABORt

Description	Scanning is aborted (forcibly terminated).	
Examples	ABORt	

ROUTe:CLOSe

Description	Closes the specified channel.	
Parameters	<channel_list (1 channel)>	Only one channel can be closed at a time.
Examples	ROUT:CLOS (@102)	Close channel 102 in internal/external switch module (depends on SWIT:MOD?).

ROUTe:OPEN:ALL

Description	Open all channels.	
Examples	ROUT:OPEN:ALL	No channel will be closed.

ROUTe:SCAN

Description	Set the channel scan list.	
Parameters	<channel_list>	
Examples	ROUT:SCAN (@101:832)	Enable channels from 101 to 832 (256 channels) for scanning, while EXTernal switch module is selected, and 8 relay cards are installed.

Note: This command is not supported when the resistance range is auto range. The resistance range must be set to a fixed range, for example `RESistance:RANGe 3.0000E-03`, before using this command. After setting the scan list, you need to initiate the scan through the command `INITiate`. After the scan is started, it is not recommended to send instructions other than "`abort`", "`fetch?`", "status: operation?", otherwise the scan result will be abnormal.

SWITch:MODule

Description	Set the switch module selection. Reset to default value (DISable) when power on.	
Parameters	{DISable | INTernal | EXTernal}	
	= DISable	Specify the front panel input without using any switch module.
	= INTernal	Specify the rear panel input with using the internal switch module(s).
	= EXTernal	Specify the front panel input with using the external switch module(s).

Examples	SWIT:MOD INT	

SWITch:MODule?

Description	Query the switch module selection.	
Response	{DISABLE | INTERNAL | EXTERNAL}	
Examples	SWIT:MOD?	
	INTERNAL	

SWITch:MODule:STATe?

Description	Query the specified switch module's slots state.	
Parameters	{INTernal | EXTernal}	
Response	For NTernal switch modules, <NR1 (0 or 1)>,< NR1 (0 or 1)> For EXTernal switch modules, <NR1 (0 or 1)>,< NR1 (0 or 1)>,< NR1 (0 or 1)>,<NR1 (0 or 1)>,< NR1 (0 or 1)>,< NR1 (0 or 1)>,<NR1 (0 or 1)>,< NR1 (0 or 1)>	
Examples	SWIT:MOD:STAT? EXT	
	0,1,0,0,0,0,0,0	Only the 2# slot in external switch box is connected.

Remote Command Examples

Compound Headers Using a Tree – Usage and Examples

Figure 47 presents the instrument command structure that has implemented compound headers using a tree structure. Headers were chosen with short form mnemonic value.

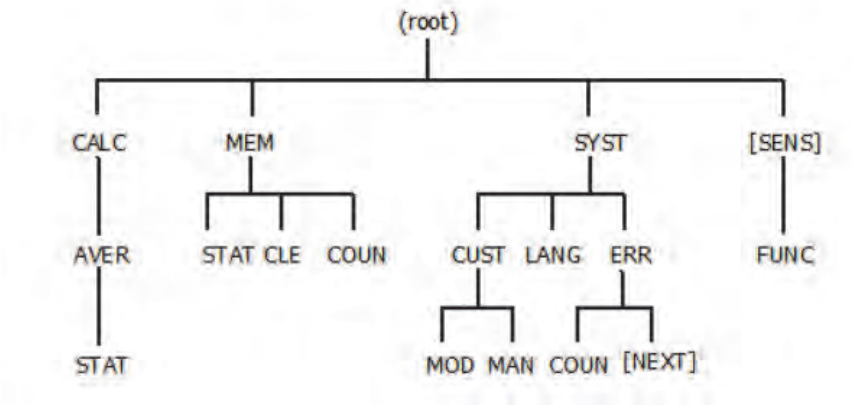


Figure 47. Compound header organization example using a tree

Then the following commands shall behave as described:

- **:CALC:AVER:STATE ON;:MEM:STATE ON<PMT>** The leading colon (:) in the second <PROGRAM MESSAGE UNIT> puts the parser at the top of the command tree. Both paths are legal.
- **:CALC:AVER:STATE ON<PMT>MEM:STATE ON<PMT>** The first <PMT> puts the parser at the top of the command tree. A leading colon (:) at the beginning of the next <PROGRAM MESSAGE UNIT> is unnecessary because the previous <PROGRAM MESSAGE UNIT> in a <PROGRAM MESSAGE> starts the parser at the root.
- :MEM:STAT ON;CLE;COUN?<PMT>The entire path is not given in the second and third <PROGRM MESSAGE UNIT> elements. Because the "**CLE**" and "**COUN**" are referenced to the same tree level as the "**STAT**", "**:MEM:**" is assumed to be prefixed to the second and third <PROGRM MESSAGE UNIT> elements. This commands is equivalent to **:MEM:STAT ON;:MEM:CLE;:MEM:COUN?<PMT>**
- **:SYST:LANG ENG;CUST:MOD?;MAN?<PMT>** Same as 3), the second and third <PROGRAM MESSAGE UNIT> elements are assumed to be prefixed by the implied prefix of the immediately previous command, "**:SYST:**". This command is equivalent to **:SYST:LANG ENG;:SYST:CUST:MOD?;:SYST:CUST:MAN?<PMT>**
- **:SYST:LANG ENG;*IDN?;CUST:MOD?;MAN?<PMT>** The insertion of the common commands has no effect on the application of the prefixing rules. This command is equivalent to **:SYST:LANG ENG;*IDN?;:SYST:CUST:MOD?;:SYST:CUST:MAN?<PMT>**

The following examples would cause an error as described:

- **:CALC:AVER:STATE ON;MEM:STATE ON<PMT>** The second <PROGRAM MESSAGE UNIT> would cause an error, since node "**MEM**" is not a sub-node of "**CALC**". The parser attempts to execute the command "**:CALC:AVER:MEM:STATE ON**", which is illegal. The parser is unable to look at any nodes closer to the root than node "**CALC:AVER**". Only the "**:CALC:AVER:STATE ON**" can be parsed correctly.
- **:SYST:ERR?;COUN?<PMT>** Although the "**:SYST:ERR?**" is equivalent to "**:SYST:ERR:NEXT?**", default nodes in the tree shall not alter the header path of the parser, which means nothing can be added to the header path when the default nodes is omitted. The parser attempts to execute the second <PROGRAM MESSAGE UNIT> as ""**:COUN?**", which is illegal. Only the "**:SYST:ERR?**" can be parsed correctly. This command can be corrected as **:SYST:ERR:NEXT?;COUN?<PMT>**

Note

<PMT> is used to indicate a <PROGRAM MESSAGE TERMINATOR>

Input Channel Slection/Route Scan Programming Examples

Front Panel Measurement, Internal Trigger

In this scenario, it is desired to measure the resistance and/or voltage from the front panel input post under internal triggering, without using any internal/external module. Below are three methods that can be used.

1. Disable continuous initiation, READ one measurement

Command	Action
SWITch:MODule DISable	Configure the instrument to measure the signal from the front panel input post without using internal/external switch channels.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
INITiate:CONTinuous OFF	Disable continuous measurement.
READ?	Acquire one measurement then return the reading (voltage and/or resistance).
READ?	Acquire another measurement then return the reading (voltage and/or resistance).

2. Disable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule DISable	Configure the instrument to measure the signal from the front panel input post without using internal/external switch channels.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Initiate one measurement.

Command	Action
STATus:OPERation?	Query the Operation Status register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

3. Enable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule DISable	Configure the instrument to measure the signal from the front panel input post without using internal/external switch channels.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
INITiate:CONTinuous ON	Enable continuous measurement.
FETCh?	Return the latest reading (voltage and/or resistance).
FETCh?	Return the latest reading (voltage and/or resistance).

Front Panel Measurement, External Trigger

In this scenario, it is desired to measure the resistance and/or voltage from the front panel input post under external triggering, without using any internal/external module. Below are three methods that can be used.

1. Disable continuous initiation, READ one measurement

Command	Action
SWITch:MODule DISable	Configure the instrument to measure the signal from the front panel input post without using internal/external switch channels.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
INITiate:CONTinuous OFF	Disable continuous measurement.
READ?	Acquire one measurement when a triggering event occurs, then return the reading (voltage and/or resistance).
READ?	Acquire one measurement when another triggering event occurs, then return the reading (voltage and/or resistance).

2. Disable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule DISable	Configure the instrument to measure the signal from the front panel input post without using internal/external switch channels.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Initiate the instrument to Trigger Wait State.
*TRG	Trigger one measurement (Trigger Key signal can achieve the same result).

Command	Action
STATus:OPERation?	Query the Operation Status register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

3. Enable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule DISable	Configure the instrument to measure the signal from the front panel input post without using internal/external switch channels.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
INITiate:CONTinuous ON	Enable continuous measurement.
*TRG	Trigger one measurement (Trigger Key signal can achieve the same result).
STATus:OPERation?	Query the Operation Status register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

Module Internal, Single Channel, Internal Trigger

In this scenario, it is desired to measure the resistance and/or voltage from the internal switch channel under internal triggering. Below are three methods that can be used.

1. Disable continuous initiation, READ one measurement

Command	Action
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.
READ?	Acquire one measurement then return the reading (voltage and resistance).
READ?	Acquire another measurement then return the reading (voltage and/or resistance).

2. Disable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.

Command	Action
INITiate	Initiate one measurement.
STATus:OPERation?	Query the Operation Statues register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

3. Enable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous ON	Enable continuous measurement.
FETCh?	Return the latest reading (voltage and/or resistance).
FETCh?	Return the latest reading (voltage and/or resistance).

Module Internal, Single Channel, External Trigger

In this scenario, it is desired to measure the resistance and/or voltage from the internal switch channel under external triggering. Below are three methods that can be used.

1. Disable continuous initiation, READ one measurement

Command	Action
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.
READ?	Acquire one measurement then return the reading (voltage and resistance) until one Trigger Key signal is detected.
READ?	Acquire another measurement then return the reading (voltage and/or resistance) until one Trigger Key signal is detected.

2. Disable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.

Command	Action
INITiate	Initiate the instrument to Trigger Wait State.
*TRG	Trigger one measurement (Trigger Key signal can achieve the same result).
STATus:OPERation?	Query the Operation Statues register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

3. Enable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous ON	Enable continuous measurement.
*TRG	Trigger one measurement (Trigger Key signal can achieve the same result).
STATus:OPERation?	Query the Operation Statues register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

Module External, Single Channel, Internal Trigger

In this scenario, it is desired to measure the resistance and/or voltage from the external switch channel under internal triggering. Below are three methods that can be used.

1. Disable continuous initiation, READ one measurement

Command	Action
SWITch:MODule EXTernal	Configure the instrument to use the external switch channel as measurement input channel.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.
READ?	Acquire one measurement then return the reading (voltage and/or resistance).
READ?	Acquire another measurement then return the reading (voltage and/or resistance).

2. Disable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule EXTernal	Configure the instrument to use the external switch channel as

Command	Action
	measurement input channel.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Initiate one measurement.
STATus:OPERation?	Query the Operation Statues register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

3. Enable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule EXTernal	Configure the instrument to use the external switch channel as measurement input channel.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous ON	Enable continuous measurement.
FETCh?	Return the latest reading (voltage and/or resistance).
FETCh?	Return the latest reading (voltage and/or resistance).

Module External, Single Channel, External Trigger

In this scenario, it is desired to measure the resistance and/or voltage from the external switch channel under internal triggering. Below are three methods that can be used.

1. Disable continuous initiation, READ one measurement

Command	Action
SWITch:MODule EXTernal	Configure the instrument to use the external switch channel as measurement input channel.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.
READ?	Acquire one measurement then return the reading (voltage and/or resistance) until one Trigger Key signal is detected.
READ?	Acquire another measurement then return the reading (voltage and/or resistance) until one Trigger Key signal is detected.

2. Disable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule EXTernal	Configure the instrument to use the external switch channel as measurement input channel.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Initiate the instrument to Trigger Wait State.
*TRG	Trigger one measurement (Trigger key signal can achieve the same result).
STATus:OPERation?	Query the Operation Statues register until the Bit 11 (Measure Done) is set.
FETCh?	Return the latest reading (voltage and/or resistance).

3. Enable continuous initiation, FETCh one measurement

Command	Action
SWITch:MODule EXTernal	Configure the instrument to use the external switch channel as measurement input channel.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
ROUTe:CLOSe (@102)	Configure channel 102 to be measurement input channel.
INITiate:CONTinuous ON	Enable continuous measurement.
*TRG	Query the Operation Status register until the Bit 11 (Measure Done) is set.
STATus:OPERation?	Query the operation status until bit 11 (measure done).
FETCh?	Return the latest reading (voltage and/or resistance).

Module Internal, One-Shot Scan, Internal Trigger

In this scenario it is desired to scan and measure several internal switch channels in a one-shot fashion under internal triggering.

Command	Action
*RST	Reset the instrument to the power-on state.
*CLS	Clear the Status Byte Register and all event registers, and clear the Error Queue.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal.
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
SWIT:MOD:STAT? INT	Query the internal switch module's slots state.
ROUTe:SCAN (@101:132)	According to the active slots' state, configure scan channel list from 101 to 132.

Command	Action
FUNCtion RVOLtage	Configure to measure the ACR+DCV.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Initiate scan.
STATus:OPERation?	Query the Operation Statues register until the Bit4 (Sweep Done) and Bit 8 (Scan Done) is set.
FETCh?	Return the latest reading (32 pairs of voltage and resistance).

Module Internal, One-Shot Scan, External Trigger

In this scenario it is desired to scan and measure several internal switch channels in a one-shot fashion under external triggering.

Command	Action
*RST	Reset the instrument to the power-on state.
*CLS	Clear the Status Byte Register and all event registers and clear the Error Queue.
TRIGger:SOURce EXTernal	Configure the trigger source to be external.
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel.
SWIT:MOD:STAT? INT	Query the internal switch module's slots state.
ROUTe:SCAN (@101:132)	According to the active slots' state, configure scan channel list from 101 to 132.
FUNCtion RVOLtage	Configure to measure the ACR+DCV.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Initiate scan.
STATus:OPERation?	Query the Operation Status register, until the Bit 12 (Ready for Initiate Trigger) is set.
*TRG	Trigger one measurement (Trigger key signal can achieve the same result).
STATus:OPERation?	Repeat the last 2 steps until the Bit 4 (Sweep Done) and Bit 8 (Scan Done) of the Operation Status register is set.
FETCh?	Return the latest reading (32 pairs of voltage and resistance).

Module External, One-Shot Scan, Internal Trigger

In this scenario it is desired to scan and measure several external switch channels in a one-shot fashion under internal triggering.

Command	Action
`*RST`	Reset the instrument to the power-on state.
`*CLS`	Clear the Status Byte Register and all event registers and clear the Error Queue.
`TRIGger:SOURce IMMediate`	Configure the trigger source to be internal.
`SWITch:MODule EXTernal`	Configure the instrument to use the external switch channel as measurement input channel.
`SWIT:MOD:STAT? EXT`	Query the external switch module's slots state.
`ROUTe:SCAN (@101:132)`	According to the active slots' state, configure scan channel list from 101 to 132.
`FUNCtion RVOLtage`	Configure to measure the ACR+DCV.
`INITiate:CONTinuous OFF`	Disable continuous measurement.
`INITiate`	Initiate scan.
`STATus:OPERation?`	Query the Operation Statues register until the Bit 4 (Sweep Done) and Bit 8 (Scan Done) is set.
`FETCh?`	Return the latest reading (32 pairs of voltage and resistance).

Module External, One-Shot Scan, External Trigger

In this scenario it is desired to scan and measure several external switch channels in a one-shot fashion under external triggering.

Command	Action
`*RST`	Reset the instrument to the power-on state.
`*CLS`	Clear the Status Byte Register and all event registers, and clear the Error Queue.
`TRIGger:SOURce EXTernal`	Configure the trigger source to be external.
`SWITch:MODule EXTernal`	Configure the instrument to use the external switch channel as measurement input channel.
`SWIT:MOD:STAT? EXT`	Query the external switch module's slots state.
`ROUTe:SCAN (@101:132)`	According to the active slots' state, configure scan channel list from 101 to 132.
`FUNCtion RVOLtage`	Configure to measure the ACR+DCV.
`INITiate:CONTinuous OFF`	Disable continuous measurement.
`INITiate`	Initiate scan.
`STATus:OPERation?`	Query the Operation Status register, until the Bit 12 (Ready for Initiate Trigger) is set.

Command	Action
*TRG	Trigger one measurement (Trigger key signal can achieve the same result).
STATus:OPERation?	Repeat the last 2 steps until the Bit 4 (Sweep Done) and Bit 8 (Scan Done) of the Operation Status register is set.
FETCh?	Return the latest reading (32 pairs of voltage and resistance).

Memory Programming Examples

Front Panel Measurement, Internal / External Trigger

Command	Action
*RST	Reset the instrument to the power-on state.
*CLS	Clear the Status Byte Register and all event registers, and clear the Error Queue.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal. If the external triggering is used, the following steps are the same.
INITiate:CONTinuous ON	Enable continuous measurement.
SWITch:MODule DISable	Configure the instrument to measure the signal from the front panel input post without using internal/external switch channels.
FUNCtion RVOLtage	Configure to measure the ACR+DCV.
MEMory:STATe ON	Enable memory function and clear stored memory data.
*TRG	Trigger one storage (Trigger key signal can achieve the same result).
STATus:OPERation?	Query the Operation Status register until the Bit 10 (Memory Trigger Done) is set.
…	Repeat the last 2 steps according to measurement requirement.
MEMory:DATA?	Return all the stored memory data.

Module Internal / External, Single Channel, Internal / External Trigger

Command	Action
*RST	Reset the instrument to the power-on state.
*CLS	Clear the Status Byte Register and all event registers, and clear the Error Queue.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal. If the external triggering is used, the following steps are the same.
INITiate:CONTinuous ON	Enable continuous measurement.
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel

Command	Action
	as measurement input channel. If the external triggering is used, the following steps are the same.
FUNCtion RVOLtage	Configure to measure the ACR+DCV.
MEMory:STATe ON	Enable memory function and clear stored memory data.
ROUTe:CLOSe (@xxx)	Configure channel xxx to be measurement input channel.
STATus:QUEStionable?	Query Questionable Status register, the memory function is triggered successfully only when the Bit 11 (Memory Full) is not set.
*TRG	Trigger one storage (Trigger key signal can achieve the same result).
STATus:OPERation?	Query the Operation Status register until the Bit 10 (Memory Trigger Done) is set.
…	Repeat the last 4 steps according to measurement requirement.
MEMory:DATA?	Return all the stored memory data.

Module Internal / External, Multiple Channel, Internal / External Trigger

Command	Action
*RST	Reset the instrument to the power-on state.
*CLS	Clear the Status Byte Register and all event registers, and clear the Error Queue.
TRIGger:SOURce IMMediate	Configure the trigger source to be internal. If the external triggering is used, the following steps are the same.
INITiate:CONTinuous ON	Enable continuous measurement.
SWITch:MODule INTernal	Configure the instrument to use the internal switch channel as measurement input channel. If the external triggering is used, the following steps are the same.
FUNCtion RVOLtage	Configure to measure the ACR+DCV.
MEMory:STATe ON	Enable memory function and clear stored memory data.
ROUTe:CLOSe (@xxx)	Configure channel xxx to be measurement input channel.
STATus:QUEStionable?	Query Questionable Status register, the memory function is triggered successfully only when the Bit 11 (Memory Full) is not set.
*TRG	Trigger one measurement and storage (Trigger Key signal can achieve the same result).
STATus:OPERation?	Query the Operation Status register until the Bit 10 (Memory Trigger Done) is set.
…	Repeat the last 4 steps according to measurement requirement.
MEMory:DATA?	Return all the stored memory data.

List of Error Message

Error Code	Error Name
0	No error
-100	Command error
-101	Invalid character
-102	Syntax error
-103	Invalid separator
-104	Data type error
-105	GET not allowed
-108	Parameter not allowed
-109	Missing parameter
-110	Command header error
-111	Header separator error
-112	Program mnemonic too long
-113	Undefined header
-114	Header suffix out of range
-115	Unexpected number of parameters
-120	Numeric data error
-121	Invalid character in number
-123	Exponent too large
-124	Too many digits

Error Code	Error Name
-128	Numeric data not allowed
-130	Suffix error
-131	Invalid suffix
-134	Suffix too long
-138	Suffix not allowed
-140	Character data error
-141	Invalid character data
-144	Character data too long
-148	Character data not allowed
-150	String data error
-151	Invalid string data
-158	String data not allowed
-160	Block data error
-161	Invalid block data
-168	Block data not allowed
-170	Expression error
-171	Invalid expression
-178	Expression data not allowed
-180	Macro error
-181	Invalid outside macro definition

Error Code	Error Name
-183	Invalid inside macro definition
-184	Macro parameter error
-200	Execution error
-201	Invalid while in local
-202	Settings lost due to rtl
-203	Command protected
-210	Trigger error
-211	Trigger ignored
-212	Arm ignored
-213	Init ignored
-214	Trigger deadlock
-215	Arm deadlock
-220	Parameter error
-221	Settings conflict
-222	Data out of range
-223	Too much data
-224	Illegal parameter value
-225	Out of memory
-226	Lists not same length
-230	Data corrupt or stale

Error Code	Error Name
-231	Data questionable
-232	Invalid format
-233	Invalid version
-240	Hardware error
-241	Hardware missing
-250	Mass storage error
-251	Missing mass storage
-252	Missing media
-253	Corrupt media
-254	Media full
-255	Directory full
-256	File name not found
-257	File name error
-258	Media protected
-260	Expression error
-261	Math error in expression
-270	Macro error
-271	Macro syntax error
-272	Macro execution error
-273	Illegal macro label

Error Code	Error Name
-274	Macro parameter error
-275	Macro definition too long
-276	Macro recursion error
-277	Macro redefinition not allowed
-278	Macro header not found
-280	Program error
-281	Cannot create program
-282	Illegal program name
-283	Illegal variable name
-284	Program currently running
-285	Program syntax error
-286	Program runtime error
-290	Memory use error
-291	Out of memory
-292	Referenced name does not exist
-293	Referenced name already exists
-294	Incompatible type
-300	Device-specific error
-310	System error
-311	Memory error

Error Code	Error Name
-312	PUD memory lost
-313	Calibration memory lost
-314	Save/recall memory lost
-315	Configuration memory lost
-320	Storage fault
-321	Out of memory
-330	Self-test failed
-340	Calibration failed
-350	Queue overflow
-360	Communication error
-361	Parity error in program message
-362	Framing error in program message
-363	Input buffer overrun
-365	Time out error
-400	Query error
-410	Query INTERRUPTED
-420	Query UNTERMINATED
-430	Query DEADLOCKED
-440	Query UNTERMINATED after indefinite response
-500	Power on

Error Code	Error Name
-600	User request
-700	Request control
-800	Operation complete

Maintenance

There are no parts requiring for users to repair and maintain inside the Product, and no special maintenance is needed. It is only necessary to replace the fuse as needed.

Change the Fuse

Please refer to the *Figure 48*.

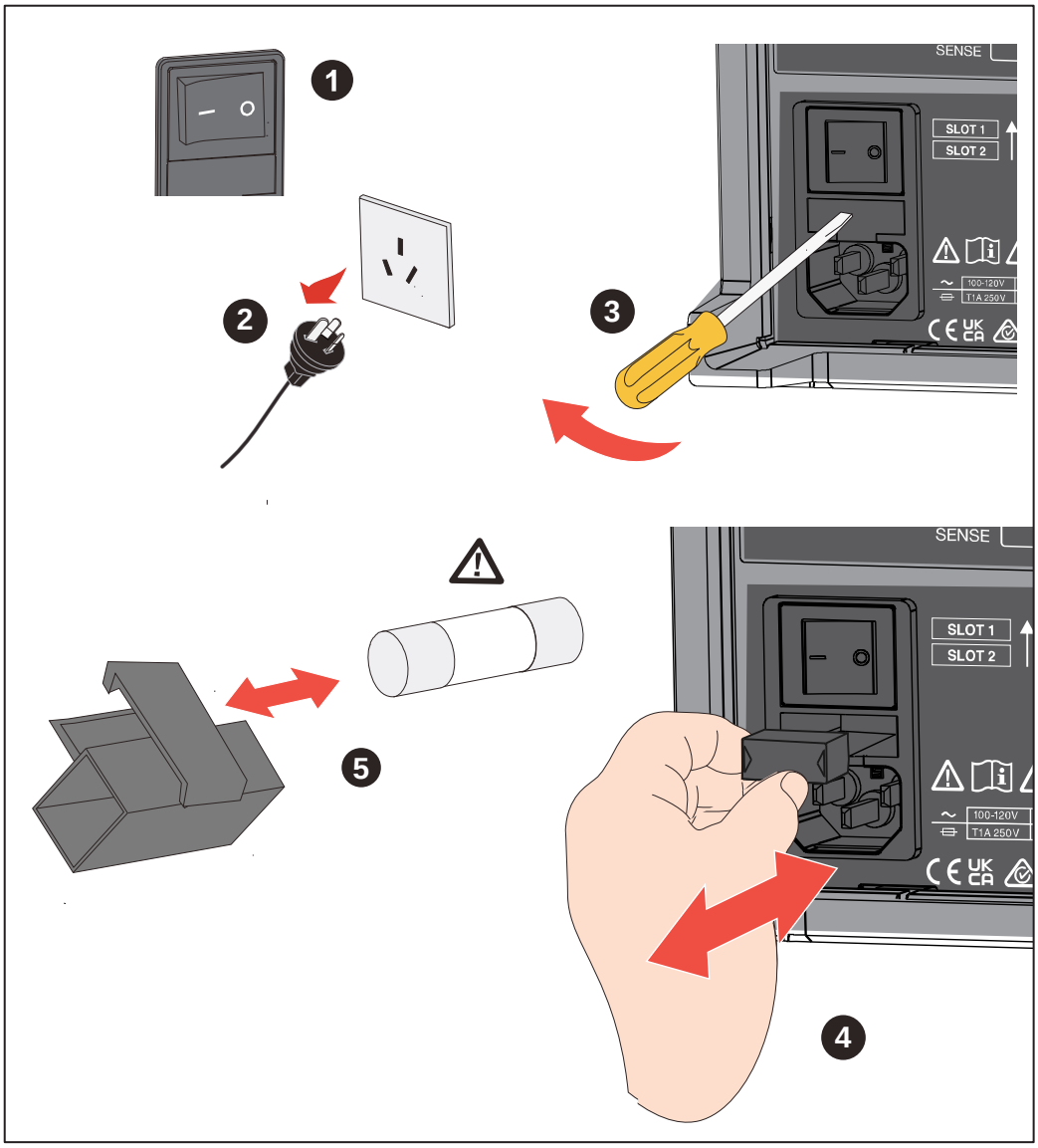


Figure 48. Change the Fuse

⚠ Caution

To prevent damage to the instrument, use only the fuses specified by Fluke. Please see the section *Table 7* and *How to Contact Fluke*.

To change the fuse:

1. Turn off the Product, unplug the power cord from mains power connector, and disconnect all test leads.
2. Insert a flat screwdriver into the clip under the fuse box and gently pry it until it is possible to hold the fuse holder by hand and take it out.
3. Remove the old fuse from the fuse holder and replace it with a new one.
4. Push the fuse holder back into place until the clip is locked.
5. Check the circuit before reconnecting the mains power to ensure the current does not blow the fuse again.

Calibration

For more information on the calibration, please refer to the Product's *Calibration Manual*.

Specifications

BT5300 Battery Tester

Measurement Items

Measurement Items	ACR, DCV, enclosure potential measurement
Measurement method	AC 4-wire method (1 kHz)
Rated input	DC ± 11 V
Input impedance	10 MΩ or high-Z（>10 GΩ）
Loop resistance supported	≤10 Ω @ 3 mΩ Range ≤ 20 Ω @ Other ranges
Trigger	Internal/external
Trigger delay	ON/OFF, Delay time: 0~9.999 s
Average	ON/OFF, Average count: 2 to 16
Measurement storage	Up to 512 sets
Channel extension	Internal: Up to 2 SW9010 multiplexer cards can be added for up to 64 channels[1] External: Up to 256 channels by using SW1080 switch mainframe
External interface	RS-232C, Ethernet
Other functions	Contact check

[1] *BT5311 and BT5321 only*

Sampling Time

Sampling speed (ACR and DCV simultaneously)	Sample time (50 Hz/60 Hz)
Ex-Fast	10 ms / 8.3 ms
Fast	20 ms / 16.7 ms
Medium	100 ms / 83.3 ms
Slow	200 ms / 166.7 ms

Range and Accuracy

ACR measurement

Range	3 mΩ	30 mΩ	300 mΩ	3 Ω	10 Ω
Max. displayed value	5.0000 mΩ [1]	50.000 mΩ	500.00 mΩ	5.0000 Ω	15.000 Ω
Resolution	0.1 µΩ	1 µΩ	10 µΩ	100 µΩ	1 mΩ
Test current[1]	100 mA/200 mA/300 mA	100 mA	10 mA	1 mA	1 mA
Test current frequency	1 kHz ± 1 Hz				

Range	3 mΩ	30 mΩ	300 mΩ	3 Ω	10 Ω
Accuracy[2,3]	0.2% * rdg + 6 dgt				
Temperature coefficient (>28 °C or <18 °C)	(0.05% * rdg + 0.005% * F.S.)/°C				
Response time (Pure resistance, typical)	< 20 ms				

1 *5.0000 mΩ Max. displayed value @ test current = 300 mA*
7.5000 mΩ Max. displayed value @ test current = 200 mA
15.0000 mΩ Max. displayed value @ test current = 100 mA
2 *Test current error ±10%*
3 *For 3 mΩ range, Slow sampling rate, the accuracy for different test current*
*100 mA 0.5% * rdg + 20 dgt*
*200 mA 0.3% * rdg + 12 dgt*
300 mA 0.2% rdg + +6 dgt*
4 *With the different sampling speed, extra error need to be added*
3 mΩ rang Ex-fast: ±30 dgt; Fast: ±10 dgt; Medium: ±5 dgt
30 mΩ to 10 Ω range Ex-fast: ±3 dgt; Fast: ±2 dgt; Medium: ±2 dgt

DCV measurement

	BT5310/BT5311	BT5320/BT5321
Digit	6.5-digit	7.5-digit
Range	10V	
Max. displayed value	11.00000 V	11.000000 V
Resolution	10 µV	1 µV
Accuracy[1]	25ppm * rdg + 50 µV	18ppm * rdg + 25 µV
Response time (Typical)	< 20 ms	< 20 ms
Temperature coefficient (>28 °C or <18 °C)	(5 ppm of reading + 1 ppm of range) /°C	(1 ppm of reading + 1 ppm of range) /°C

1 *With the different sampling speed, extra error needs to be added*
BT5310/BT5311: Ex-Fast: ±50 µV; Fast: ±30 µV; Medium: ±10 µV
BT5320/BT5321: Ex-Fast: ±50 µV; Fast: ±20 µV; Medium: ±5 µV

SW1080 Switch Mainframe

Number of slots	8
Card supported	SW9010 Multiplexer card
Max. input voltage	DC ±11V
Power supply and control	Powered and controlled by BT5300 Series Batter Tester.

SW9010 Multiplexer Card

Wiring	4-wire connection
Number of channels	32 channels
On/Off time	3 ms, typical
Channel switching	Open before close
Maximum allowed voltage	DC ± 10 V
Maximum allowed current	750 mA
Loop resistance	1.5 Ω, typical
Electrostatic capacity	300 pF, typical
Relay life cycle	> 10 million times with load
Short protection fuse (Self-recovery)	Each channel Rated current: 750 mA; Fusing current: 1.5 A
Measurement connector	D-sub 68-pin, Female, compatible with buckle or screw UNC #2-56

General Specifications

Dimensions (H x W x L)	BT5300: 216 mm x 133 mm x 383 mm SW1080: 430mm x 128 mm x 260 mm SW9010: 202 mm x 26 mm x 222 mm
Wtight (Typical, without accessory and pakage)	BT5300: 7.3 kg (Without SW9010) SW1080: 9.0 kg (Without SW9010) SW9010: 495 g
Display	4.3” TFT LCD, resolution 480 x 272
Operation temperature	0 °C to +50 °C
Storage temperature	-10 °C to +60 °C
Operation temperature	Non-condensing (<10°C)
	≤ 90% RH (10 °C to 30 °C)
	≤ 75% RH (30 °C to 40 °C)
	≤ 45% RH (40 °C to 50 °C)
Altitude	3000 m
Storage altitude	12000 m
Rated voltage	AC 100-120 V / 220-240 V (Auto selection)
Rated frequency	50/60 Hz
Rated power	35 W
Fuse	1 A, 250 V, 5 x 20 mm, Slow

Safety	IEC 61010-1: overvoltage category II, pollution degree 2
Electromagnetic Compatibility (EMC)	
International	IEC 61326-1, Industrial Electromagnetic Environment; IEC 61326-2-2, CISPR 11: Group 1, Class A
Group 1: Equipment has intentionally generated and/or uses conductively-coupled radio frequency energy that is necessary for the internal function of the equipment itself. Class A: Equipment is suitable for use in all establishments other than domestic and those directly connected to a low-voltage power supply network that supplies buildings used for domestic purposes. There may be potential difficulties in ensuring electromagnetic compatibility in other environments due to conducted and radiated disturbances. Caution: This equipment is not intended for use in residential environments and may not provide adequate protection to radio reception in such environments. Emissions that exceed the levels required by CISPR 11 can occur when the equipment is connected to a test object.	
Korea (KCC)	Class A Equipment (Industrial Broadcasting & Communication Equipment)
Class A: Equipment meets requirements for industrial electromagnetic wave equipment and the seller or user should take notice of it. This equipment is intended for use in business environments and not to be used in homes.	
Warranty	
BT5300 Series	3 years
SW1080	3 years
SW9010	1 year
	Note: Relays, fuses and connectors are not covered by warranty.

Appendix

Appendix 1. AC Four-terminal Method

The instrument uses the AC four-terminal method. Generally, when measuring small resistances, the four-wire resistance measurement method should be used as much as possible. This is because when measuring resistance using two-wire method, the resistance of test leads and contact resistance will introduce additional errors, which often have a greater influence when measuring a small resistance. By using four-wire method, the current excitation loop and measurement loop for voltage drop on the resistor are separated, the measured voltage is not affected by the voltage drop in the current loop and is the real voltage across the resistor, so the error due to test leads and contact resistances is eliminated. And the GUARD terminals should be connected to the protective shield to reduce the error caused by interference and leakage.

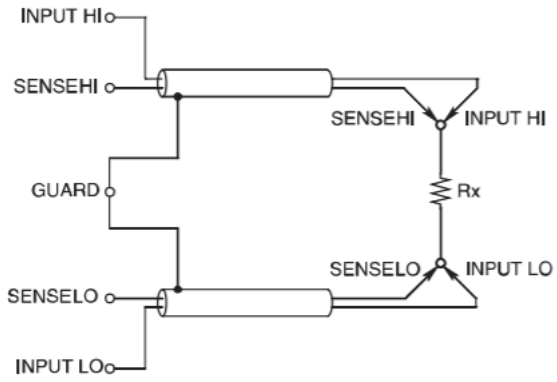


Figure 49. Principle of the AC four-terminal method

When the Instrument measures the internal resistance of a battery, it will inject an AC current, I_input, from the SOURCE terminals on the front panel to the battery under test. The voltage drop, V_sense, due to the impedance of the battery is measured on the SENSE terminals, almost no current flows through the lead resistances and contact resistances since the SENSE terminals are connected to the high internal impedance of the Instrument. As a result, the voltage drop across the lead resistances and contact resistances can be eliminated, making it negligible. According to the synchronized related algorithm, the internal impedance of the battery is separated into resistance and reactance, and only the resistive component is displayed.

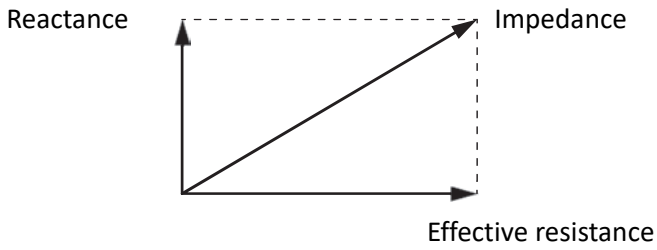


Figure 50. Impedance diagram

If the lead resistance, the contact resistance between the battery and leads, or the contact resistance between the leads and the Instrument is too large, the Instrument can no longer inject normal test current, resulting in an abnormal measurement status indicated by "- - - - -".

Appendix 2. Precautions for Making Custom Test Cables

Making Custom Test Leads for Multiplexer cards

Multiplexer Cards use 68-pin D connectors to connect batteries to be test. For the pin definition of the connectors, see the section *Multiplexer cards*. Test leads connected to a Multiplexer Card include connectors, housings and wires.

The model of the connectors on Multiplexer Cards is TE 5787082-7. The connectors, housings and wire with the matched specifications can be used. Some of the recommended wiring combinations are shown in Table 24.

Table 24. Combinations of connectors, housings, and wires

Connector	Housing	Wires
TE 1-5750913-7	TE 5786152-3 (Screw fixed)	3M 3644B/68 (Shield, twisted pair, 28AWG)
TE 5749621-7	TE 5749195-2 (Snap fixed)	3M 3659/64 (Shield, 28AWG)
TE 5749111-6	None	3M 1700/34 (Twisted, 28AWG)
TE 5786090-7	TE 787032-7 (Snap fixed) or none	3M 3756/68 (30AWG)

The housings used for connectors have screw fixed, snap fixed, and not any fixture. For screw fixing method, 2-56 screws are used to lock to the connector, which is not easy to fall off during handling; For snap fixing method, it is automatically locked when plugged in, and can be unlocked and pulled out by pressing the side button, which can realize faster plugging and unplugging.

Shielded wires can improve the anti-electric field interference ability of the Instrument; the twisted-pair wire can improve the anti-magnetic field interference ability of the Instrument and reduce the effects of eddy current generated by surrounding conductors. It is recommended to use at least 26 to 28 AWG wires to measure the resistance within 3 mΩ. 30 AWG wires are lighter, but may reduce the load capacity of the Battery Tester.

The connection to the battery can be simplified by making or purchasing terminal blocks (such as ADLINK's DIN-68S-01): connect the multiplexer card to the terminal block close to the battery through a cable with a connector, and then connected from the header on the terminal block to the battery. At the battery end, the cable will be separated and connected to the batter under test, and the formed loop will introduce eddy current error. To optimize the wiring here, please refer to the section *Appendix 3. Effect of Eddy Currents and Suggested Solution*.

Configuring Battery Probe Tips

The BT5300 Battery Tester uses 4-wire method to measure internal resistance of batteries. To measure, connect the SOURCE HI and SENSE HI to the positive electrode of the battery, connect the SOURCE LO and SENSE LO to the negative electrode of the battery. As shown in *Figure 51*, two concentric probe tips can be connected together, or to connect using for separate probe tips.

The SOURCE and SENSE test points of the concentric tips are at the same position, the measured internal resistance is the resistance between the positive and negative electrodes' test point, that is, the resistances of battery tabs are included.

For separate tips, the SOURCE and SENSE test points are at different positions, measured internal resistance is closer to the internal resistance of the battery, and measurement result is usually smaller than that of the concentric tips. The further the distance of two test points, the smaller the effect of the resistance of battery tabs.

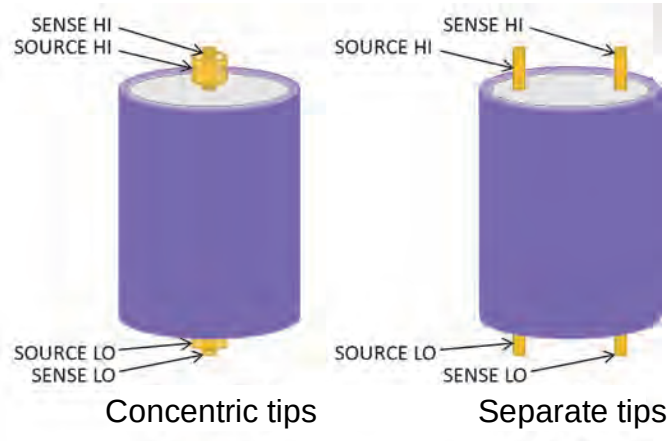


Figure 51. Connection between battery probe tips and the cell

Appendix 3. Effect of Eddy Currents and Suggested Solution

Effect of Eddy Currents

To measure the internal resistance of the battery, the SOURCE terminals output a AC current (about 1 kHz) across the battery, this current flows the internal resistance of the battery, resulting in a voltage with the same phase as the AC current, and this voltage is acquired by the SENSE terminals; then the internal resistance of the battery can be calculated based on the proportion and phase relations between the voltage acquired by SENSE terminals and the current output by SOURCE terminals.

When current flows through SOURCE wires, an alternating magnetic field is generated; this alternating magnetic field generates an induced voltage on the nearby SENSE wires. Ideally, there is no loss in the alternating magnetic field, and the voltage induced by the magnetic field is 90° out of phase with the alternating current. The battery tester can detect the phase of the measured voltage, and allows the induced voltage has no effect on the measurement of the battery's internal resistance.

In actual measurement, if there is a conductive object around the wire, the alternating magnetic field generates an eddy current in the conductive object. This eddy current has energy loss, which shifts the phase of the magnetic field induced voltage, so that the component with the same phase with the current occurs in the SENSE voltage. This in-phase components are superimposed on the voltage generated by the internal resistance, causing error in measurements.

Suggested Scheme: Separate the SENSE and SOURCE cables

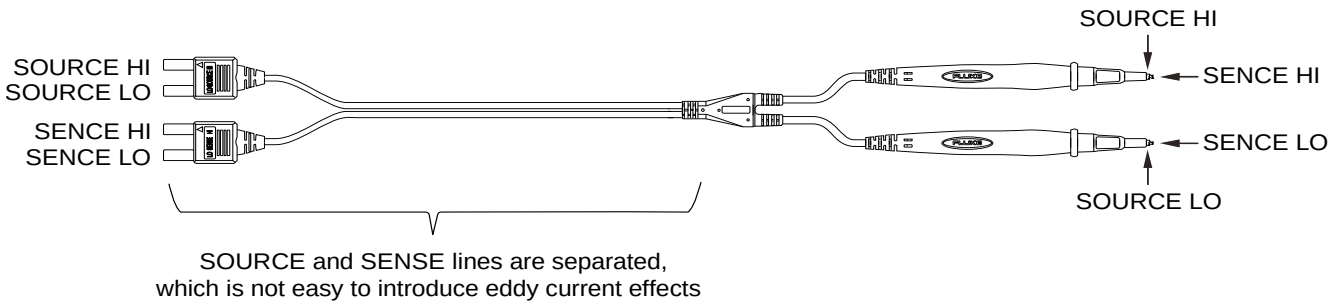


Figure 52. BTL310 test lead

In the design of the Fluke test lead, the SENSE and SOUCE lines connected to the Instrument are separated. This design ensures that most area of the test lead are hardly affected by eddy currents and ensure the stability of the data during manual testing.

Suggested Scheme: Use Twisted Pair

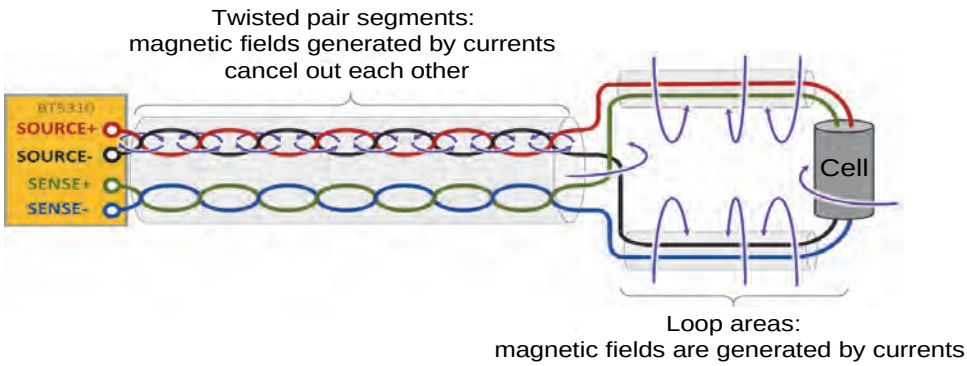


Figure 53. Schematic diagram of twisted pair test

To reduce the error due to the eddy current, we recommended to use twisted pair for SOURCE and SENSE, respectively, as shown in *Figure 53*. In the twisted pair segment, the magnetic field generated by the current of the SOURCE wires cancels each other, and the induced voltage generated by the SENSE wires in the alternating magnetic field also cancels each other, minimizing the electromagnetic induction from SOURCE to SENSE.

However, at the position close to the battery, it is inevitable that a loop area is surrounded by the SOURCE and SENSE wire respectively, and the overlapping area of loops has obvious electromagnetic induction. If there are conductors near this area, eddy currents will be easily generated and errors will be introduced, as shown in *Figure 54*.

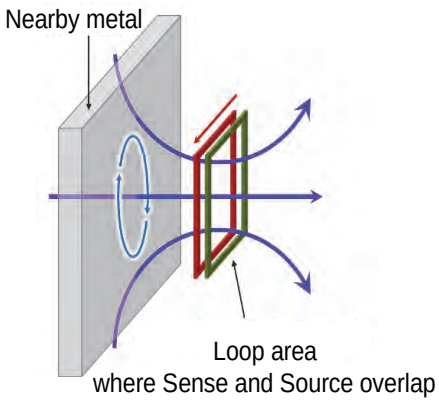


Figure 54. Effect of eddy current on ACR measurement

Suggested Optimization Scheme: Reduce the Overlap of Loops

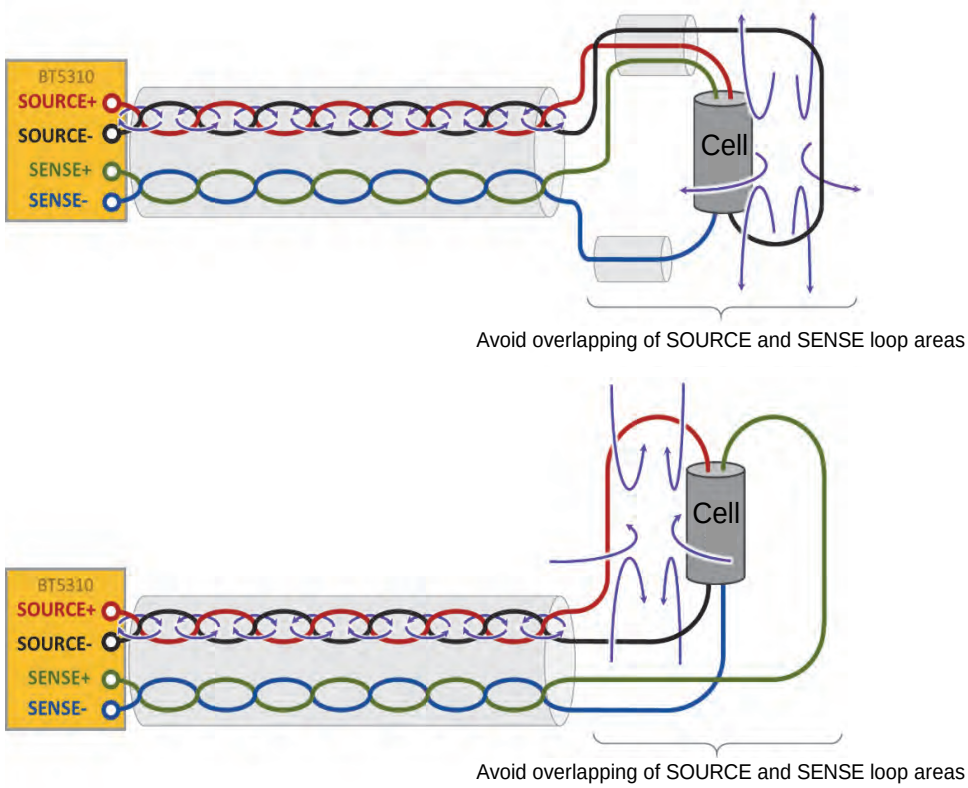


Figure 55. Reducing the effect of eddy current by reducing the overlap area of loops

The loop wiring of the SOURCE and SENSE wire is designed to avoid overlap as much as possible, which can reduce the effect of eddy current.

Suggested Optimization Scheme: Use Magnetic Field Shielding Materials

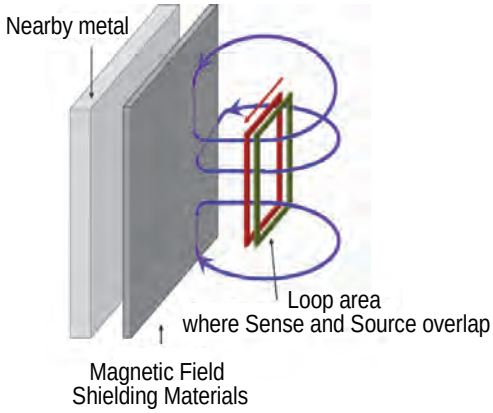


Figure 56. Reducing the effect of eddy current by reducing the overlap area of loops

Placing a magnetic field shielding material between the loop area and the conductor can also reduce the effect of eddy currents. As shown in *Figure 56*, the magnetic shielding material should be a material with high magnetic permeability and not easy to conduct electricity. The shielding material can restrain the magnetic field inside it, and the magnetic field on the nearby conductor metal is obviously weakened; and because the magnetic shielding material is not conductive, it is not easy to generate eddy currents inside it.

Appendix 4. Zero Adjustment

Zero adjustment is a function which adjusts the zero point by deducting the residual value obtained during 0 Ω measurement. For this reason, zero adjustment must be performed when connection is made to 0 Ω.

However, connecting a sample with zero resistance is difficult and therefore is not practical. In this respect, when performing the actual zero adjustment, create a pseudo connection to 0 Ω and then adjust the zero point.

Principle of Zero Adjustment

Creating a pseudo connection to 0

If an ideal 0 Ω connection is made, the voltage between SENSE-HI and SENSEL-LO becomes 0 V according to the Ohm's Law of $V = I \times R$. In other words, if you set the voltage between SENSE-HI and SENSE-LO to 0 V, this gives you the same state of 0 Ω connection.

Performing Zero Adjustment on the Instrument

The instrument uses a measurement fault detection function to monitor the state of connection between the four measurement terminals. For this reason, to perform zero adjustment, you need to make connections between the terminals appropriately, as shown in *Figure 57*.

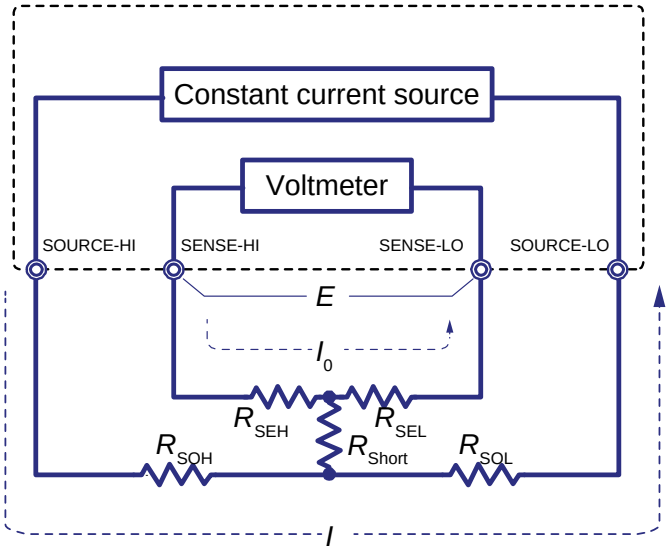


Figure 57. Pseudo connection to 0 Ω

In *Figure 57*, short SENSE-HI and SENSE-LO to set the voltage between SENSE-HI and SENSE-LO to 0 V. Use R_{SEH} and R_{SEL} to represent cable resistances respectively, the SENSE terminal voltage, V, can be expressed as

$$V = I_0 \times (R_{SEH} + R_{SEL})$$

Because the cable resistances, R_{SEH} and R_{SEL}, are usually less than 10 Ω or lower, land SENSE-HI and SENSE-LO are voltage measurement terminals with high input impedance, almost no current flows. Therefor I_0 = 0. The voltage between SENSE-HI and SENSE-LO is almost 0 V.

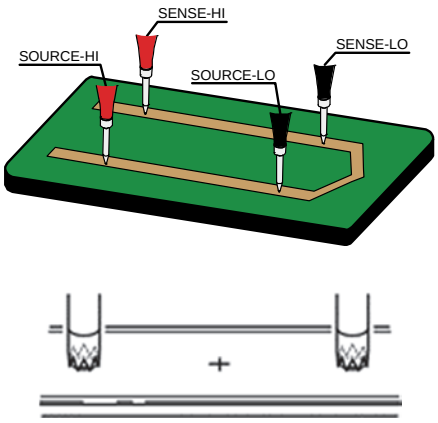
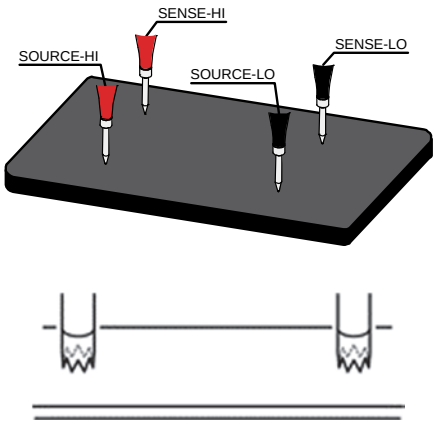
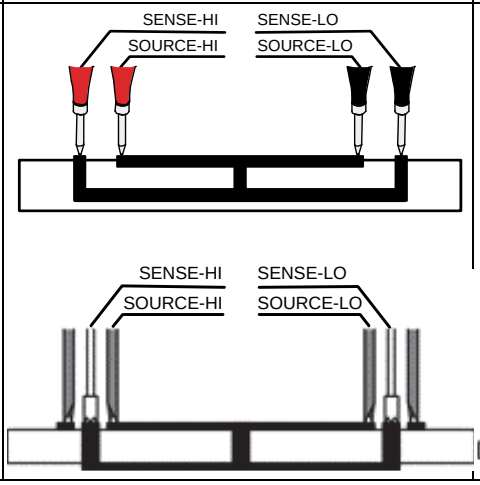
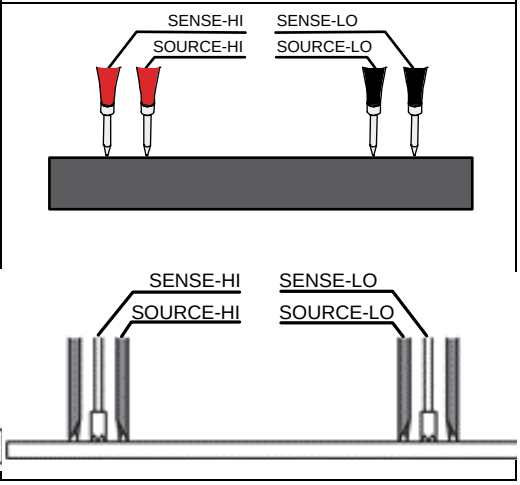
Furthermore, measurement current *I* flowing out from SOURCE-HI will go to SOURCE-LO but not to the cable of SENSE-HI or SENSE-LO. This enables the voltage between SENSE-HI and SENSE-LO to be kept accurately at 0 V, and appropriate zero adjustment becomes possible.

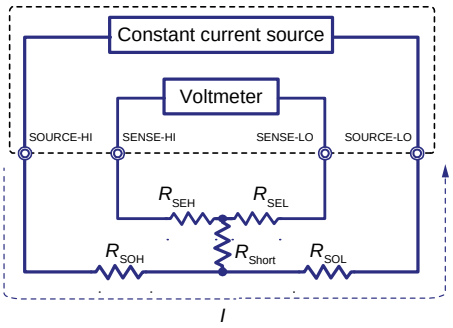
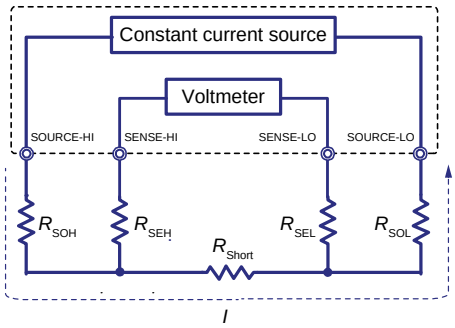
Zeroing Using a Zero-adjust Board

To perform zero adjustment using crown tips or similar PIN TYPE LEADs, a dedicated zero-adjust board is needed, and you cannot use a metal board or similar object to replace the zero-adjust board.

Table 25 shows cross sectional diagrams and equivalent circuits of the two connection methods: connecting test leads to zero adjustment board and connecting that to a metal board or similar object. Connection using the zero-adjust board results in 0 V between SENSE-HI and SENSE-LO; However, for the connection using a metal board or similar object, the voltage between SENSE-HI and SENSE-LO is not 0 V.

Table 25. Test leads connection methods in zero adjustment

	Using the zero-adjust board	Using a metal board or similar object
Connection method		
Tip of lead		

	Using the zero-adjust board	Using a metal board or similar object
Equivalent circuit	 (a)	 (b)
Resistance between SENSE-HI and SENSE-LO	$R_{SEH} + R_{SEL}$	$R_{SEH} + R_{Short} + R_{SEL}$
Path of measurement current *I*	$R_{SOH} \rightarrow R_{SOL}$	$R_{SOH} \rightarrow R_{Short} \rightarrow R_{SOL}$
Voltage between SENSE-HI and SENSE-LO	0	$I \times R_{Short}$
As connection for zero adjustment	Correct	Wrong

Zeroing Using Custom Zero-adjust Board, Probes or Clip Type Leads

Table 25 shows the correct and wrong connection methods for zero adjustment. For a measurement system consists of custom zero-adjust board, probes, or clip type leads, please refer to *Table 25* for the correct connection method.

Appendix 5. Scan Mode to Improve Test Efficiency

The test efficiency of OCV test benches is getting higher and higher

When the battery tester is integrated in a OCV test bench, it usually cooperates with a channel switching circuit and is controlled by a PC to switch and measure multiple channels, so that a battery tester can complete the voltage and internal resistance measurement of tens fo hundreds of cells.

With the increasing efficiency requirements of cell production lines, traditional OCV test benches cannot meet the efficiency requirements of production lines. Improving the test efficiency by adding OCV test benches will bring additional cost. Adding battery testers to the same OCV system will bring the problem of mutual interference between instruments.

The Fluke Battery Tester has built-in Multiplexer Cards, through a unique scan mode, it can not only ensure the high stability of the test results, but also maximize the test efficiency.

Comparison of Three Test Methods of OCV Test Bench

In traditional OCV test benches, there are two main test methods:

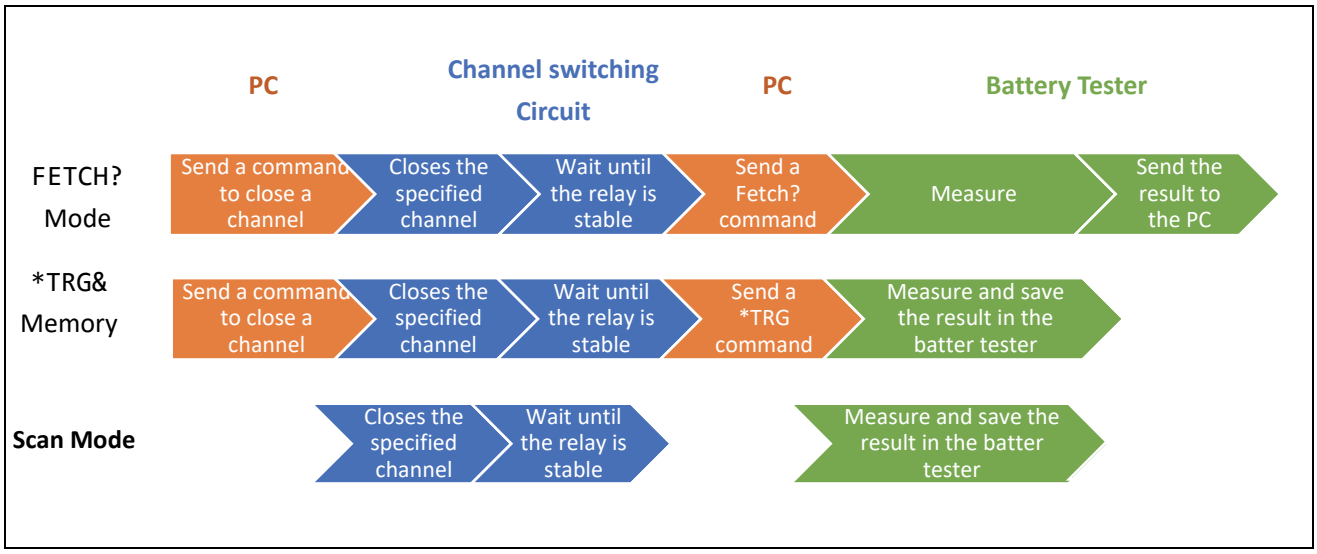
- Measure every channel by using `FETCH?` command and send every measurement result to the PC separately. It takes about 600 ms to 1s to complete the measurement of one channel.
- Measure every channel and save the measurement in the memory of the instrument using `*TRG` command and the Memory function of the instrument. Different from the first method above, this method will not sent the result separately to the PC after each measurement, but will upload all results to the PC after all measurements are completed. It takes about 350 ms to complete the measurement of one channel.

The Fluke Battery Tester provides the scan mode, which can maximize the test efficiency.

- Scan mode: Send a test sequence to the Instrument at one time. And the Instrument automatically measure, and switch channels based on the test sequence during the testing. After all the test are completed, all data will be uploaded to the PC at one time. It takes only 100 ms to complete the measurement of one channel.

The following table lists the process comparison of completing a channel switching and testing in the three modes.

Table 26. Comparison of channel switching and test process



As can be seen from the table, the characteristics of the Scan Mode are:

- Only three steps are needed, which saves the communication time between the PC and channel switching circuit, the battery tester.
- The channel switching circuit (i.e., SW9010 Multiplexer Card) and the battery tester are one instrument, and the working time between them is optimized, so the “wait until the relay is stable” time is much less than the other two methods.

Example Commands for Scan Mode

Table 27 Lists example commands for scan mode: the voltage and internal resistance measurements of 256 cells are completed by sending command one time.

Table 27. Example command for Scan Mode

`*RST`	Reset the Instrument
`*CLS`	Set the registers to 0
`RESistance:RANGe 0.3`	Set resistance measurement range. The Scan Mode is not supported in the resistance auto-range
`SAMPle:RATE EXFast`	Set the sampling rate to EX-Fast
`SWITch:MODule EXTernal`	Configure the Instrument to use external module
`TRIGger:SOURce IMMediate`	Set the trigger source to be internal
`ROUTe:SCAN (@101:832)`	Configure scanning channel: slot 1 to 8, channel 01 to 32 on each slot, total 256 channels
`FUNCtion RVOLtage`	Set the test function to Voltage + Internal Resistance

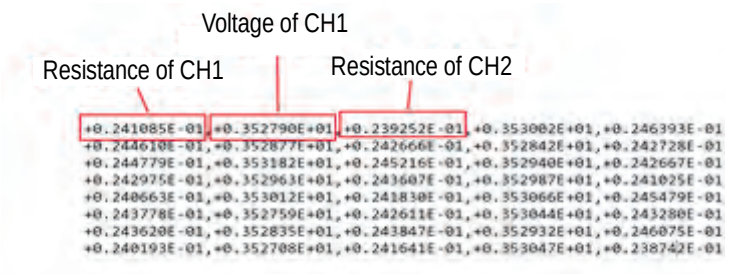
`INITiate:CONTinuous OFF`	Disable continuous measurement
`INITiate`	Start scanning
`STATus:OPERation?`	Query scan state
`FETCh?`	Query readings, the following is the returned results. 

Table 28 lists the typical values of the time to complete the voltage and internal resistance measurement of 256 channels at different sampling rate, that is, the time the PC takes from sending `INITiate` to obtaining all readings by sending `FETCH?`.

Table 28. Typical time for voltage and internal resistance measurement

Sampling speed	EX-FAST	FAST	MEDIUM	SLOW
Measurement time (typical)	<25 s	<30 s	<60 s	<90 s

Appendix 6. Use BT5300 to Measure Internal Resistance, Open-Voltage, and Enclosure Potential

With the increasing requirements for cell testing, in addition to measure the internal resistance (AC-IR) and open circuit voltage (OCV) of the cell, it is also necessary to test the enclosure potential. In a typical OCV test bench, there are up to three instruments to complete the test:

- Battery tester: internal resistance measurement
- 7.5-digit DMM: open-circuit voltage measurement
- 6.5-digit DMM: enclosure potential measurement

The BT5300 Series integrates a 6.5- or 7.5-digit voltmeter with high-z (>10 GΩ) inputs, a single instrument can complete these tests. The following takes the BT5321 as an example to introduce how to complete these tests through the input terminals on the front panel or built-in Multiplexer Card(s).

Measuring with Front Panel Input Terminals

Figure 58. Measuring ACR, DCV and enclosure potential - front panel

Connect the front panel input terminals of the BT5321 to the switching circuit, and switch between different measurement functions through the relays in the switching circuit. The following is a schematic diagram of the switching circuit.

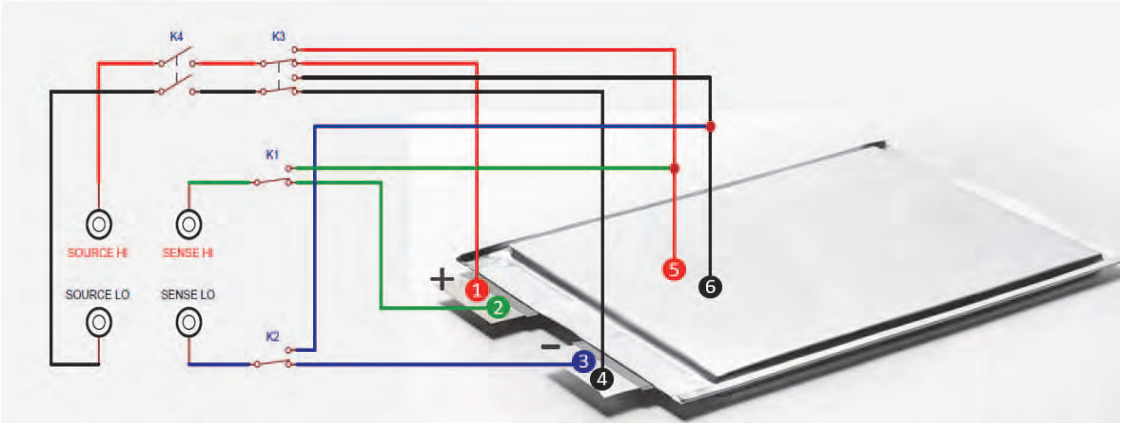


Figure 59. Schematic diagram of switching circuit - front panel

In *Figure 59*, SOURCE HI, SOURCE LO, SENSE HI and SENSE LO correspond to the front panel input terminals of BT5321; K1, K2, K3 and K4 are relays, numbers 1~6 represent probe tips, and line segments represent connected test cables.

1. For different test functions, it is necessary to set the relays to the corresponding state first:

Test function	K1 state	K2 state	K3 state	K4 state
ACR+DCV	Down	Down	Down	Close
Enclosure potential contact check	Up	Up	Up	Close
Positive to enclosure voltage	Down	Up	Up or down	Open
Negative to enclosure voltage	Up	Down		

2. After the warming up of the BT5321, complete different measurement according to the following instructions.

   1) Initializing instrument settings

Command	Action
`*RST`	Reset the Instrument
`SYSTem:CALibration`	Execute one self-calibration. See the section *Self-Calibraion* for more details.

   2) ACR+DCV measurement function: measure the internal resistance and open-circuit voltage of the cell

Command	Action
`FUNCtion RVOLtage`	Set the function to ACR+DCV measurement.
`RESistance:RANGe 0.003`	Select a appropriate resistance range, such as 3 mΩ. The voltage range does not to be set since there is only one

Command	Action
	voltage measurement range of 10 V.
`RESistance:CURRent:MAX C300`	Set the current range, such as 300 mA. If 300 mA test current cannot complete the test due to the test system, it can be adjusted to 200 mA (`RESistance:CURRent:MAX C200`) or 100 mA (`RESistance:CURRent:MAX C100`). The test current setting is only applied to the 3 mΩ range, and there is no need to set the test current under other ranges. For more details about test current, see the section *Max Measure Current*.
`ADJust?`	Short the four probe tips (1 to 4) connecting positive and negative electrodes of the cell to the zero-adjust board to perform zero adjustment. A returned value of 0 means that the zero adjustment is successful. For more details about zero adjustment, see the section *Zero-Adjustment*. See the section *Appendix 4. Zero Adjustment* for the production of the zero-adjust board.
`CALCulate:AVERage 3`	Set average count and enable average function. Turning on the average function will improve the stability of test results, but it will take longer test time. Users can determine whether to turn on the average function and set appropriate average count based on actual effect.
`CALCulate:AVERage:STATe ON`	
`SAMPle:RATE SLOW`	Set the test speed, such as "**Low**".
`INITiate:CONTinuous OFF`	Disable continuous measurement.
`READ?`	Initiate one measurement, a set of internal resistance (in Ω) and voltage (in V) readings will be obtained.

3) Enclosure potential contact check

Determine whether the two probe tips (5, 6) connected to the cell enclosure are conductive by measuring the resistance, to determine whether they are well connected to the cell enclosure. If this function test is not required, the connecting wires of probe tips 5 and 6 can be combined and connected to one probe, for example probe tip 5.

Command	Action
`*RST`	Reset the Instrument.
`CALCulate:AVERage:STATe OFF`	Disable the average function.
`FUNCtion RESistance`	Set the function to ACR measurement.
`RESistance:RANGe 10`	Set the resistance measurement range to 10 Ω.
`SAMPle:RATE EXFAST`	Set an appropriate test speed, in this case it is Ex-Fast.
`INITiate:CONTinuous OFF`	Disable continuous measurement.
`READ?`	Initiate one measurement and return a reading of internal resistance (in Ω). If the measured value is a reasonable value, such as <15 Ω, it means that the probe tips 5 and 6 are conductive.

4) Positive to enclosure or negative to enclosure voltage:

Measure the voltage between the probe tips 2 and 6, or voltage between the probe tips 3 and 5.

Command	Action
`*RST`	Reset the Instrument.
`FUNCtion VOLTage`	Set the function to DCV measurement.
`SAMPle:RATE FAST`	Set an appropriate test speed, such as "**Fast**".
`INPut:IMPedance:HIGH ON`	Set the input impedance to High-Z (>10 GΩ) (For more details, see the section *Input Impedance*.)
`INITiate:CONTinuous OFF`	Disable continuous measurement.
`READ?`	Initiate one measurement to obtain a voltage reading (in V). Note: If the voltage needs to be measured quickly for many times, the MEMORY function can be used. For more details about MEMORY function, see the section *Memory Programming Examples*.

Measuring Through Rear Panel Multiplexer Cards

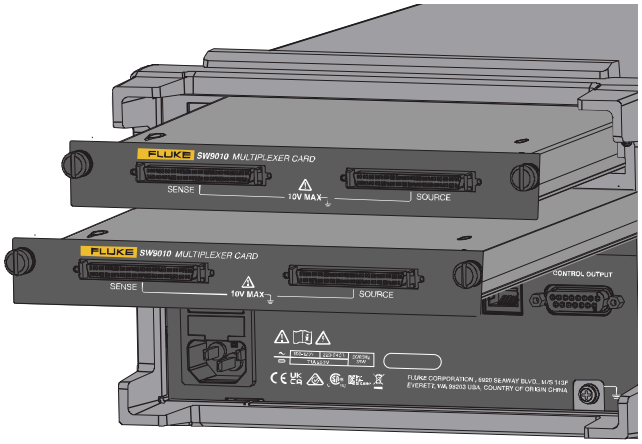


Figure 60. Measure ACR, DCV and Enclosure Potential - Rear Panel

Up to 2 SW9010 cards can be installed in the BT5321. A single SW9010 supports 32 channels, and each channel can be configured to measure ACR+DCV or enclosure potential. The following takes 32 cells as an example, the SW9010 in the upper slot (slot 1) is set to measure ACR+DCV, and the SW9010 in the lower slot (slot 2) is set to measure enclosure potential.

1. Connecting the cell

   In the following example, channel 1 of the SW9010 in slot 1 and channel 1 of the SW9010 in slot 2 are connected to the same cell at the same time. The line segments represent connected test cables, and number 1 to 6 represent probe tips.

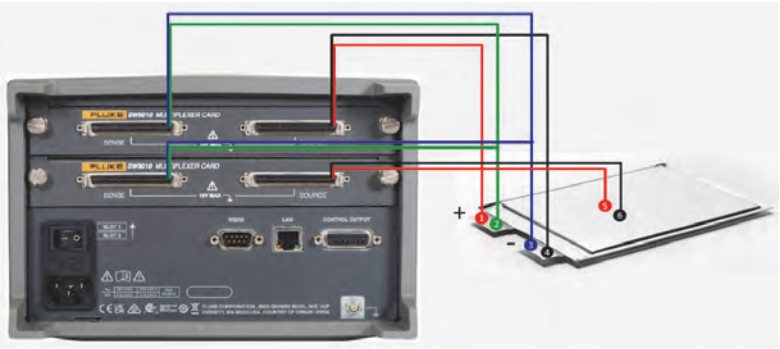


Figure 61. Schematic diagram of switching circuit - rear panel

See the section *Connect the Cell* for more details about wiring method.

Remote Control Commands

The following describes how to test 32 cells by using Scan Mode. See the section *Appendix 5. Scan Mode to Improve Test Efficiency* for more details about Scan Mode.

1) Initializing instrument settings

After the warming up of the Instrument, execute the following instructions:

Command	Action
`*RST`	Reset the Instrument.
`*CLS`	Clear registers.
`SYSTem:CALibration`	Execute one self-calibration.
`SWITch:MODule INTernal`	Configure the Instrument to use internal Multiplexer Cards.

2) ACR+DCV measurement

Complete the ACR+DCV measurements of 32 cells using Scan Mode.

Command	Action
`FUNCtion RVOLtage`	Set the test function to ACR+DCV.
`RESistance:RANGe 0.003`	Select a appropriate resistance range, such as 3 mΩ.
`RESistance:CURRent:MAX C300`	Set the current range, such as 300 mA. If 300 mA test current cannot complete the test due to the test system, it can be adjusted to 200 mA (`RESistance:CURRent:MAX C200`) or 100 mA (`RESistance:CURRent:MAX C100`). The test current setting is only applied to the 3 mΩ range, and there is no need to set the test current under other ranges.
`CALCulate:AVERage 3`	Set average count and enable average function. This command is optional. Turning on the average function will improve the stability of test results, but it will take longer test time. Users can determine whether to turn on the average function and set appropriate average count based on actual effect.
`CALCulate:AVERage:STATe ON`	

Command	Action
SAMPle:RATE SLOW	Set the test speed, such as "**Low**".
SWITch:MODule:STATe? INTernal	Query the state of the internal Multiplexer Cards. In this case, return "1, 1" if the states of both SW9010s in slot 1 and slot 2 are normal.
ROUTe:SCAN (@101:132)	Configure scanning channel: from channel 01 to channel 32 in slot 1.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Start scanning.
STATus:OPERation?	Query the Operation Status register until the Bit 4 (Sweep Done) and Bit 8 (Scan Done) is set.
FETCh?	After querying that the corresponding bit in the previous step is set or waiting until all channel switching and measurement are completed, send this command to obtain 32 sets of internal resistance (in Ω) and voltage (in V) readings corresponding to 32 channels.

3) Enclosure potential contact check

Determine whether the two probe tips (5, 6) connected to the cell enclosure are conductive by measuring the resistance, to determine whether they are well connected to the cell enclosure. If this function test is not required, the connecting wires of probe tips 5 and 6 can be combined and connected to one probe, for example probe tip 5.

Command	Action
*RST	Reset the Instrument.
*CLS	Clear registers.
SWITch:MODule INTernal	Configure the Instrument to use internal Multiplexer Cards.
FUNCtion EPCCheck	Set the instrument function to enclosure potential contact check.
RESistance:RANGe 10	Set the resistance measurement range to 10 Ω.
SAMPle:RATE EXFAST	Set an appropriate test speed, in this case it is Ex-Fast.
CALCulate:AVERage:STATe OFF	Disable the average function. The purpose of contact detection is only to determine whether the two probe tips are connected well, so the averaging function is not needed to improve the stability of the data.
SWITch:MODule:STATe? INTernal	Query the state of the internal Multiplexer Cards. In this case, return "1, 1" if the states of both SW9010s in slot 1 and slot 2 are normal.
ROUTe:SCAN (@201:232)	Configure scanning channel: from channel 01 to channel 32 in slot 2.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Start scanning.

Command	Action
STATus:OPERation?	Query the Operation Status register until the Bit 4 (Sweep Done) and Bit 8 (Scan Done) is set.
FETCh?	After querying that the corresponding bit in the previous step is set or waiting until all channel switching and measurement are completed, send this command to obtain internal resistance readings (in Ω) of 32 channels. If a reading is reasonable, such as <15 Ω, it means that the probe tips (5 and 6) corresponding to the channel are conductive.

4) Positive to enclosure or negative to enclosure voltage

Measure the voltage between the probe tips 2 and 6, or voltage between the probe tips 3 and 5.

Command	Action
*RST	Reset the Instrument.
*CLS	Clear registers.
SWITch:MODule INTernal	Configure the Instrument to use internal Multiplexer Cards.
FUNCtion PEVOLTAGE (or FUNCtion NEVOLTAGE)	Set the instrument function to positive to enclosure voltage (or negative to enclosure voltage).
INPut:IMPedance:HIGH	Set the input impedance to High Z (>10 Ω).
SAMPle:RATE FAST	Set an appropriate test speed, such as "**Fast**".
SWITch:MODule:STATe? INTernal	Query the state of the internal Multiplexer Cards. In this case, return "1, 1" if the states of both SW9010s in slot 1 and slot 2 are normal.
ROUTe:SCAN (@201:232)	Configure scanning channel: from channel 01 to channel 32 in slot 2.
INITiate:CONTinuous OFF	Disable continuous measurement.
INITiate	Start scanning.
STATus:OPERation?	Query the Operation Status register until the Bit 4 (Sweep Done) and Bit 8 (Scan Done) is set.
FETCh?	After querying that the corresponding bit in the previous step is set or waiting until all channel switching and measurement are completed, send this command to obtain voltage readings (in Ω) of 32 channels.

Appendix 7. Instrument Installation

Introduction

This sheet explains how to use the rack-mount kit (the Kit) to mount the BT5300 Battery Tester (the Product) into a standard 19-inch rack panel.

⚠⚠ WARNING

To prevent possible injury, do not restrict access to the Product power cord, which is the mains disconnecting device. If access to the power cord is inhibited by rack mounting, a properly rated accessible proximate mains disconnecting switch must be provided as part of the installation.

Preparation

Before the Kit is installed, remove six 8-32 screws (①) from the Product.

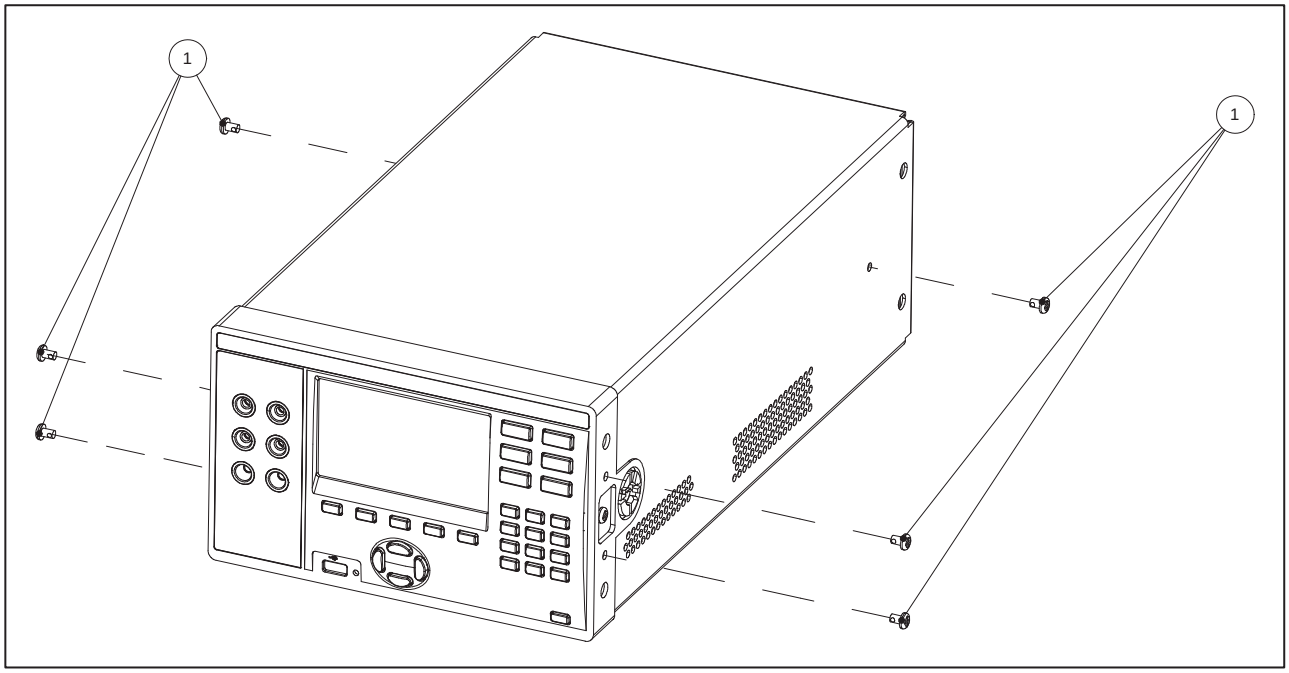


Figure 62. Instrument installation - preparation

Install a Single Rack-Mount Kit

Use the Kit to mount the Product on the left or right side of a standard 19-inch rack.

To mount the Product on the left-side of the rack:

1. Attach one of the rack brackets (②) to the right-front side of the Product with three #8-32 x ½ inch panhead screws (①). Keep the bracket (②) face with the three holes facing toward the front.

2. Attach the other rack bracket (②) to the left-front side of the Product with three #8-32 x ½ inch panhead screws (①).
3. With three M6 panhead hex screws (⑤), and three nuts, fasten the right-side of Rack Faceplate (③) to the left side of rackmount.
4. Install the entire assembly into the rack. From the rear of the rack, align the assembly to the holes in the rack. At the front of the rack, use six M6 panhead hex screws (⑤) and six nuts to fasten the Rack Faceplate (③) and Rack Screw Plate (④) through the rack and Rack Brackets (②).

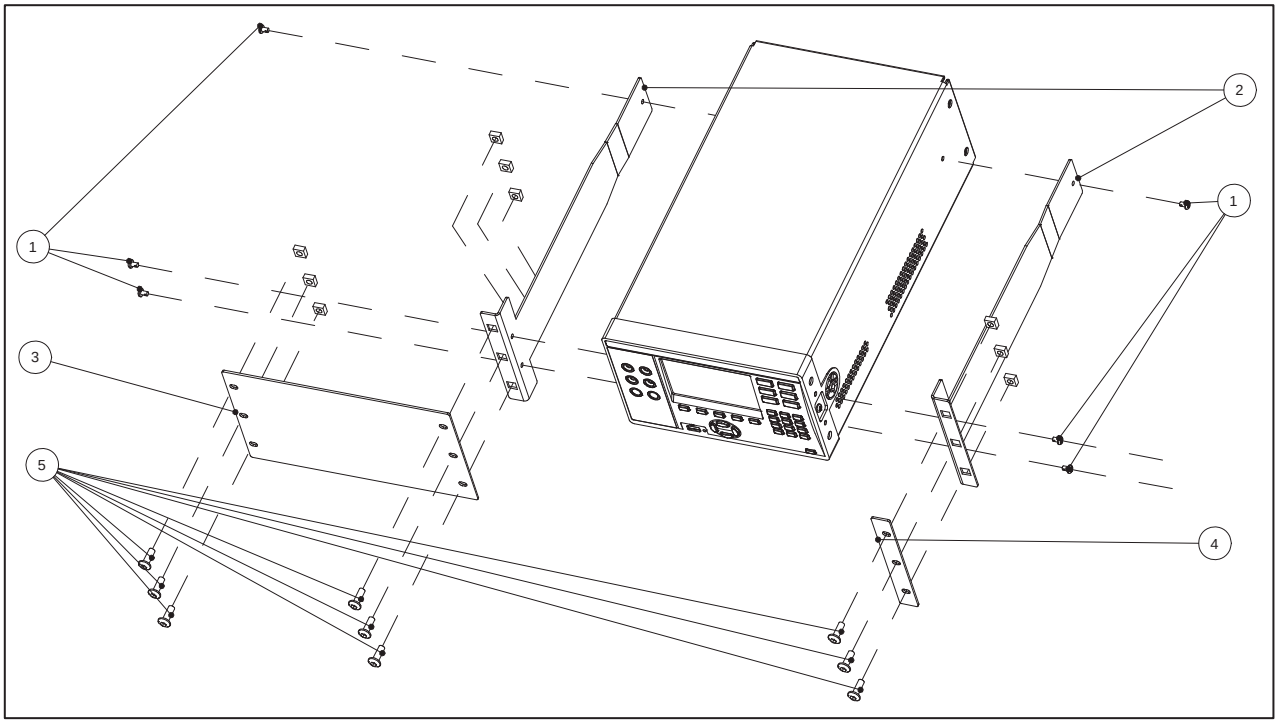


Figure 63. Single rack-mount kit

Install a Dual Rack-Mount Kit

To Install a Dual Rack-Mount Kit:

1. Place both Products side-by-side on a flat surface and use three #8-32 x ½-inch panhead screws (①) to install the Rack Bracket (②) to the outer left and right sides of the Product. Refer to step 1 under Install a Single Rack-Mount Kit.
2. Attach the Inner Rack Bracket (⑥) to the inner right and left sides of both Products with six #8-32 x ½-inch panhead screws (①).
3. Attach the Inner Rack Bracket (⑥) to the inner right and left sides of both Products with six #8-32 x ½-inch panhead screws (①). And insert the two guide pins into the two holes in both sides of the Inner Rack Bracket (⑥).
4. Align the front tabs of the Inner Rack Brackets (⑥) and fasten the Small Rack Screw Plate (⑦) to the front tabs with two #8-32 x ½-inch panhead screws (①).

5. Install the entire assembly from the rear of the rack, aligning the holes of the Rack Bracket (②) to the inside of the rack frame. At the front of the rack, use six M6 panhead hex screws (⑤) and nuts to fasten the Rack Screw Plate (④) through the rack and Rack Brackets (②).

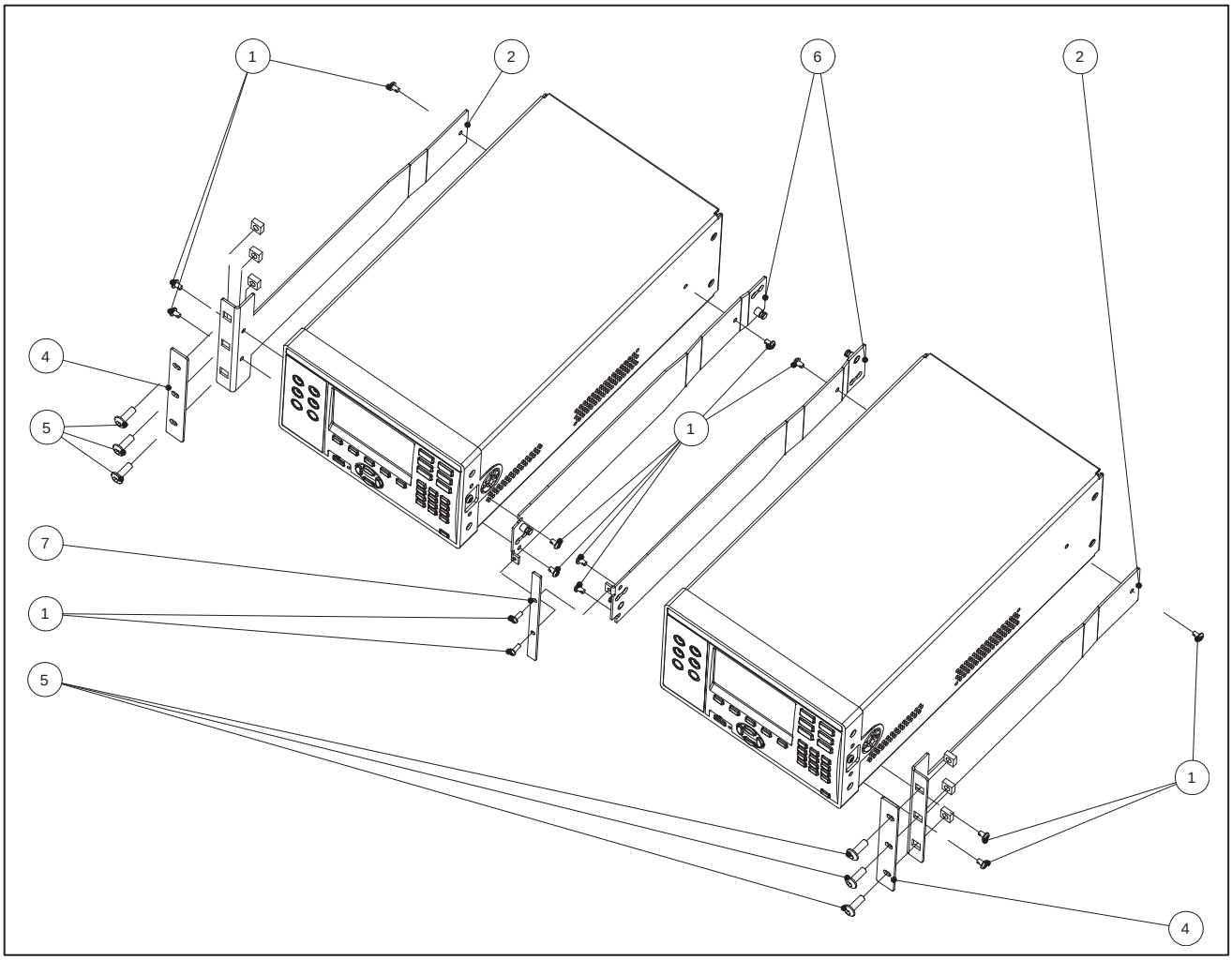


Figure 64. Dual rack mount-kit

Overall Dimensions of the Product

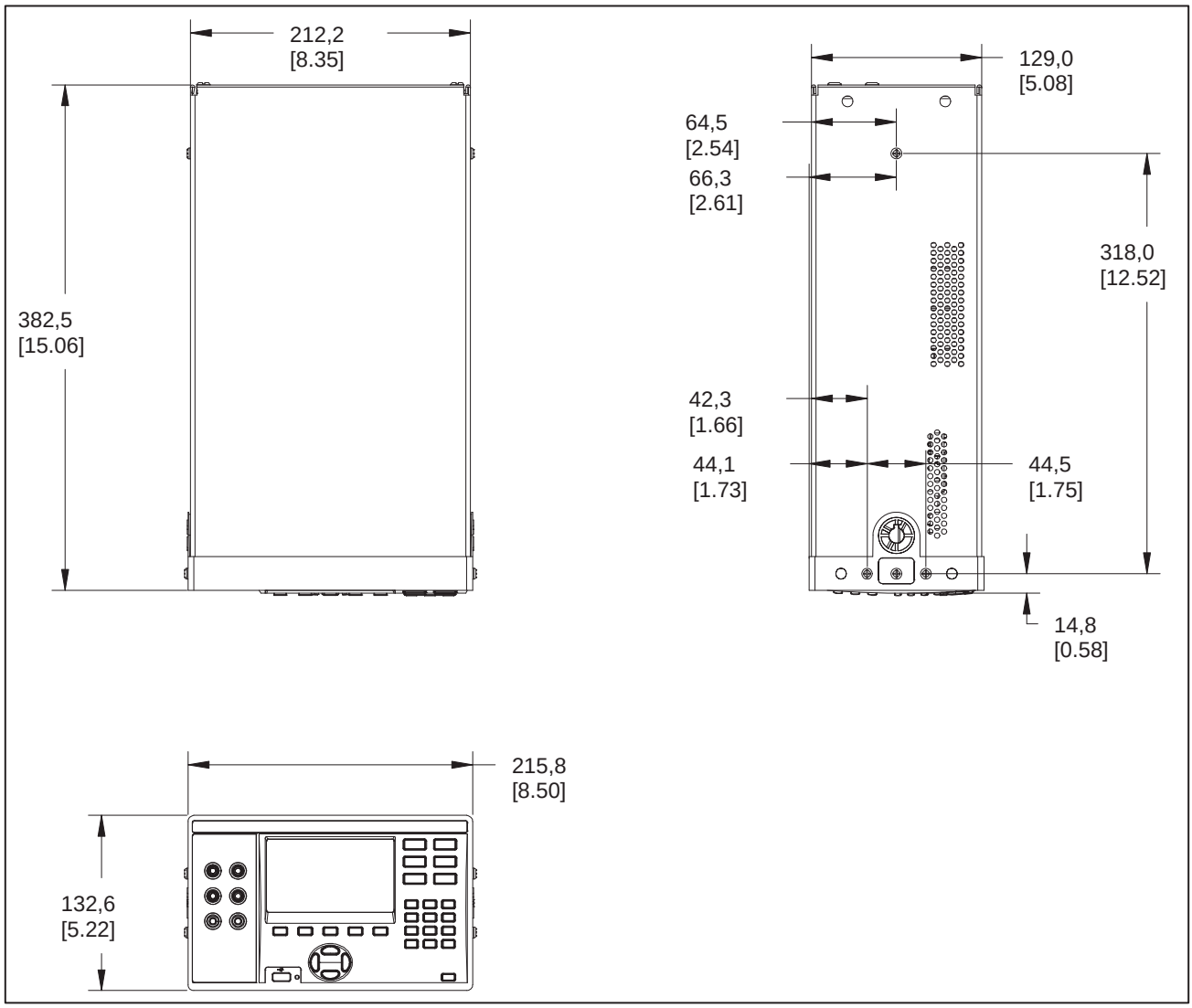


Figure 65. Overall dimensions of the Product

Appendix 8. SW1080 Appearance

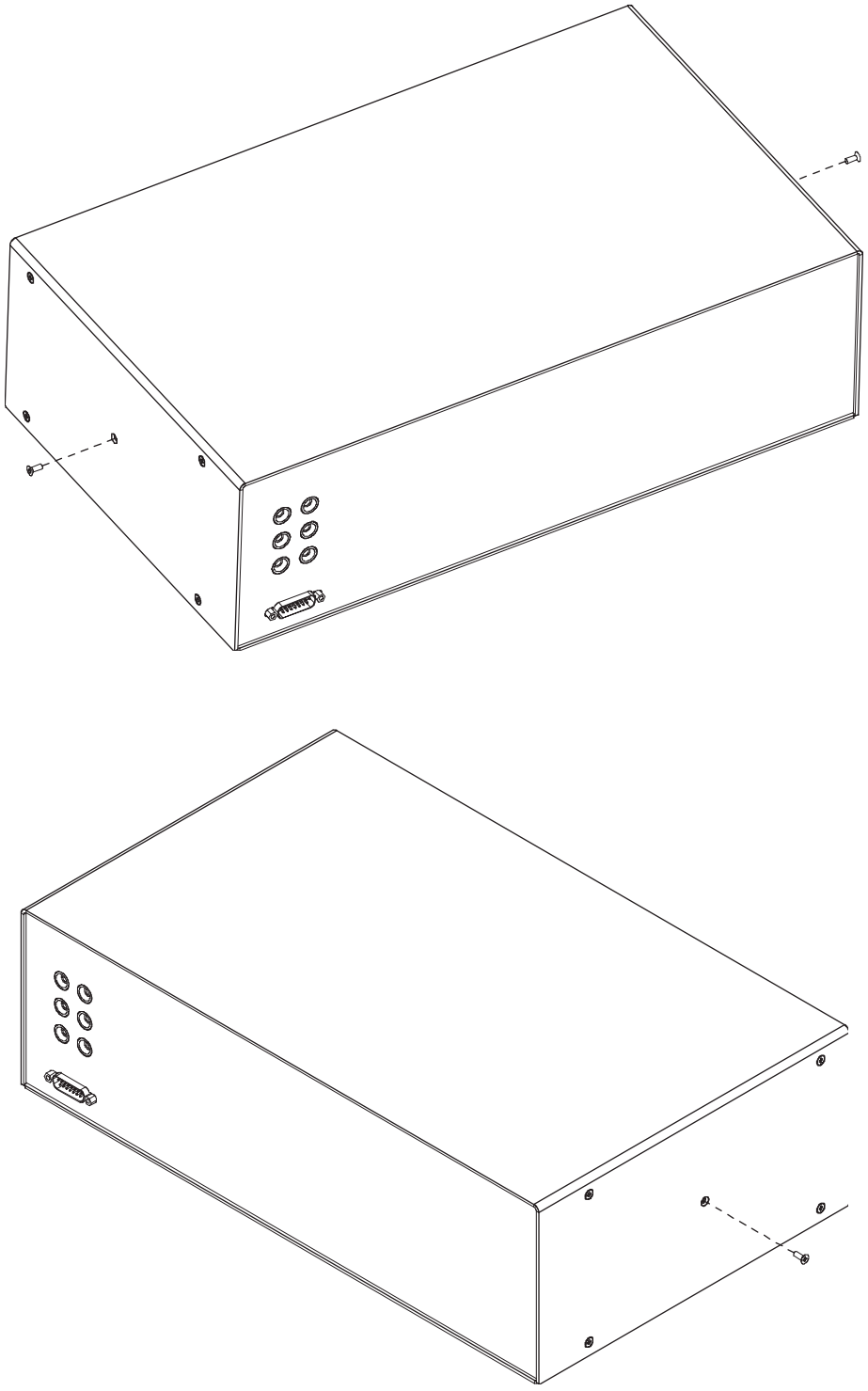


Figure 66. SW1080 appearance