

# Keysight BT2152A Self-Discharge Analyzer

Operating and  
Service Guide

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# Legal and Safety Information

## Legal Notices

## Safety Notices

## Safety Symbols

## Legal Notices

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This product complies with the WEEE Directive 2002/96/EC marketing requirement. The affixed product label (see below) 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 1, this product is classified as "Monitoring and Control instrumentation" product.

Do not dispose in domestic household waste.

To return unwanted products, contact our local Keysight office.



## Safety Symbols

	A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or DEATH. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.
	A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.
	Direct current
	Alternating current
	Frame or chassis terminal
	Standby supply. Unit is not completely disconnected from AC mains when switch is off.
	 Risk of electric shock
	 Refer to accompanying documents
	Earth ground terminal
	The CE mark is a registered trademark of the European Community.
	The ETL mark is a registered trademark of Intertek.
	The RCM mark is a registered trademark of the Spectrum Management Agency of Australia. This signifies compliance with the Australian EMC Framework regulations under the terms of the Radio Communications Act of 1992.
	South Korean Class A EMC Declaration This equipment is Class A suitable for professional use and is for use in electromagnetic environments outside of the home.
	Contains one or more of the 6 hazardous substances above the maximum concentration value (MCV), 40 Year EPUP.
ISM1-A	This text indicates that the instrument is an Industrial Scientific and Medical Group 1 Class A product (CISPER 11, Clause 4).
ICES/NMB-001	This text indicates product compliance with the Canadian Interference- Causing Equipment Standard (ICES-001).

## Safety Notices

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings or instructions elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Keysight Technologies assumes no liability of the customer's failure to comply with the requirements.

**WARNING**

**General**

Do not use this product in any manner not specified by the manufacturer. The protective features of this product may be impaired if it is used in a manner not specified in the operating instructions.

---

**WARNING**

**Environmental Conditions**

Never use the instrument outside of the specified environmental conditions described under **Environmental Conditions**.

---

**WARNING**

**Ground the Instrument**

This product is provided with protective earth terminals. To minimize shock hazard, the instrument must be connected to the AC mains through a grounded power cable, with the ground wire firmly connected to an electrical ground (safety ground) at the power outlet. Any interruption of the protective (grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in injury or death.

---

**WARNING**

**Do Not Operate in an Explosive Atmosphere**

Do not operate the instrument in the presence of flammable gases or fumes.

---

**WARNING**

**Do Not Remove the Instrument Cover**

Only qualified, service-trained personnel who are aware of the hazards involved should remove covers. Always disconnect external power.

---

**WARNING**

**Do Not Modify the Instrument**

Do not install substitute parts or perform any unauthorized modification to the product. Return the product to a Keysight Sales and Service Office for service and repair to ensure that safety features are maintained.

---

**WARNING**

**Fuses**

The instrument contains an internal fuse, which is not customer accessible.

---



**WARNING**

**Cleaning**

To prevent electric shock, always unplug the unit before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not use detergent or chemical solvents. Do not attempt to clean internally.

---

**WARNING**

**In Case of Damage**

Instruments that are not functioning correctly, appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

---



# 1

## Quick Reference

**Welcome**

**Models and Specifications**

**Command Quick Reference**

## Introduction

### What is self-discharge?

Self-discharge of an electrical cell is the loss of charge over time while not connected to any load. Some amount of self-discharge is a normal attribute resulting from chemical reactions taking place within the cell. Additional self-discharge can result from leakage current paths existing within the cell. Particulate contaminants and dendrite growths produce internal “micro-shorts”, creating such leakage current paths. These are not normal attributes and they can lead to catastrophic failure of the cell. For this reason it is a priority to evaluate cells for self-discharge.

Electrically, self-discharge can be modeled as a high-value resistance existing in parallel across the cell. Note that self-discharge current is very difficult to measure in practice. Usually a defective cell can only be detected after days or weeks of aging. This is where the proprietary technology of the Keysight BT2152A Self-Discharge Analyzer provides a superior method of measuring self-discharge over other traditional methods.

### Advantages of the Keysight BT2152A Self-Discharge Analyzer

The Keysight BT2152A Self-Discharge Analyzer uses a proprietary measurement technique to determine the open-circuit discharge of the cell due to its internal parallel resistance. This proprietary direct measurement technique lets you determine the quality of the cell within one to two hours after the cell has been initially charged and rested. This can significantly reduce the test time required to determine the self-discharge characteristic of the cell due to internal parallel resistance. Key test features are as follows:

- The voltage applied to the cell is quickly matched ( $\pm 5 \mu\text{V}$ ) to the actual cell voltage. This minimizes any new charge or discharge and limits any new RC settling to a minimum.
- The voltage applied to the cell is very stable ( $\pm 10 \mu\text{V}_{\text{peak}}$ ) to minimize continuing charge redistribution current noise on the self-discharge current measurement.
- The Measurement System accurately measures low-level self-discharge currents to  $\pm (0.33\% \text{ of reading} + 1 \mu\text{A})$ .

### Contact Keysight Technologies

You can contact Keysight Technologies for warranty, service, or technical support.

Use [www.keysight.com/find/assist](http://www.keysight.com/find/assist) for information on contacting Keysight worldwide, or contact your Keysight Technologies representative.

## Models and Specifications

### Front and Rear Views

### Specifications

### Characteristics

### Self-Discharge Measurement Criteria

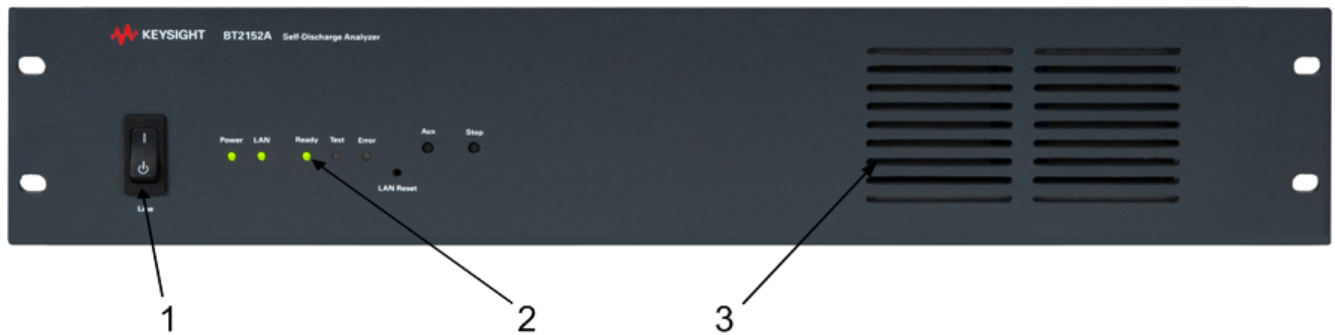
### External Temperature Measurement

### Dimensions and Airflow

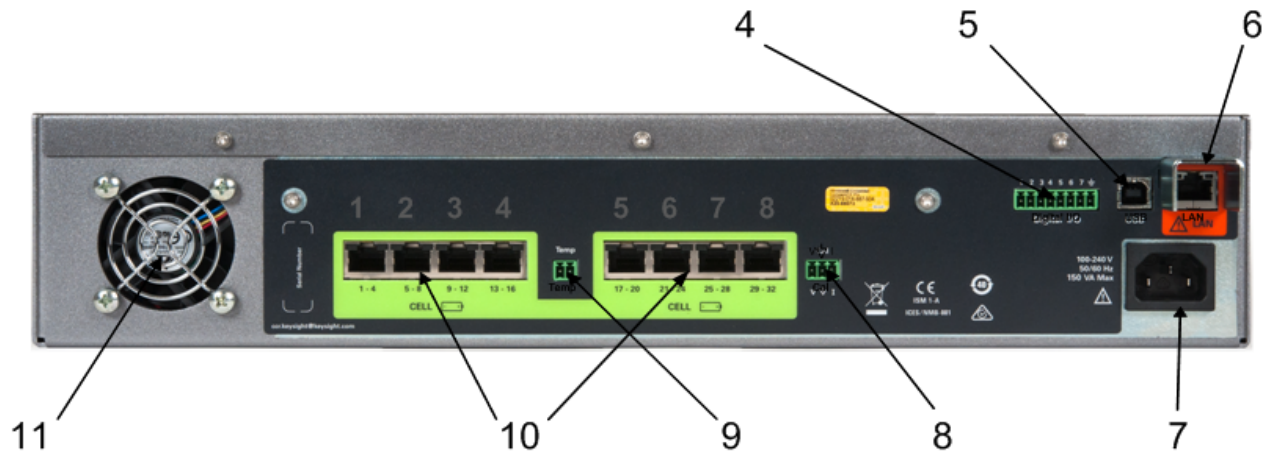
## Models

- Keysight BT2152A - 32 channel Self-Discharge Analyzer

## Front and Rear Views



1. Line switch	Turns the unit on or off
2. Status Indicators and switches	<p><b>Power:</b> Green LED indicates power is on.</p> <p><b>LAN:</b> Green LED indicates the LAN connection is active. Flashing green indicates an LXI identification query is sent. Flashing blue indicates a SCPI command is received. Red indicates a LAN fault.</p> <p><b>Ready:</b> Amber indicates the unit is warming up. A warmup time of 1 hour is required. Green indicates the unit is ready to start the test.</p> <p><b>Test:</b> Flashing blue indicates that cell matching has been initiated. Blue indicates a test is running. Off indicates no test is running. Flashing orange indicates calibration.</p> <p><b>Error:</b> Red indicates an error has occurred. Off indicates protection is cleared.</p> <p><b>LAN reset:</b> This recessed switch performs a software system LAN reset.</p> <p><b>Aux:</b> This switch is reserved for future use.</p> <p><b>Stop:</b> This switch aborts any current measurements and sequences. The unit returns to a state of being ready for initialization.</p>
3. Air Inlet	Air inlet requires a minimum of 6 inch (15 cm) clearance



4. Digital connector	An 8-pin digital IO interface
5. USB	USB interface connector
6. LAN	10/100/1000 Base-T Left LED indicates link speed (Green 1 Gbps, Orange is 100 Mbps, Off is 10 Mbps with activity blinking) Right LED indicates activity
7. Universal AC input	Standard IEC 320 connector
8. Calibration port	Calibration port
9. Temperature sensor	Temperature sensor input (requires an external 10 kΩ thermistor)
10. RJ45 connectors	Eight RJ45 connectors for 32-channel cell connections (4 cell connections are available on each RJ45 connector)
11. Air Outlets <sup>1</sup>	The rear air outlet requires a minimum of 6 inch (15 cm) clearance

## Specifications

Unless otherwise noted, specifications are warranted over the ambient temperature range of 20°C to 30°C after a 1 hour warm-up period.

Parameter	Specification
Number of channels:	Standard 32 channels Optional configurations available in 4- channel increments
Current measurement accuracy: <sup>1</sup>	± (0.33% + 1 μA)
Voltage measurement accuracy:	± (0.05% + 1 mV)

<sup>1</sup> Current measurement accuracy is measured at 1 minute integration.

## Characteristics

Characteristics are not warranted but are descriptions of performance determined either by design or by type testing. Characteristics are typical unless otherwise noted.

Parameter	Characteristic
Voltage measurement and output range:	0.5 V to + 4.5 V
Current measurement range:	± 10 mA
Programmable resistance range:	0.1 Ω to 10 Ω
Initial cell voltage matching	± 5 μV
Voltage sourcing stability (typical) <sup>1,2</sup>	± 10 μV <sub>peak</sub>
Warm-up time after power-on:	1 hour
Environmental conditions:	
Operating environment:	Indoor use, installation category II (for AC input), pollution degree 2
Ambient temperature range: <sup>3</sup>	20°C to 30°C
Relative humidity:	Up to 80% (non-condensing)
Altitude:	Up to 2000 meters
Storage temperature:	-30°C to 70°C
Digital Port	
Max voltage rating:	+16.5 VDC/- 5 VDC between pins
Pins 1 & 2 as FLT:	Maximum low-level output voltage = 0.5 V @ 4 mA Maximum low-level sink current = 4 mA Typical high-level leakage current = 1 mA @ 16.5 VDC
Pins 1-7 as outputs:	Maximum low-level output voltage = 0.5 V @ 4 mA; 1 V @ 50 mA; 1.75 V @ 100 mA Maximum low-level sink current = 100 mA Typical high-level leakage current = 0.8 mA @ 16.5 VDC
Pins 1-7 as inputs:	Maximum low-level input voltage = 0.8 V Minimum high-level input voltage = 2 V Typical low-level current = 2 mA @ 0 V (internal 2.2k pull-up) Typical high-level leakage current = 0.12 mA @ 16.5 VDC
Pin 8:	Pin 8 is common (internally connected to chassis ground)
AC input	
Range:	100-240 VAC
Frequency:	50/60 Hz
VA:	170 VA Max

<sup>1</sup> Output voltage stability is measured over 24 hours at 1 minute integration.

<sup>2</sup> Specification applies at output terminals. Cabling and interconnect errors may degrade this significantly.

<sup>3</sup> Maximum rate-of-change (dT/dt) must be <5°C/hour.

## Self-Discharge Measurement Criteria

To quickly measure the self-discharge behavior of a Lithium ion cell requires characterizing a number of test parameters, and verifying that their effect will result in a valid self-discharge measurement.

The following inequality describes the parameter constraints that must be satisfied for a valid self-discharge measurement, one that results in a voltage value between 0.5 V and 4.5 V.

$$0.5V \leq V_{CELL} + I * (6.2\Omega + R_{CABLES} + R_{ESR} - \langle res \rangle) \leq 4.5V$$

where

$V_{CELL}$  is the open circuit voltage of the cell. This can be provided by the user, or measured with the Keysight BT2152A.

$I$  is the instantaneous current obtained during the self-discharge test. This is the Keysight BT2152A's current measurement value. The inequality constraints must be satisfied for all measured current results, both positive and negative. This includes the initial current, final settled current value, and any transients that may occur. Note that the current measurement range for the unit is  $\pm 10$  mA; however, the resultant value should be positive and much lower than 10 mA -- usually in the 10 to 100 microampere range.

$R_{CABLES}$  is the resistance of the total cable wiring from the Keysight BT2152A to the cell under test. This can be provided by the user through external measurements, or it can be calibrated directly by the Keysight BT2152A's **CALibration:WIRE:RESistance:AUTO** command. It can also be modified using the **SENSe:WIRE:RESistance:CONFigure** command.

$R_{ESR}$  is cell's internal equivalent series resistance. This can be provided by the user if necessary by adding it to the resistance of the total cabling wiring from the Keysight BT2152A to the cell under test, using the **SENSe:WIRE:RESistance:CONFigure** command. Typically this value is less than 10 m $\Omega$ .

$\langle res \rangle$  is the user-selected output resistance from 0.1  $\Omega$  to 10  $\Omega$ . This is the same value entered using the **INITiate:TEST:MATChed** command.

## External Temperature Measurement

The external temperature sensor input on the rear panel requires an external 10 k $\Omega$  thermistor.

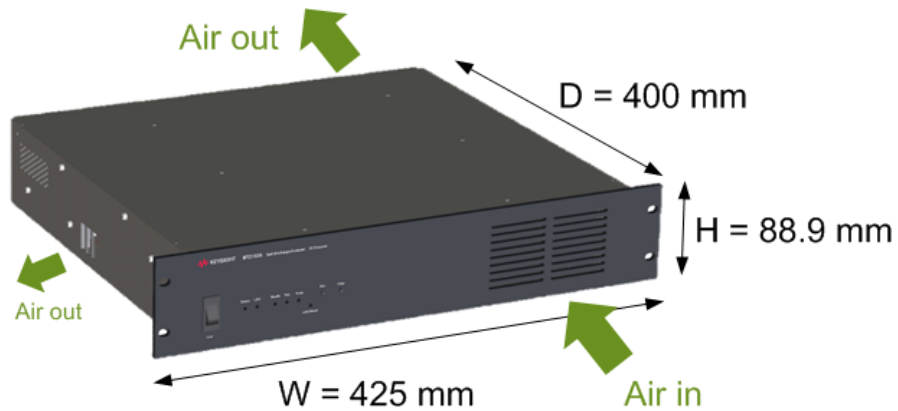
Measurement Input	Characteristic
Thermistor Requirements:	Negative Temperature coefficient (NTC) 10 k $\Omega$ Nominal Resistance at 25°C Programmable Beta value (4073 default)
Temperature measurement range:	5°C to 100°C
Temperature measurement uncertainty:	$\pm 1.5^\circ\text{C}$
Maximum total lead resistance allowed:	10 $\Omega$



## Dimensions and Airflow

**CAUTION** Do not block the air intake at the front and side, or the exhaust at the rear of the instrument.

---



- The front air inlet requires a minimum of 6 inch (15 cm) clearance. Inlet air temperature must be within the temperature range of 20°C to 30°C.
- The rear air outlet requires a minimum of 6 inch (15 cm) clearance.
- The small air outlet on the left side of the unit must also be unrestricted, but clearance could be as small as 10 mm if rack mounted.
- The instrument should not be installed in a pressured rack or enclosure.

## Command Quick Reference

### CALibration

:DATE <date>	Sets the calibration date
:END	Ends calibration
:LOAD	Loads the previous calibration values
:RESult? <value>	Enters the resulting measurement for calibration
:SECure	
:CODE <code>	Sets a calibration security code
:STATe 0 OFF 1 ON	Secures or unsecures calibration
:START	Initiates calibration
:STEP <step>	Steps through the different calibration processes
:STORe	Stores the cal constants in the EEPROM
:STRing <string>	Stores a message in calibration memory
:VALue? <step>	Returns the calibration constants of the step
:VERification	
:END	Ends the verification process
:STARt <channel>	Starts the verification process
:VOLTage <voltage>	Enters the output voltage for verification
:MEASure	
:INITiate <time>, <tint>	Starts a verification measurement
:WIRE	
:RESistance	
:AUTO	Runs auto-calibration of the wire resistance
:CLEar	Resets all wiring resistance values to zero
:LOAD <value>	Loads the wiring resistance values from a file
:SAVE <value>	Saves the wiring resistance values to a file

### Common Commands

ABORt	Aborts the measurement in progress
*CAL?	Initiates auto-calibration on all channels
*CLS	Clears status
*IDN?	Returns instrument identification
*OPC?	Returns "1" to the output buffer when all pending operations complete
*RST	Resets the instrument
*TST?	Runs a self-test
*WAI	Pauses command processing until all pending operations are complete

[SOURCE:]DIGital	[SOURCE:] is optional
:INPut	
:DATA?	Reads the state of the digital control port
:OUTPut	
:DATA <value>	Sets the state of the digital control port
:PIN<1-7>	
:FUNCTion DIO DINPut FAULT INHibit	Specifies the pin function
:POLarity POSitive NEGative	Specifies the pin polarity

**FETCH**

:CURRent	
:LATest? (@<chanlist>)	Returns the most recent measurements
:LOG? <values/chan> [,<offset/chan>], (@<chanlist>)	Returns the measurement log in ASCII
:BINary? <values/chan>, (@<chanlist>)	Returns the measurement log in binary
:POINts?	Returns the number of readings available
:PROBecheck? (@<chanlist>)	Returns results of the probe check test
:TEMPerature	
:LATest?	Returns the most recent temperature
:LOG? <values> [,<offset>]	Returns the temperature log in ASCII
:LOG	
:BINary? <values>	Returns the temperature log in binary
:POINts?	Returns the number of readings available
:VOLTage	
:LATest? (@<chanlist>)	Returns the most recent measurements
:LOG? <values/chan> [,<offset/chan>], (@<chanlist>)	Returns the measurement log in ASCII
:LOG	
:BINary? <values/chan>, (@<chanlist>)	Returns the measurement log in binary
:POINts?	Returns the number of readings available
:OCV? (@<chanlist>)	Retrieves the open-circuit voltage values

**FORMat**

:BORDER NORM SWAP	Selects the byte order for binary block transfers
-------------------	---

**INITiate**

:TEST	
:MATChed <time><units>, <ovp>, <uvp>, <res> [,<tint>[,<curr>[,<ocp>]]], (@<chanlist>)	Sets parameters for the voltage matched discharge current measurement
:OCV (@<chanlist>)	Initiates an open-circuit voltage test
:PROBecheck (@<chanlist>)	Initiates a probe check test

**LXI**

:IDENTify[:STATe] 0|OFF|1|ON Turns the front panel LXI identify indicator on or off

**OUTPut**

:INHibit  
 :MODE LATChing|LIVE|OFF Sets the operating mode of the Inhibit Input digital pin  
 :PROTection  
 :CLEar Resets any protection events that have occurred

**SENSe**

:OCV  
 :AVAILable? Returns availability of the OCV measurement  
 :PROBecheck  
 :AVAILable? Returns availability of the probe check test  
 :THERmistor  
 :CONFigure <temp>, <resistance>, <beta> Specifies parameters for the external thermistor  
 :TTIME  
 :REMAining? Returns the remaining time for the present test  
 :VERification  
 :AVAILable? Returns availability of the calibration verification  
 :WIRE  
 :RESistance  
 :AVAILable? Returns availability of the wire resistance values  
 :CONFigure <resistance>, (@<chanlist>) Specifies the wiring resistance of each channel

**STATus**

:ALARm  
 [:EVENT]? Queries the alarm event register  
 :CONDition? Queries the alarm condition register  
 :CURRent? Returns the sum of the over-current condition bits  
 :VOLTage? Returns the sum of the over-voltage condition bits  
 :UNDer? Returns the sum of the under-voltage condition bits  
 :ENABle <value> Sets the alarm enable register.  
 :OPERation  
 [:EVENT]? Queries the operation event register  
 :CONDition? Queries the operation condition register  
 :ENABle <value> Sets the operation enable register

## SYSTem

:COMMunicate	
:ENABle 0 OFF 1 ON <interface>	Enables or disables the remote interface
:LAN	
:CONTRol?	Reads the initial control connection port number
:DHCP 0 OFF 1 ON	Enables or disables DHCP
:DNS[1 2] "<address>"	Assigns static IP addresses of DNS servers
:DOMain?	Returns the domain name
:GATeway "<address>"	Assigns a default gateway address
:HOSTname "<name>"	Assigns a hostname
:IPADdress "<name>"	Assigns a static IP address
:MAC?	Returns the instrument's MAC address
:SMASk "<mask>"	Assigns a subnet mask
:TELNet	
:PROMpt "<string>"	Sets the command prompt for Telnet
:WMESsage "<string>"	Sets the welcome message for Telnet
:UPDate	Saves any changes made to the LAN settings
:WINS[1 2] "<address>"	Assigns the static IP addresses of WINS servers
:DATE <yyyy>, <mm>, <dd>	Sets the date of the system clock
:ERRor?	Reads and clears one error from the error queue
:TIME <hh>, <mm>, <ss>	Sets the time of the system clock
:TEMPerature?	Returns the external sensor's temperature value



# 2

## Installing the Analyzer

### **Before Installation**

**Connect the Power Cord**

**Connect the Interfaces**

**Connect the Cell Cables**

### Before Installation

#### Inspect the Unit

When you receive your Keysight BT2152A Self-Discharge Analyzer, inspect it for any obvious damage that may have occurred during shipment. If there is damage, notify the shipping carrier and nearest Keysight Sales and Support Office immediately. Refer to [www.keysight.com/find/assist](http://www.keysight.com/find/assist).

Until you have checked out the unit, save the shipping carton and packing materials in case the unit has to be returned.

#### Check for Items Supplied

Before getting started, check the following list and verify that you have received these items.

BT2152A Items	Description	Part Number
Power cord	A power cord suitable for your location	Call Keysight Sales & Support Office
LAN cable	LAN interface cable - cable is installed	Keysight 8121-3010 L-COM TRD8150R-7
Digital connector	8-pin connector for the digital port	Keysight 1253-6408; Phoenix Contact 1840421
Thermistor connector	2-pin connector for an external thermistor	Keysight 0360-3009 Phoenix Contact 1840366
Calibration connector	3-pin connector for an calibration connections	Keysight 0360-3038 Phoenix Contact 1840379
Safety booklet	Includes safety information	Keysight 9320-6797
Calibration certificate	Calibration certificate referenced to serial number	None

Refer to the box packing list for any additional items that may be included with your shipment. If anything is missing, please contact your nearest Keysight Sales and Support Office.

#### Review Safety Information

This instrument is a Safety Class 1 instrument, which means it has a protective earth terminal. That terminal must be connected to earth ground through a power source equipped with an earth ground. Refer to the [Safety Notices](#) page for general safety information. Before installation or operation, check the instrument and review this guide for safety warnings and instructions. Safety warnings for specific procedures are located at appropriate places throughout this guide.



## Observe Environmental Conditions

**WARNING** Do not operate the instrument in the presence of flammable gases or fumes.

---

The environmental conditions of the instrument are documented under **Characteristics**. Basically, the unit should only be operated indoors in a controlled environment. Do not operate the unit in areas where the ambient temperature is outside the 20°C to 30°C range. This applies for rack-mounting as well as for bench use.

## Provide Adequate Air Flow

**CAUTION** Do not block the air intake at the front and side, or the exhaust at the rear of the instrument.

---

The dimensions of your instrument as well as an outline diagram are given under **Dimensions**. Fans cool the unit by drawing air through the front and exhausting it out the side and back. The unit must be installed in a location that allows sufficient space of at least 6 inches (15 cm) at the front and back of the unit for adequate air circulation.

## Connect the Power Cord

**WARNING**

**FIRE HAZARD** Use only the power cord that was supplied with your instrument. Using other types of power cords may cause overheating of the power cord, resulting in fire.

**SHOCK HAZARD** The power cord provides a chassis ground through a third conductor. Be certain that your power outlet is of the three-conductor type with the correct pin connected to earth ground.

---

Connect the power cord to the **IEC 320 connector** on the rear of the unit. If the wrong power cord was shipped with your unit, contact your nearest Keysight Sales and Support Office.

The AC input on the back of your unit is a universal AC input. It accepts nominal line voltages in the range of 100 VAC to 240 VAC. The frequency can be 50 Hz or 60 Hz.

**NOTE**

The detachable power cord may be used as an emergency disconnecting device. Removing the power cord will disconnect AC input power to the unit.

---

## Connect the Interfaces

### LAN Connections

### USB Connections

### Digital Port Connections

### Thermistor Connections

If you have not already done so, install the Keysight IO Libraries Suite, which can be found at [www.keysight.com/find/iolib](http://www.keysight.com/find/iolib).

#### NOTE

For detailed information about GPIB, USB, and LAN interface connections, refer to the documentation included with the Keysight IO Libraries Suite.

## LAN Connections

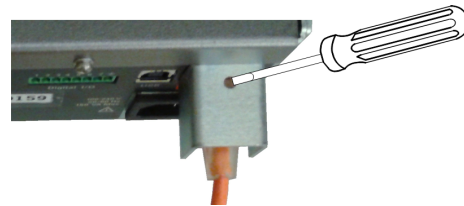
#### CAUTION

**Equipment Damage** Never insert any cell cables (RJ45) into the LAN connector. The LAN and RJ45 terminals are NOT compatible.

1. Connect the instrument to the site LAN or to your computer using the LAN cable that is connected to the unit. The cable comes connected to prevent any output cables from being accidentally inserted into the LAN connector.

#### NOTE

The LAN cable comes installed to prevent any cell cables from being accidentally inserted into the LAN connector. If you need to remove the LAN cable, insert a small screwdriver or equivalent into the hole and push down on the cable latch to release it.



2. The as-shipped LAN settings are configured to automatically obtain an IP address from the network using a DHCP server (DHCP is set On). The DHCP server will register the instrument's hostname with the dynamic DNS server. The hostname as well as the IP address can then be used to communicate with the instrument. If you are using a private LAN, you can leave all LAN settings as they are. Most Keysight products and most computers will automatically choose an IP address using auto-IP if a DHCP server is not present. Each assigns itself an IP address from the block 169.254.nnn. The front-panel Lan indicator will come on when the LAN port has been configured.

3. Use the Connection Expert utility of the Keysight IO Libraries Suite to add the instrument and verify a connection. To add the instrument, you can request the Connection Expert to discover the instrument. If the instrument cannot be found, add the instrument using the instrument's hostname or IP address.

4. You can now use Interactive IO within the Connection Expert to communicate with your instrument, or program the instrument directly using the applicable **SYSTem:COMMunicate:LAN** commands.

## USB Connections

1. Connect the instrument to the USB port on your computer using a customer-supplied USB cable. .
2. With the Connection Expert utility of the Keysight IO Libraries Suite running, the computer will automatically recognize the instrument. This may take several seconds. When the instrument is recognized, your computer will display the VISA alias, IDN string, and VISA address. This information is located in the USB folder.
3. You can now use Interactive IO within the Connection Expert to communicate with your instrument, or program the instrument directly using the applicable **SYSTem:COMMunicate:LAN** commands.

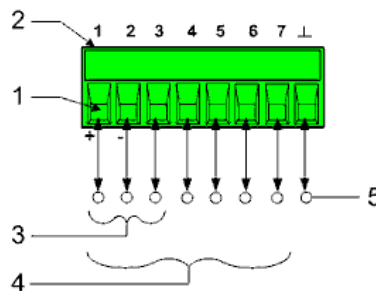
## Digital Port Connections

**NOTE**

Twist and shield all signal wires to and from the digital connector. With shielded wire, connect only one end of the shield to chassis ground to prevent ground loops.

An 8-pin connector and a quick-disconnect connector plug are provided for accessing the digital port functions. Refer to **Items Supplied** for part numbers. Disconnect the connector plug to make your wire connections. The connector plug accepts wires sizes from AWG 14 (1.5 mm<sup>2</sup>) to AWG 28 (0.14 mm<sup>2</sup>). Strip the wire insulation back 7 mm.

1. Insert wires
2. Tighten screws
3. Fault/Inhibit configurable pins (observe INH polarity)
4. Digital IO-configurable pins
5. Signal common

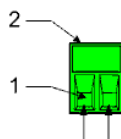


Information on using the digital port is found under **Using the Digital Port**. The electrical characteristics are described under **Common Characteristics**.

## Thermistor Connections

A 2-pin connector and a quick-disconnect connector plug are provided for the thermistor connections. Refer to **Items Supplied** for part numbers. AWG 14 (1.5 mm<sup>2</sup>) to AWG 28 (0.14 mm<sup>2</sup>). Strip the wire insulation back 7 mm.

1. Insert wires
2. Tighten screws



Use an appropriate off-the-shelf thermistor. For example: Keysight 0837-4194; Amphenol Advanced Sensors RL1005-5744-103-SA. Refer to **SENse:THERmistor:CONFigure** for additional information.

## Connect the Cell Cables

### Making the Cables

#### RJ45 Wire Colors Codes and Pinout Numbers

#### 32-Channel Mapping to RJ45 Connectors

This section describes how to make and connect the cell cables.

### Making the Cables

Two methods of cabling are available:

#### 1. RJ45 to bare wire

Obtain off-the-shelf RJ45 CAT6+ shielded cables. Many lengths are available. For example: Manufacturer = Belden. Part number = C6F1106010. Maximum allowable cable length = 25 meters.

Cut the cable in the middle. Now, you have two pieces half the previous length. Each piece has an RJ45 on one side and bare wires on the other.

Connect the RJ45 CAT6+ cables from the instrument to the test fixture.



#### NOTE

When using shielded cables like Cat 6A or Cat 7, leave the shield floating at the cell end of the cable. The cable shield connects to the instrument chassis at the BT2152A end of the cable.

**Wire resistance calibration** is recommended when all RJ45 cables have been installed in the instrument to allow for more accurate output resistance selections. Wire resistance calibration is also recommended whenever any RJ45 connector is unplugged, reinserted, or reseated. Wire resistance must be between  $0\Omega$  and  $5\Omega$ .

#### 2. RJ45 to RJ45

Obtain off-the-shelf RJ45 CAT6+ shielded cables. Many lengths are available. For example: Manufacturer = Belden. Part number = C6F1106010. Maximum allowable cable length = 25 meters.

Obtain off-the-shelf RJ45 board mount receptacles. For example: Manufacturer = Amphenol. Part number = RJSSE-5380-04.

Mount the RJ45 receptacle on the test fixture. Connect the RJ45 CAT6+ cables from the instrument to the receptacle.

## 2 Installing the Analyzer



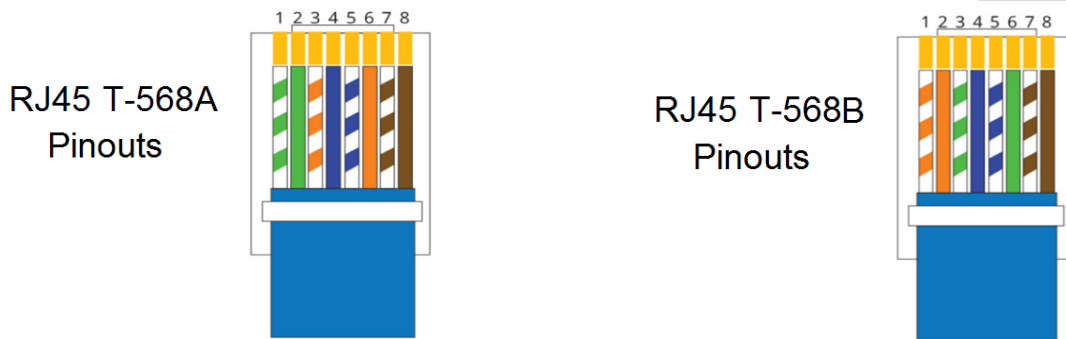
**NOTE**

When using shielded cables like Cat 6A or Cat 7, leave the shield floating at the cell end of the cable. The cable shield connects to the instrument chassis at the BT2152A end of the cable.

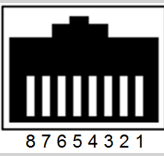
**Wire resistance calibration** is recommended when all RJ45 cables have been installed in the instrument to allow for more accurate output resistance selections. Wire resistance calibration is also recommended whenever any RJ45 connector is unplugged, reinserted, or reseated. Wire resistance must be between 0Ω and 5Ω.

### RJ45 Wire Color Codes and Pinout Numbers

The following figures illustrate the color codes and pin-outs of two types of RJ45 connectors, as viewed from the *bottom* of the connector.



The following table shows the mapping of the color-coded wires into both T-568A and T-568B connectors. The table also shows the channel-assignment mapping of channels 1 through 4.

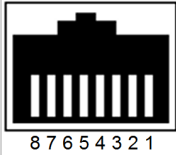
	RJ45 Pin 8	RJ45 Pin 7	RJ45 Pin 6	RJ45 Pin 5	RJ45 Pin 4	RJ45 Pin 3	RJ45 Pin 2	RJ45 Pin 1
Channels 1 to 4	-1	+1	-3	-2	+2	+3	-4	+4
T- 568A	brown	wht/brn	orange	wht/blu	blue	wht/org	green	wht/grn
T- 568B	brown	wht/brn	green	wht/blu	blue	wht/grn	orange	wht/org

## 32-Channel Mapping to RJ45 Connectors

The following figure shows the channel assignments for the 32-channel self-discharge analyzer.



The following table shows the channel-assignment mapping of all 32 channels.

	RJ45 Pin 8	RJ45 Pin 7	RJ45 Pin 6	RJ45 Pin 5	RJ45 Pin 4	RJ45 Pin 3	RJ45 Pin 2	RJ45 Pin 1
RJ45 #1 Channels 1 to 4	-1	+1	-3	-2	+2	+3	-4	+4
RJ45 #2 Channels 5 to 8	-5	+5	-7	-6	+6	+7	-8	+8
RJ45 #3 Channels 9 to 12	-9	+9	-11	-10	+10	+11	-12	+12
RJ45 #4 Channels 13 to 16	-13	+13	-15	-14	+14	+15	-16	+16
RJ45 #5 Channels 17 to 20	-17	+17	-19	-18	+18	+19	-20	+20
RJ45 #6 Channels 21 to 24	-21	+21	-23	-22	+22	+23	-24	+24
RJ45 #7 Channels 25 to 28	-25	+25	-27	-26	+26	+27	-28	+28
RJ45 #8 Channels 29 to 32	-29	+29	-31	-30	+30	+31	-32	+32





# 3

## Operating the Analyzer

**Understanding Front Panel Operation**

**Using the Digital Port**

**Maintaining Cell Stability During Testing**

## Understanding Front Panel Operation

**What Happens at power-on?**

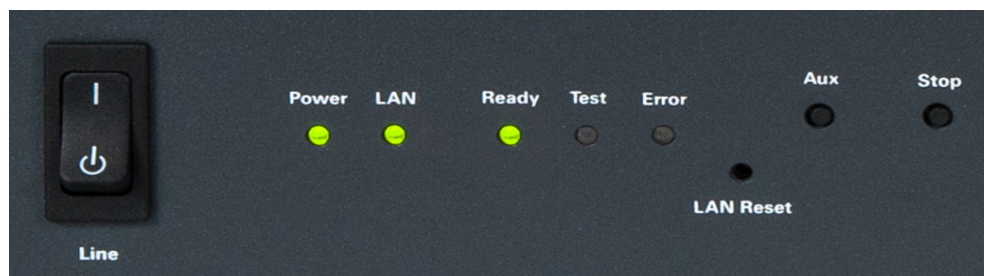
**What happens when a test is initiated?**

**What happens when a test stops?**

**What happens when the reference temperature exceeds its specification?**

**What happens when a protection event or error occurs?**

The following indicators and controls are on the front panel.



**NOTE** The **AUX** button is not active, and is reserved for future use.

### What happens at power-on?

Turn the unit on with the front-panel **Line** switch.

**NOTE** It may take about 60 seconds or so for the unit to completely boot up.

When the unit is first turned on, the **Power** LED turns green, indicating that power is on.

The **LAN** indicator turns green when the LAN connection is active. Flashing green indicates an active LXI identification state. Red indicates the LAN is disconnected. Pressing the **LAN reset** button on the front panel will attempt to restore the LAN connection. If this does not work, restoring LAN communication must be done using the test program.

The **Ready** indicator turns orange, indicating that the unit is warming up. A warm up time of about **1 hour** is required for the unit to meet its specified performance. It is possible to send commands and operate the unit during the warm up time, but it is advisable to allow the unit to fully warm up before running any test. If power was cycled and off for less than 5 minutes after warmup, subsequent warm up will be about 30 minutes.

**NOTE** The **Ready** status is driven by elapsed time. If the unit is powered off and then powered on again, the Ready LED will again turn orange for about one hour.

The **Test** and **Error** indicators should be off. If the Error LED is red, either a protection event or an error has occurred (see **What happens when a protection event or error occurs?**).

### What happens when a test is initiated?

Before initiating a test, wait for the **Ready** indicator to change from orange to green, which means the unit is warmed up and ready for testing. It is possible to send commands and operate the unit prior to the LED changing to green, but it is advisable to let the unit warm up to meet specified performance.

The **LAN** indicator flashes blue when any SCPI commands or queries are sent.

The **Test** indicator flashes blue when the cell matching process has been initiated and is running.

The **Test** indicator stops flashing and turns solid blue when the cell measurement test is running and data logging is occurring.

The **Test** indicator turns off when the measurement logging has completed.

### What happens when a test stops?

Normally, a test runs for the duration of its programmed test time and then stops. A test can also be stopped before the completion of its programmed time by pushing the **Stop** button or sending an **Abort** command.

When a test stops or is stopped, the **Test** indicator turns off.

The **Power**, **LAN**, and **Ready** indicators are green. The **Test** and **Error** indicators are off.

### What happens when the reference temperature exceeds its specification?

The **Ready** indicator turns orange when the internal reference temperature is slightly out of regulation. There may be a problem with the airflow. Check that the airflow at the vents is unobstructed. Once the internal temperature is restored, the Ready indicator will turn to green.

The **Ready** indicator flashes red when the internal reference temperature has increased to a point where damage could occur. When this happens the internal heaters are disabled and the operating temperature range will not be maintained. Turn the unit off, let it cool down, then turn it on to clear the condition.

### What happens when a protection event or error occurs?

The **Error** indicator turns red when either a protection event or an error has occurred.

If a protection event occurs on a channel, that channel is disconnected from the cell. You can continue running the test on other channels. The channel that tripped protection remains disconnected from the cell until protection is cleared.

If an error occurs, the instrument will continue to operate with errors present.

Clearing the protection event or error can only be done using the test program. There is no front panel control to clear protection events or errors. Once the test program clears the protection event or error, the Error LED turns off.

## Using the Digital Port

### Bi-Directional Digital I/O

#### Digital Input only

#### Fault Output

#### Inhibit Input

### Fault/Inhibit System Protection

## Digital Control Port

A Digital Control Port consisting of seven I/O pins is provided to access various control functions. Each pin is user-configurable. The following control functions are available for the I/O pins.

The following table describes the possible pin configuration for the digital port functions. For a complete description of the electrical characteristics of the digital control port, refer to the [Characteristics](#) section.

Function	Description
DIO	General-purpose ground-referenced digital input/output function. The output can be set with [SOURce:]DIGital:OUTPut:DATA.
DINPut	Digital input-only mode. The digital output data of the pin is ignored.
FAULt	Applies only to pin 1. Pin 1 functions as an isolated fault output. The fault signal is true when any output is in a protected state. Pin 2 serves as the isolated common for pin 1. When pin 1 is set to the FAULt function, the instrument ignores any commands to program pin 2. Queries of pin 2 will return FAULt. If pin 1 is changed from FAULt to another function, pin 2 is set to DINPut.
INHibit	Applies only to pin 3. When pin 3 is configured as an inhibit input; a true signal at the pin will disable the output.
Common	Applies only to pin 8. Connected to ground.

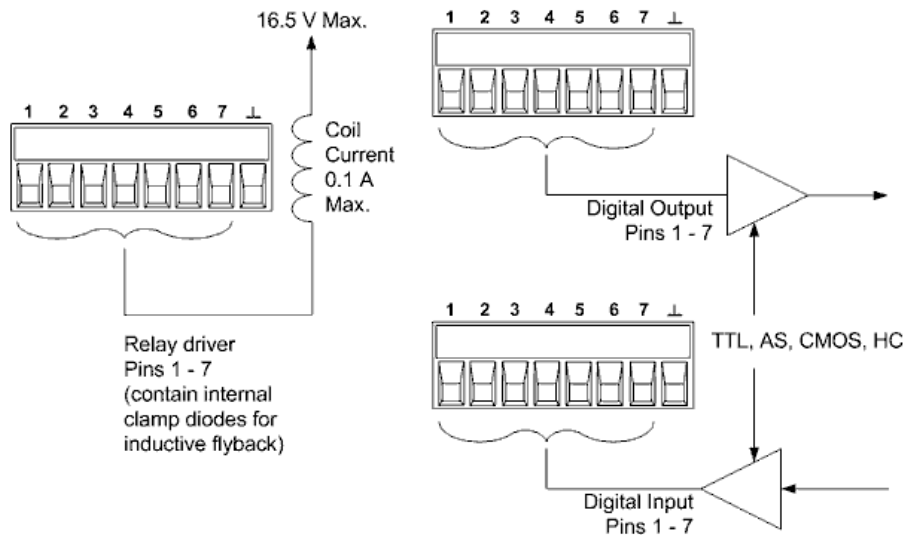
In addition to the configurable pin functions, the signal polarity (Positive or Negative) for each pin is also configurable. For level signals, POSitive indicates a voltage high at the pin. NEGative indicates a voltage low at the pin. For edge signals, POSitive means a rising edge and NEGative means a falling edge.

## Bi-Directional Digital I/O

Each of the seven pins can be configured as general purpose bi-directional digital inputs and outputs. The polarity of the pins can also be configured. Pin 8 is the signal common for the digital I/O pins. Data is programmed according to the following bit assignments:

Pin	7	6	5	4	3	2	1
Bit Weight	6 (msb)	5	4	3	2	1	0 (lsb)

The digital I/O pin can be used to control both relay circuits as well as digital interface circuits. The following figure illustrates typical relay circuits as well as digital interface circuit connections using the digital I/O functions



To configure the pins for digital I/O:

```
DIG:PIN1:FUNC DIO
DIG:PIN2:FUNC DIO
DIG:PIN3:FUNC DIO
DIG:PIN4:FUNC DIO
DIG:PIN5:FUNC DIO
DIG:PIN6:FUNC DIO
DIG:PIN7:FUNC DIO  \\ sets the function for all 7 pins to digital IO
DIG:PIN1:POL POS
DIG:PIN2:POL POS
DIG:PIN3:POL POS
DIG:PIN4:POL POS
DIG:PIN5:POL POS
DIG:PIN6:POL POS
DIG:PIN7:POL POS  \\ sets the function for all 7 pins to positive
DIG:OUTP:DATA 7  \\ configures pins 1 through 7 as "0000111"
```

## Digital Input

Each of the seven pins can be configured as digital input only. The polarity of the pins can also be configured. Pin 8 is the signal common for the digital input pins. The pin status reflects the true condition of the external signal that is applied to the pin. The pin state is not affected by the setting of DIGital:OUTPut:DATA.

To configure the pins for digital input only:

## 3 Operating the Analyzer

```
DIG:PIN1:FUNC Dinp
DIG:PIN2:FUNC Dinp
DIG:PIN3:FUNC Dinp
DIG:PIN4:FUNC Dinp
DIG:PIN5:FUNC Dinp
DIG:PIN6:FUNC Dinp
DIG:PIN7:FUNC Dinp  \\ sets the function for all 7 pins to digital input
DIG:PIN1:POL POS
DIG:PIN2:POL POS
DIG:PIN3:POL POS
DIG:PIN4:POL POS
DIG:PIN5:POL POS
DIG:PIN6:POL POS
DIG:PIN7:POL POS  \\ sets the function for all 7 pins to positive
DIG:INP:DATA?      \\ reads the data on the pins
```

### Fault Output

Pins 1 and 2 can be configured as a fault-output pair. The Fault Output function enables a fault condition to generate a protection fault signal from the **Alarm Status Group** on the digital port.

Both pins 1 and 2 are dedicated to this function. Pin 1 is the Fault output; pin 2 is the common for pin 1. This provides for an optically-isolated output. The polarity of pin 1 can also be configured. When the pin polarity is positive, a fault condition causes the isolated output to conduct. Note that the Fault output signal remains latched until the fault condition is removed and the protection circuit is cleared using `OUTput:PROTEction:CLEar`.

#### NOTE

Pin 2's selected function is ignored. Pin 2 should be connected to the ground of the external circuit.

To configure the Fault Output function:

```
DIG:PIN1:FUNC FAUL  \\ sets the function for all 7 pins to digital IO
DIG:PIN1:POL POS    \\ sets the function for all 7 pins to positive
```

### Inhibit Input

Pin 3 can be configured as a remote inhibit input. The Inhibit input function lets an external input signal disconnect or connect the input channels. The Inhibit input is level triggered. Pin 8 is the common for pin 3.

Use the `OUTput:INHibit:MODE` command to specify the following non-volatile Inhibit input modes: Latching, Live, or Off.

To configure the Inhibit Input function:

```
DIG:PIN3:FUNC INH  \\ sets the function for pin 3 to Inhibit
DIG:PIN3:POL POS  \\ sets the polarity for pin 3 to positive
OUTP:INH:MODE LIVE \\ sets the inhibit mode to Live
```

```

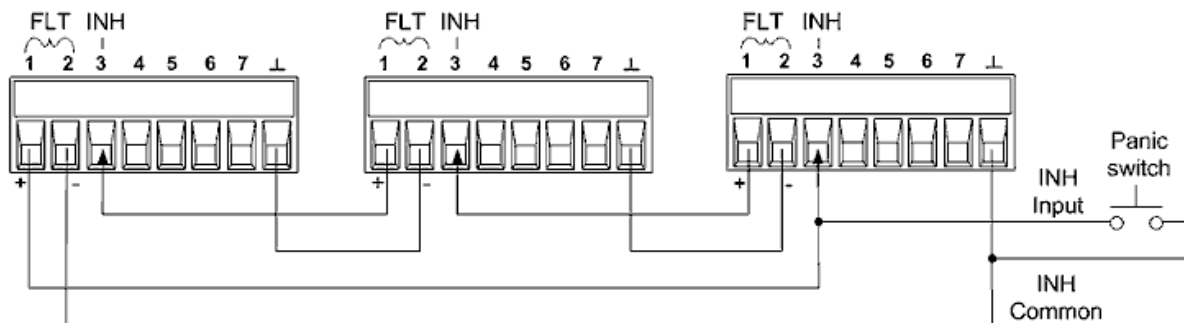
OUTP:INH:MODE LATC  \\ sets the inhibit mode to Latched
OUTP:INH:MODE OFF   \\ sets the inhibit mode to Off

```

## Fault/Inhibit System Protection

As shown in the following figure, when the Fault outputs and Inhibit inputs of several instruments are daisy-chained, an internal fault condition in one of the units will disconnect all channels without intervention by either the controller or external circuitry. Note that when using the Fault/Inhibit signals in this manner, both signals must be set to the same polarity.

Also, as shown in the figure, you can also connect the Inhibit input to a manual switch or external control signal that will short the Inhibit pin to common whenever it is necessary to disconnect all channels. **Negative** polarity must be programmed for all pins in this case. You can also use the Fault output to drive an external relay circuit or signal other devices whenever a protection fault occurs.



## Clearing a System Protection Fault

To restore all instruments to a normal operating condition when a fault condition occurs in a daisy-chained system protection configuration, two fault conditions must be removed:

1. The initial protection fault or external Inhibit signal.
2. The subsequent daisy-chained fault signal (which is sourced by the Inhibit signal).

### NOTE

Even when the initial fault condition or external signal is removed, the fault signal is still active and will continue to disconnect the channels of all the units.

To clear the daisy-chained fault signal if the operating mode of the Inhibit input is Live, simply clear the output protection on any ONE unit as explained under Clearing Protection Functions. If the operating mode of the Inhibit input is Latched, turn off the Inhibit input on ALL units individually. To re-enable the chain, re-program the Inhibit input on each unit to Latched mode.

## Maintaining Cell Stability During Testing

### A Cell's Percent State of Charge

#### Charge Redistribution and Equilibrium

#### Expected Self-Discharge Current and Temperature Dependency

#### Temperature Impact on Current Measurement

#### Impact of Stress and Vibration on Current Measurement

**NOTE**

The voltage of most Lithium Ion cells is very sensitive to vibration and mechanical stress or deflection. Once a self-discharge test has started, it is important that the cell not be moved or disturbed, and is not subjected to vibration. The temperature sensor must be mounted on or attached to the cell before the test and not touched or have its connection adjusted during the test. Cells are microphonic – any touching or tapping them, or any vibration or shock will affect the cell's voltage and thus the measured current value.

---

### A Cell's Percent State of Charge

Self-discharge current is somewhat less for lower levels of percent state of charge (% SOC), falling off at a greater rate below ~45% SOC. The cell's voltage tends to be less stable and more temperature sensitive at lower levels of % SOC. For these reasons, it is generally recommended that the cells should ideally be at 60% SOC or higher for achieving good self-discharge current measurements.

### Charge Redistribution and Equilibrium

Right after a cell is charged or discharged, it takes a considerable amount of time for the electron charge to uniformly distribute itself within the cell and be at equilibrium. During this time, the cell's voltage is dropping or rising at an exponential rate, depending on whether it had been charged or discharged. In comparison, when a cell's charge is fully distributed and at equilibrium, its voltage falls off at a much lower and linear rate, due to the internal self-discharge current. Depending on the cell's makeup, it can take from several days to two weeks for a cell to reach charge equilibrium.

When the cell is connected to the Keysight BT2152A, the system holds its output voltage constant after it goes through the cell voltage matching process. If the cell is at charge equilibrium, the only influence on the cell's voltage is due to self-discharge. As the BT2152A holds its voltage constant, the net result is the BT2152A needs to only replenish the self-discharge current to maintain constant voltage. However, when a cell has recently been charged or discharged and then connected to the BT2152A, additional charging current will be drawn from the BT2191A (after charging) or discharging current will be sourced back into the BT2152A (after discharging) in addition to the self-discharge current. The peak of this current can be several orders of magnitude greater than the self-discharge current alone.



## Expected Self-Discharge Current and Temperature Dependency

It is normal for cells to exhibit a small amount of self-discharge. It is difficult to definitively state what a cell's expected self-discharge current should be, as many factors exist regarding a cell's design and makeup that can affect this value. Notwithstanding, for cells at a room temperature of typically 23 °C, testing has shown it can typically range from just a few micro-amperes for sub 1 Ah cells to 50 to 100 micro-amperes for 10 to 20 Ah cells.

All other things being equal, a cell's self-discharge current can approximately double for a 10 °C increase in temperature. This applies to good cells not exhibiting excessive self-discharge leakage current caused by internal defects or other problems.

## Temperature Impact on Current Measurement

A cell's voltage temperature dependency can be expressed as a temperature coefficient of voltage (TCV), and can be quantified in microvolts per degree C ( $\mu\text{V}/^\circ\text{C}$ ). Since the BT2152A's method to measure a cell's self-discharge current relies on matching its internal voltage source to the cell's voltage and then connecting them together, it is easy to see how the self-discharge current measurement is impacted by any change of the cell's voltage afterward. Several things can be done to reduce the effect of temperature on self-discharge current measurements:

- It turns out a cell's TCV is dependent on its % SOC. It can vary from as low as zero at certain points to as much as 100's of  $\mu\text{V}/^\circ\text{C}$ , typically at very low % SOC levels. Generally having the cell charged to 70% SOC or better helps reduce the cell's TCV. Still, you may have to contend with a TCV in the range of 20 to 100  $\mu\text{V}/^\circ\text{C}$
- An indoor test environment can experience a few degrees temperature cycle each day. The series resistance between the BT2152A and the cell affects the measurement's sensitivity to the cell's TCV
  - Increasing this series resistance reduces the sensitivity to a cell's TCV but increases the time it takes for the measurement to settle to the final self-discharge current value.
  - The BT2152A has a programmable series resistance for this purpose.
  - Temperature sensitivity is a significant factor for larger cells, as they usually require a longer measurement settling time due to their proportionally larger capacity.
- Depending on how long the self-discharge measurement takes, it may be necessary to take further steps to hold the cell's temperature steady. Possibilities include:
  - Surrounding the cell with thermal insulation.
  - Incorporating a substantial thermal mass (metal plate) that the cell is held against, to dampen temperature change. The thermal mass can be passive or actively temperature regulated.
  - Using a thermal chamber having a regulated temperature.

### **Impact of Stress and Vibration on Current Measurement**

A cell's voltage can be altered by mechanical stress and vibration. Any change of the cell's voltage impacts the self-discharge current. Static stress can induce a relatively fixed voltage shift while vibrations can create substantial peak-to-peak deviations in the measurement. Take care to:

- not subject the cell to stress.
- isolate the cell from any direct vibration that may exist.

# 4

## Programming Reference

**Introduction to the SCPI Language**

**Programming Samples**

**Commands by Subsystem**

**Status Tutorial**

**Reset and Interface Settings**

**SCPI Error Messages**

## Introduction to the SCPI Language

### Command Types

### Keywords

### Queries

### Syntax Conventions

### Parameter Types

### Device Clear

## Command Types

SCPI (Standard Commands for Programmable Instruments) is an ASCII-based instrument command language designed for test and measurement instruments. SCPI has two types of commands, common and subsystem.

**Common commands** are defined by the IEEE 488.2 standard to perform common interface functions such as reset, status, and synchronization. All common commands consist of a three-letter mnemonic preceded by an asterisk: \*RST, \*IDN?

**Subsystem commands** perform specific instrument functions. They can be a single command or a group of commands. The groups are comprised of commands that extend one or more levels below the root. Subsystem commands are arranged alphabetically according to the function they perform. The following figure shows a portion of a subsystem command tree, from which you access the commands located along the various paths.

```
INITiate
  :TEST
    :OCV (@1)
```

## Keywords

Keywords, also referred to as headers, are instructions recognized by the instrument. Common commands are also keywords.

INITiate is the root keyword, TEST is a second-level keyword, OCV is a third-level keyword. Colons (:) separate the keyword levels.

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

In the above examples, INIT and INITiate are both acceptable forms. You can use upper- or lower-case letters. Therefore, INITIATE, init, and Init are all acceptable. Other forms such as INITiat, are not valid and will generate an error.

## Queries

Following a keyword with a question mark (?) turns it into a query (Example: FETCh:CURRent:LATest?). If a query contains parameters, place the query indicator at the end of the last keyword, before the parameters. Insert a space between the query indicator and the first parameter.

You can query the programmed value of most parameters. For example, you can query the latest current reading by sending:

```
FETCh:CURRent:LATest? (@1)
```

You must read back all the results of a query before sending another command to the instrument. Otherwise, a *Query Interrupted* error will occur and the unreturned data will be lost.

## Syntax Conventions

- Colons (:) separate keyword levels. Blank spaces must be used to separate command parameters from their corresponding keyword. Note the space between VALue and the <voltage> parameter. If a command requires more than one parameter, use a comma to separate adjacent parameters. In the following calibration command, the voltage and current value parameters must be separated with a comma.

```
CALibration:VALue <voltage>, <current>
```

- Triangle brackets ( < > ) indicate that you must specify a value for the enclosed parameter. In the example above, the <voltage> parameter is enclosed in triangle brackets. The brackets are not sent with the command string. You must specify a value for the parameter.
- A vertical bar ( | ) separates multiple parameter choices for a given command string.
- Square brackets ( [ ] ) enclose some syntax elements - nodes and parameters for example. This indicates that the element is optional and can be omitted. The brackets are not sent with the command string. Any keyword enclosed in brackets is optional and can be omitted. However, if you are combining several commands within the same message string, you must include the optional commands to place the command parser at the correct level in the hierarchy.

## Parameter Types

The SCPI language defines several data formats to be used in commands and queries.

### Channel Parameter

The channel parameter <chanlist> is required to address one or more cell channels. Cell channels are numbered from 1 to 32. It has the following syntax for the entire range of channels:

```
(@1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,
29,30,31,32)
or
(@1:32)
```

You can specify any combination of channels and ranges, provided the channels are in ascending order, as follows:

```
(@1:8,10,12,14,16,18,20:32)
```

The channel list, shown as <chanlist> throughout this document, must be preceded with the @ symbol and must be enclosed in parentheses (). Query results are channel list order-sensitive. Results are returned in the order they are specified in the list.

#### NOTE

When adding a channel list parameter to a query, you must include a space character between the query indicator (?) and the channel list parameter. Otherwise error -103, Invalid separator will occur.

## Numeric Parameters

Commands that require numeric parameters will accept all commonly used decimal representations of numbers including optional signs, decimal points, and scientific notation. If a command accepts only certain specific values, the instrument will automatically round the input numeric parameters to the accepted values. The following command requires a numeric parameter to enable channels 1 through 4 in the alarm register:

```
STATus:ALARm:ENABle 15
```

## Boolean Parameters

Boolean parameters represent a single binary condition that is either true or false. For a false condition, the instrument will accept "OFF" or "0". For a true condition, the instrument will accept "ON" or "1". When you query a Boolean setting, the instrument will always return "0" or "1". The following command requires a Boolean parameter:

```
SYSTem:COMMunicate:LAN:DHCP OFF|0|ON|1
```

## ASCII String Parameters

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

```
SYSTem:COMMunicate:LAN:DNS "198.105.232.4"
```

## Device Clear

Device Clear is an IEEE-488 low-level bus message that you can use to return the instrument to a responsive state. Different programming languages and IEEE-488 interface cards provide access to this capability through their own unique commands. The status registers, the error queue, and all configuration states are left unchanged when a Device Clear message is received.

Device Clear performs the following actions:

- If a measurement is in progress, it is aborted.
- The instrument returns to the trigger idle state.
- The instrument's input and output buffers are cleared.
- The instrument is prepared to accept a new command string.

**NOTE**

The ABORt command is the recommended method to terminate an instrument operation.

---

## Programming Samples

### Setting up and running a test

#### Retrieving all test values

#### Stopping/aborting a test

#### Clearing protection events and errors

#### NOTE

The unit requires a warm-up time of 1 hour for the measurement circuits to stabilize so that the test results meet specifications. When the unit is fully warmed up, the front panel **Ready** indicator changes from amber to green. You can send programming commands to the unit while it is warming up; you just cannot calibrate the unit.

### Setting up and running a test

You need only one command to set up and run a test. For example, send:

```
INITiate:TEST:MATChed 75, 4.2, 2.8, 1, 1, 0.0001, 0.001, (@1:16)
```

This command matches the cell open-circuit voltage at the start of the test and runs according to the following settings:

Test duration in minutes: 75

Maximum voltage: 4.2

Minimum voltage: 2.8

Output resistance in ohms: 1.0

Time interval in seconds: 1.0

Initial cell current in amps: 0.0001

Over-current protection in amps: 0.001

Cell channels: 1 through 16.

The test begins immediately after sending this command.

The front panel **Test** indicator flashes blue when cell matching has been initiated. The indicator stops flashing and remains blue during the entire time the discharge test is running. After about 75 minutes, the test will stop, the Test indicator turns off, and the final discharge values are stored in the unit until the host computer reads the data out.

### INIT:TEST:PROB probe check and query sequence

The following initiates a probe check test and returns the status of the channel probes.

```
INIT:TEST:PROB (@1:16)
While(SENS:PROB:AVAILable? == 0) \\ wait for data to become available
Sleep(1000);
FETC:PROB? (@1:16) \\ return comma-separated boolean values
```



## INIT:TEST:OCV measurement and query sequence

The following initiates an open-circuit voltage test and returns the measured open-circuit voltage.

```
INIT:TEST:OCV 4.2, 2.8, 0.001, 1, (@1:16)
While(SENSe:OCV:AVAILable? == 0) \\ wait for data to become available
Sleep(1000);
FETC:VOLT:OCV? (@1:16)
```

## INIT:TEST:MATC measurement and query sequence

The following matches the cell open-circuit voltage, initiates a test sequence, and returns the latest current and voltage measurement.

```
INIT:TEST:MATC 75, 4.2, 2.8, 1, 0.125, 0.0001, 0.001, (@1:16)
While(SENSe:TTime:REMAining? > 0) \\ wait for test to finish
Sleep(1000);
FETC:VOLT:LAT? (@1:16)
FETC:CURR:LAT? (@1:16)
```

## Retrieving all test values

One command returns all test values from all specified cell channels. You can first query the number of available measurement points. Then retrieve the measurements.

```
FETCh:CURRent:LOG:POINts? \\ returns the number of available points
FETCh:CURRent:LOG? 100, (@1:16)
```

This command retrieves 100 current measurements from channel 1 to 16. The readings are returned sequentially in channel groups (i.e. x,x,x,x,x,x,x, ... y,y,y,y,y,y,y, ...) where x represents all the measurements for channel 1, y represents all the measurements for channel 2 etc.

## Measurement array query and retrieval

The intent here is to query how many points are available, then use that information to query UP TO 200 but not more than the number of points available per channel. If the FETCh command is sent immediately after the INITiate:TEST command is sent, there may be no data to fetch for quite a while.

```
numCurrPointsPerChannel = 200;
numCurrPointsPerChannel = min( numCurrPointsPerChannel , FETC:CURR:LOG:POIN?
)
FETC:CURR:LOG? numCurrPointsPerChannel, (@1:16)
```

or

```
numVoltPointsPerChannel = 200;
numVoltPointsPerChannel = min( numVoltPointsPerChannel , FETC:VOLT:LOG:POIN?
)
FETC:VOLT:LOG? numVoltPointsPerChannel, (@1:16)
```

## Stopping/aborting a test

Because the INITiate:TEST commands could take hours to execute, it may be necessary to stop the test in the middle to debug or fix a problem like a damaged fixture or cell installed backwards.

If the host computer is located in another building in a distributed factory environment, stopping the program may not be practical.

The front panel **Stop** button can be used to immediately stop a test. This will safely stop the test without losing test data or test configuration. Note that the ABORT command performs the same function as the front panel Stop button.

## Clearing protection events and errors

When the Error LED is red, either a protection event or an error has occurred and need to be cleared.

**Protection events occur** due to an over-voltage (OV), under-voltage (UV), or over current (OC) condition. The unit will latch off and cannot be operated until the fault is cleared. To clear the fault the cause of the fault must first be removed and then the protect status then needs to be cleared. These faults are part of the Alarm Status Group.

To query if a protection event has occurred, send:

```
STATus:ALARm:EVENT?
```

The value returned indicates the type of protection event: Over-voltage = 1; Over-current = 2; Under-voltage = 512. The command reads and clears the fault when it is sent to the instrument. To determine if the protection condition still exists, send:

```
STATus:ALARm:CONDition:CURRent?  
STATus:ALARm:CONDition:VOLTage?  
STATus:ALARm:CONDition:VOLTage:UNDER?
```

If a value other than zero is returned when these commands are sent, the condition is still present and must be removed. If the condition is no longer present, send the following command to clear protection status. This will turn the front panel Error LED off.

```
OUTPut:PROTection:CLEar
```

**Errors occur** due to a variety of command processing errors, such as failing to read back the result from a query command. The instrument will continue to operate with errors present. Note that the front panel Error light does not turn on from command processing errors.

To read and clear error codes send:

```
SYSTem:ERRor?
```

Each time this command is sent, one error is removed from the error queue. When the query returns a zero, all error have been removed from the queue.

## Commands by Subsystem

**Calibration**

**Common Commands**

**Digital**

**Fetch**

**Format**

**Initiate**

**LXI**

**Output**

**Sense**

**Status**

**System**

## Calibration Commands

**NOTE**

Read the **calibration** section before calibrating. Improper calibration can reduce accuracy and reliability.

---

### CALibration:DATE <"date">

#### CALibration:DATE?

Stores the calibration date in nonvolatile memory. Enter any ASCII string up to 16 characters. The query returns the date. If no date is stored, an empty quoted string ("" ) is returned.

Parameter	Typical Return
<"date">String program data. Enclose string parameters in single or double quotes.	date of last calibration
Enter a calibration date: CAL:DATE "2/2/2017"	

### CALibration:END

Ends the calibration process. This command should be used *after* the calibration constants have been set, but before storing the calibration using CAL:STOR.

Parameter	Typical Return
(none)	(none)
End calibration: CAL:END	

### CALibration:LOAD

Loads the previous calibration values. For example, this can be used if there has been an error in the calibration procedure. This command is only valid prior to executing the CALibration:STORe command. Once the CALibration:STORe command has been executed, the previous calibration values are overwritten.

Parameter	Typical Return
(none)	(none)
Loads the previous calibration values: CAL:LOAD	

### CALibration:RESult? <value>

Used to enter the resulting measurement for calibration. The value entered depends on the calibration step. The command returns a zero (0) if the calibration step was successful.

Parameter	Typical Return
<value> is the measured result	0
Enter a calibration result: CAL:RES? 1.234567	

- If a value other than zero is returned, an error has occurred. Send SYST:ERR? to return the error.

### CALibration:SECure:CODE <code>

Sets the security code to prevent unauthorized calibration.

Parameter	Typical Return
<code> integer from 1 to 10E32	(none)
Enter a calibration code: CAL:SEC:CODE 1223334444	

- Once set, you must unsecure the unit to calibrate it, or change the calibration string or security code.
- When shipped from the factory the instrument is unsecured, with the security code set to 0 (zero).
- You cannot update the firmware using the Keysight utility without the code if calibration is locked.

### CALibration:SECure:STATE 0|OFF|1|ON ,<code>

#### CALibration:SECure:STATE?

Parameter	Typical Return
0 OFF 1 ON	0 or 1
<code> 0, or an integer from 1 to 10E32	0
Enable the secure code: CAL:SEC:STAT ON, 0	

### CALibration:STARt

Initiates the calibration procedure. The command does the following:

- Sends a \*RST command
- Closes the output relays on all channels
- Disables the OVP, UVP, OCP, and UCP protections
- Sets all instrument DACs to 3.5 V.
- Sets the calibration status bit

Parameter	Typical Return
(none)	(none)
Start calibration: CAL:STAR	

**CALibration:STEP <step>****CALibration:STEP?**

Steps through the different calibration processes; executes a reset after the command is sent. The query returns 0 (zero) if no step is sent.

Step	Calibrating:
1	Voltage value
2	Voltage offset value
3	10 mA value

Parameter	Typical Return
<step> number from 1-3	0-3
Execute calibration step 1: CAL:STEP 1	

**CALibration:STORE**

Stores the calibration constants in the EEPROM. This step overwrites the previous calibration constants. This command should be used *after* calibration has ended using CAL:END.

Parameter	Typical Return
(none)	(none)
Store the calibration constants: CAL:STOR	

**CALibration:STRing <"string">****CALibration:STRing?**

Stores a message in calibration memory. Common messages include the last calibration date, calibration due date, or calibration contact information. You can perform this query regardless of whether the instrument is secured.

Parameter	Typical Return
Quoted string of up to 128 characters	"Default Calibration"
To store a cal string: CAL:STR: "Calibration must be performed in the cal lab."	

**CALibration:VALue? <step>**

Returns the reference calibration constants of the specified step. Values are either in volts or amps, depending on the step. This allows you to query the reference calibration values before doing a new calibration to see how far the references have shifted.

Parameter	Typical Return
<step> number from 1 - 3	calibration constant (V or I)
Returns the calibration constant for step 1: CAL:VAL? 1	

### CALibration:VERification:END

Ends the verification process. This command should be used *after* the SENSE:VERify:AVailable command returns a one (1) to indicate that the calibration verification has completed.

Parameter	Typical Return
(none)	(none)
End channel verification: CAL:VER:END	

- If an ABORt, \*RST or device clear command is sent while verification is in progress, all channel settings will revert to their default settings.

### CALibration:VERification:STARt <channel>

Initiates the channel verification procedure on the specified channels.

Parameter	Typical Return
<channel> the channel to verify: from 1 - 32	1
Start channel verification: CAL:VER:STAR 1	

### CALibration:VERification:VOLTage <voltage>

#### CALibration:VERification:VOLTage?

Used to enter the voltage limit for verification. All channels included in channel verification will be set to this limit.

Parameter	Typical Return
<voltage> the voltage limit for the active channels	<voltage>
Set the voltage limit for channel verification: CAL:VER:VOLT 4.5)	

- An error is returned if the channel voltage exceeds the voltage limit.

### CALibration:VERification:MEASure:INITiate <time>, <tint>

Initiates a measurement with the specified input parameters. The front panel Test light flashes orange when this command is executed.

Parameter	Typical Return
<time> verification duration in seconds	1
<tint> between samples in seconds, from 1 to 250	1

Set the time limit and time interval for verification: `CAL:MEAS:TINT 10, 10`

- The results can be returned with the FETCh commands (i.e. FETC:VOLT:LAT?, FETC:CURR:LOG?).

### CALibration:WIRE:RESistance:AUTO

Runs auto-calibration of cable resistance on all 32 channels. This command takes about 18 minutes.

#### NOTE

**IMPORTANT** Disconnect all LI cells from the cell cables. Short the ends of the cell cables together.

Parameter	Typical Return
(none)	(none)

Start wire resistance calibration: `CAL:WIRE:RES:AUTO`

- Wire resistance values can be retrieved using `SENSe:WIRE:RESistance:CONFigure?` query.
- `CALibration:WIRE:RESistance:SAVE` must be sent to place the values in non-volatile memory.
- Flashes the **Test** light orange, and sets the calibration bit while running.

### CALibration:WIRE:RESistance:SAVE <value>

Saves the wire resistance values to the specified file location in non-volatile memory.

#### NOTE

**IMPORTANT** Wire resistance values are reset to 0 after a factory reset (\*RST) and at instrument power on. If this occurs before the new calibration values are saved they will be irretrievably lost.

Parameter	Typical Return
<value> resistance file name from 1 - 5	(none)

Save the wire resistance values in location 1: `CAL:WIRE:RES:SAVE 1`

- This includes any changed values from the `SENSe:WIRE:RESistance:CONFigure` command.
- To use the wire resistances after having performed the wire resistance calibration, a subsequent `INITiate:TEST:MATChed` command must be performed without issuing a factory reset \*RST.



**CALibration:WIRE:RESistance:LOAD <value>**

Loads the wire resistance values from the specified file location.

Parameter	Typical Return
<value> resistance file name from 1 - 5	(none)
Loads the wire resistance values in location 1: CAL:WIRE:RES:LOAD 1	

- To use the wire resistances from a loaded resistance file, a subsequent **INITiate:TEST:MATChed** command must be performed without issuing a factory reset \*RST.

**CALibration:WIRE:RESistance:CLEAr**

Resets all the volatile wiring resistance values to 0 (zero). You must load a wire resistance file or run auto-calibration in order to use non-zero resistance values.

Parameter	Typical Return
(none)	(none)
Resets the wire resistance calibration values to zero: CAL:WIRE:RES:CLE	

- Turning power on and the \*RST will also reset all wiring resistance values to zero.
- Values saved to non-volatile memory are not cleared.

## Common Commands

### ABORt

Aborts a measurement in progress, returning the instrument to the trigger idle state.

Parameter	Typical Return
(none)	(none)
Abort the measurement in progress: <code>ABOR</code>	

### \*CAL?

Transfers the calibration values to the instrument channels. This calibration is automatic and can take up to 1 hour. Returns a 0 (zero) when successful, and an error code otherwise.

#### NOTE

**IMPORTANT** Remove all connections from the **CAL** connector on the rear panel of the BT2152A before performing the channel calibration.

Parameter	Typical Return
(none)	0
Initiate transfer of calibration values to channels: <code>*CAL?</code>	

- The unit must pass self-test, which is run at the start of channel calibration. If self-test (`*TST?`) does not pass, channel calibration will abort.
- The unit must be warmed up. A warm up time of **1 hour** is required before the unit can be calibrated. The **Ready** indicator must be green, otherwise `*CAL?` will abort.
- If channel calibration fails, an error will be placed in the error queue with the channel number that failed along with measurement information detailing the issue. Use `SYSTem:ERRor?` to read the error queue. See [SCPI Error Messages](#) for more information.
- Sets the calibration status bit.

### \*CLS

*Clear Status Command.* Clears the **event registers** in all register groups. Also clears the Status Byte and Error Queue. If `*CLS` immediately follows a program message terminator (<NL>), then the Output Queue and the MAV bit are also cleared. Refer to [Status Tutorial](#) for more information.

Parameter	Typical Return
(none)	(none)
Clear Event register bits, Status byte, and Error queue: <code>*CLS</code>	

**\*IDN?**

*Identification Query.* Returns instrument's identification string, which contains four comma-separated fields. The first field is the manufacturer's name, the second field is the instrument model number, the third field is the serial number, and the fourth field is the firmware revision.

Parameter	Typical Return
(none)	<ASCII string with comma-separated fields>

Return the instrument's identification string: `*IDN?`

- Response format: Keysight Technologies,BTxxxxA,<serial number>,<revision codes>
- Typical return: Keysight Technologies,BT2152A,MY06009010,A.01.51-60-04-10  
where:
  - A.01 = major firmware revision
  - .51 = minor firmware revision
  - 60 = primary FPGA revision
  - 04 = secondary FPGA revision
  - 10 = mainboard ID

**\*OPC?**

Returns a 1 to the output buffer when all pending operations complete. The response is delayed until all pending operations such as the INIT:TEST or calibration commands complete.

Parameter	Typical Return
(none)	1

Return a 1 when commands complete: `*OPC?`

- The purpose of this command is to synchronize your application with the instrument.
- Other commands cannot be executed until this command completes.

**\*RST**

*Reset Command* Resets the instrument to pre-defined values that are either typical or safe. These settings are described in **Factory Reset State**.

Parameter	Typical Return
(none)	(none)

Reset the instrument: `*RST`

- `*RST` forces the ABORt command. This cancels any measurement actions presently occurring.
- Allow at least 4 seconds for the `*RST` to complete. Set the IO timeout to >4 seconds.

**\*TST?**

*SelfTest Query*. Performs an instrument self-test. A 0 (zero) indicates the instrument passed self-test. If self-test fails, one or more error messages will provide additional information. Use **SYSTem:ERRor?** to read the error queue. See **SCPI Error Messages** for more information.

Parameter	Typical Return
(none)	0 or 1
Perform self-test: <b>*TST?</b>	

**\*WAI**

Pauses additional command processing until all pending operations such as the INIT:TEST commands are complete. See **OPC** for more information.

Parameter	Typical Return
(none)	(none)
Wait until all pending operations complete. <b>*WAI</b>	

- **\*WAI** can only be aborted by sending the instrument a Device Clear command.

## Digital Commands

Digital commands program the digital control port on the rear panel of the instrument. The [SOURce:] keyword is optional.

### [SOURce:]DIGital:INPut:DATA?

Reads the state of the digital control port. Returns the binary-weighted value of the state of pins 1 through 7 in bits 0 through 6 respectively.

Parameter	Typical Return
(none)	<bit value>
Reads the state of the digital control port: DIG:INP:DATA?	

### [SOURce:]DIGital:OUTPut:DATA <value>

### [SOURce:]DIGital:OUTPut:DATA?

Sets the state of the digital control port. This only affects the pins whose function has been set to Digital IO operation. The port has seven signal pins and a digital ground pin. In the binary-weighted value that is written to the port, the pins are controlled according to the following bit assignments:

Pin	1	2	3	4	5	6	7
Bit number	0	1	2	3	4	5	6
Decimal value	1	2	4	8	16	32	64

Bit values corresponding to digital port pins that are not configured as DIO are ignored.

Parameter	Typical Return
0 – 127, *RST 0	<bit value>
Programs pins 1, 3, and 5 on: DIG:OUTP:DATA?	

### [SOURce:]DIGital:PIN<1-7>:FUNctIon <function>

### [SOURce:]DIGital:PIN<1-7>:FUNctIon?

Sets the pin function. The functions are saved in non-volatile memory.

<b>DIO</b>	Digital input/output mode
<b>DINPut</b>	Digital input-only mode.
<b>FAULt</b>	Pin 1 functions as an isolated fault output. Pin 2 is common for pin 1
<b>INHibit</b>	Pin 3 functions as an inhibit input.

Parameter	Typical Return
DIO DINPut FAULt INHibit	DIO, DINP, FAUL, INH
Sets pin 1 to FAULt mode: DIG:PIN1:FUNC FAUL	

**[SOURce:]DIGital:PIN<1-7>:POLarity POSitive|NEGative**  
**[SOURce:]DIGital:PIN<1-7>:POLarity?**

Sets the pin polarity. **POSitive** means a logical true signal is a voltage high at the pin. For trigger inputs and outputs, POSitive means a rising edge. **NEGative** means a logical true signal is a voltage low at the pin. For trigger inputs and outputs, NEGative means a falling edge. The pin polarities are saved in non-volatile memory.

Parameter	Typical Return
POSitive NEGative	POS or NEG
Sets pin 1 to POSitive polarity: DIG:PIN1:POL POS	

## Fetch Commands

Fetch commands return measurement data that has been acquired once a test has been started using the **INITiate:TEST** commands. They also return measurement data from an external thermistor connected to the rear panel TEMP input.

### **FETCh:CURRent:LATest? (@<chanlist>)**

### **FETCh:VOLTage:LATest? (@<chanlist>)**

Returns the most recent measurement for the specified channels in ASCII.

Parameter	Typical Return
(none)	Comma-separated values from specified channels
<chanlist> active channels from 1 - 32	(none)
Returns the latest current measurement: <code>FETC:CURR:LAT? (@1:32)</code> Returns the latest voltage measurement: <code>FETC:VOLT:LAT? (@1:32)</code>	

- The FETCh? query does not erase measurements from the reading memory. You can send the query multiple times to retrieve the same data. 8192 is the maximum number of ASCII values that can be returned in any one call.
- You can store up to 345,600 measurements per channel in the reading memory.
- The instrument clears all measurements from reading memory whenever INIT is executed.
- If INITiate:TEST:MATChed has been configured for a different channel group than the channel group specified in this command, non-active channels will return +9.91000000e37 (not a number).

### **FETCh:CURRent:LOG? <values/chan> [,<offset/chan>], (@<chanlist>)**

### **FETCh:VOLTage:LOG? <values/chan> [,<offset/chan>], (@<chanlist>)**

Returns the current or voltage measurement log for the specified channels in ASCII.

Parameter	Typical Return
<values/chan> number of readings returned per channel	Multiple comma-separated values from specified channels
<offset/chan> optional value that offsets or skips the number of readings returned from the beginning of the data log	(none)
<chanlist> active channels from 1 - 32	(none)
Returns 10 current readings per channel: <code>FETC:CURR:LOG? 10, (@1:32)</code> Returns 10 voltage readings per channel: <code>FETC:VOLT:LOG? 10, (@1:32)</code>	

- The readings are returned sequentially in channel groups (i.e. x,x,x,x,x,x,x, y,y,y,y,y,y, ....)  
Where x represents all measurements for channel 1, y represents all measurements for channel 2 etc.
- The <values/chan> parameter specifies the number of readings. So, for example, if (@1:4) is the specified channel list and values/chan is specified as 10, a total of 40 values will be returned.
- If an <offset/chan> value of 5 had been specified, the first 5 readings in each channel log would not have been returned.
- The FETCh? query does not erase measurements from the reading memory. You can send the query multiple times to retrieve the same data. 8192 is the maximum number of ASCII values that can be returned in any one call.
- You can store up to 345,600 measurements per channel in the reading memory.
- The instrument clears all measurements from reading memory whenever INIT is executed.
- If INITiate:TEST:MATCHed has been configured for a different channel group than the channel group specified in this command, non-active channels will return +9.91000000e37 (not a number).

### **FETCh:CURRent:LOG:BINary? <values/chan> (@<chanlist>)**

### **FETCh:VOLTage:LOG:BINary? <values/chan> (@<chanlist>)**

Returns the current or voltage measurement log for the specified channels in binary. These commands allow you to return all the data instead of being limited to 8192 values like ASCII readings. Use the **FORMat:BOReR** command to format the binary data.

Parameter	Typical Return
<values/chan> number of readings returned per channel	<binary data string>
<chanlist> active channels from 1 - 32	(none)
Returns 10 current readings per channel in binary: FETC:CURR:LOG:BIN? 10, (@1:32)	
Returns 10 voltage readings per channel in binary: FETC:VOLT:LOG:BIN? 10, (@1:32)	

- The readings are returned sequentially in channel groups (i.e. xxxxxxxxyyyyyyyy ....)  
Where x represents all measurements for channel 1, y represents all measurements for channel 2 etc.  
Each data point takes up 64 bits. The values returned are 64-bit floating point numbers.
- The <values/chan> parameter specifies the number of readings. So, for example, if (@1:4) is the specified channel list and values/chan is specified as 10, a total of 40 values will be returned.
- The FETCh? query does not erase measurements from the reading memory.
- You can store up to 345,600 measurements per channel in the reading memory.
- The instrument clears all measurements from reading memory whenever INIT is executed.
- If INITiate:TEST:MATCHed has been configured for a different channel group than the channel group specified in this command, non-active channels will return +9.91000000e37 (not a number).



## FETCh:CURRent:LOG:POINts? FETCh:VOLTage:LOG:POINts?

Returns the number of readings available per channel of the active channels specified in the INIT command.

Parameter	Typical Return
(none)	4020
Returns the number of current readings available: FETC:CURR:LOG:POIN?	
Returns the number of voltage readings available: FETC:VOLT:LOG:POIN?	

- If you attempt to return more readings than are available, an error will be generated. You must include any offset/chan values in the total number of readings available.

## FETCh:PROBecheck? (@<chanlist>)

Returns the boolean results of the probe check test.

Parameter	Typical Return
(none)	Comma-separated boolean values for the specified channels 0 indicates a cell is NOT present 1 indicates a cell is present
<chanlist> active channels from 1 - 32	(none)
Returns the probe check results for channels 1-32: FETC:PROB? (@1:32)	

- If INITiate:TEST has been configured for a different channel group than the channel group specified in this command, non-active channels will return 0.

## FETCh:TEMPerature:LATest?

Returns the most recent temperature of the external thermistor connected to the rear panel TEMP input (see [Rear View](#)).

Parameter	Typical Return
(none)	Comma-separated values from specified channels
Returns the latest external temperature: FETC:TEMP:LAT?	

- Same as [SYSTem:TEMPerature? EXTernal](#)
- The FETCh? query does not erase measurements from the reading memory. You can send the query multiple times to retrieve the same data. 8192 is the maximum number of ASCII values that can be returned in any one call.

- You can store up to 345,600 measurements in the reading memory.
- The instrument clears all measurements from reading memory whenever INIT is executed.

### **FETCh:TEMPerature:LOG? <values> [,<offset>]**

Returns the temperature measurement log of the external thermistor in ASCII.

Parameter	Typical Return
<values> the number of reading to return	Multiple comma-separated values
<offset> optional value that offsets or skips the number of readings returned from the beginning of the data log	(none)
Skips 5, then returns the next 10 temperature readings: <code>FETC:TEMP:LOG? 10, 5</code>	

- The FETch? query does not erase measurements from the reading memory. You can send the query multiple times to retrieve the same data. 8192 is the maximum number of ASCII values that can be returned in any one call.
- You can store up to 345,600 measurements per channel in the reading memory.
- The instrument clears all measurements from reading memory whenever INIT is executed.

### **FETCh:TEMPerature:LOG:BINary? <values>**

Returns the temperature measurement log of the external thermistor in binary. This command allows you to return all the data instead of being limited to 8192 values like ASCII readings. Use the **FORMat:BOReR** command to format the binary data.

Parameter	Typical Return
<values> number of reading to return	<binary data string>
Returns 10 temperature readings in binary: <code>FETC:TEMP:LOG:BIN? 10</code>	

- Each data point (value) takes up 64 bits. The values returned are 64-bit floating point numbers.
- The FETch? query does not erase measurements from the reading memory.
- You can store up to 345,600 measurements per channel in the reading memory.
- The instrument clears all measurements from reading memory whenever INIT is executed.

### **FETCh:TEMPerature:LOG:POINts?**

Returns the number of readings available in the temperature measurement log of the external thermistor.

Parameter	Typical Return
(none)	4020
Returns the number of temperature readings available: <code>FETC:TEMP:LOG:POIN?</code>	

- If you attempt to return more readings than are available, an error will be generated. You must include any offset values in the total number of readings available.

### **FETCh:VOLTage:OCV? (@<chanlist>)**

Retrieves the open-circuit voltage (OCV) values. This command is only applicable when used in conjunction with the **INITiate:TEST:OCV** command.

Parameter	Typical Return
(none)	Comma-separated OCV values for the specified channels
<chanlist> active channels from 1 - 32	(none)
Returns the OCV values at the start of the test: <code>FETC:VOLT:OCV? (@1:32)</code>	

- If **INITiate:TEST:MATChed** has been configured for a different channel group than the channel group specified in this command, non-active channels will return `+9.91000000e37` (not a number).

## Format Command

### FORMat:BORDER NORMal|SWAPped FORMat:BORDER?

Used for binary block transfers only. Selects the byte order for binary block transfers using FETCh?

Parameter	Typical Return
NORMal SWAPped; Default: SWAP	SWAP

Select the normal byte order: FORM:BORD NORM

- In the NORMal byte order, the most-significant byte (MSB) of each data point is returned first and the least significant byte is returned last.
- In the SWAPped byte order the least-significant byte (LSB) of each data point is returned first and the most significant byte is returned last.
- The byte order setting is stored in non-volatile memory and does not change when power has been off. The default value is restored after a reset (\*RST).
- The most common setting for this command is SWAPped.

## Initiate Commands

These commands initialize and start the discharge test.

**NOTE**

You can only execute one INIT:TEST at a time. For example, you cannot run INIT:TEST:OCV on channel 1 while running INIT:TEST:MATCH on channel 2.

**INITiate:TEST:MATChed<time>, <ovp>, <uvp>, <res>[,<tint>[,<curr>[,<ocp>]]], (@<chanlist>)**

**INITiate:TEST:MATChed? (@<chanlist>)**

Sets all parameters for the voltage matched discharge current measurement. The query form returns the present INIT:TEST:MATC parameters for each channel in the list.

Parameter	Typical Return
<time> test duration in minutes (see <b>time interval</b> between samples)	5
<ovp> over-voltage protection in volts: from 0.5 to 4.5	4.0
<uvp> under-voltage protection in volts: from 0.5 to 4.5	3.0
<res> output resistance in ohms: from 0.1 to 10	1.0
optional <tint> <b>time interval</b> between samples in seconds: from 1 to 250	1
optional <curr> initial cell current in amperes: from -10 mA to +10 mA	0.001
optional <ocp> over-current protection in amperes: from -10 mA to +10 mA	0.01
<chanlist> active channels: from 1 - 32	(none)
Configures channels 1:16 for a 6 hour test with OVP set to 4.2V, UVP set to 1.8V, output resistance 9 Ω, time interval 2s, initial cell current 0.5mA, over-current protect 1mA: INIT:TEST:MATC 360, 4.2, 1.8, 9, 2, 0.0005, 0.001, (@1:16)	

## Time Interval Parameter

The time interval <tint> parameter lets you specify an average time or time-between-samples where the samples are averaged to return a single value. The range is from 1 to 250 seconds. The default time interval is 1 second. The following table describes maximum test times for some typical time intervals. To calculate the maximum test time in hours use  $\text{Hours}=(\text{tint} * 72)$

Time interval	Maximum test time
1 second (default)	3 days
10 seconds	30 days
60 seconds	180 days
250 seconds	750 days

The following table gives the rate at which data can be returned based on the specified time interval

Time interval in seconds	Data update rate in seconds
1 - 4	4
5-8	8
9- 16	16
17-32	32
33-64	64
65-128	128
129-250	256

**INITiate:TEST:OCV <ovp>, <uvp>, <ocp>, <tint>, (@<chanlist>)**  
**INITiate:TEST:OCV? (@<chanlist>)**

Initiates an open-circuit voltage test. The results can be retrieved with **FETCh:VOLTage:OCV?**. The query form returns the present INIT:TEST:OCV parameters for each channel in the list.

Parameter	Typical Return
<ovp> over-voltage protection in volts: from 0.5 to 4.5	4.0
<uvp> under-voltage protection in volts: from 0.5 to 4.5	3.0
<ocp> over-current protection in amperes: from -10 mA to +10 mA	0.01
<tint> <b>time interval</b> between samples in seconds: from 1 to 250	1
<chanlist> active channels: from 1 - 32	(none)

Configures channels 1:16 for an open-circuit voltage test with OVP set to 4.2V, UVP set to 1.8V, over-current protect 1mA, and time interval 2s: INIT:TEST:OCV 4.2, 1.8, 0.001, 2, (@1:16)

**INITiate:TEST:PROBecheck (@<chanlist>)**

Initiates a probe check test to determine if a cell is connected to the specified channels in the channel list. Send **FETCh:PROBecheck?** to return the results of the probe check. Send **SENSe:PROBecheck:AVAlable?** to check whether a probe check test has completed.

Parameter	Typical Return
(none)	(none)

Initiate a probe check test on 16 channels: INIT:TEST:PROB (@1:16)

## LXI Command

**LXI:IDENtify[:STATe] 0|OFF|1|ON**

**LXI:IDENtify[:STATe]?**

Turns the front panel LXI identify indicator on or off. When turned on, the "LAN" status indicator on the front panel blinks on and off to identify the instrument that is being addressed.

Parameter	Typical Return
0 OFF 1 ON	0 or 1
To blink the front panel LXI indicator: LXI:IDENT ON	

## Output Commands

### OUTPut:INHibit:MODE LATChing|LIVE|OFF OUTPut:INHibit:MODE?

Sets the operating mode of the Inhibit Input digital pin (pin 3). The inhibit function disconnects or connects the input channels in response to an external signal on the Inhibit input pin. See [Using the Digital Port](#).

**LATChing** - a logic-true signal on the Inhibit input causes the input channels to disconnect. The channels remain disconnected until the Inhibit input is returned to logic-false and the latched INH status bit is cleared by sending the OUTPut:PROTection:CLEar command.

**LIVE** - allows the input channels to follow the state of the Inhibit input. When the Inhibit input is true, the channels are disconnected. When the Inhibit input is false, the channels are re-connected.

**OFF** - The Inhibit input is ignored.

Parameter	Typical Return
LATChing LIVE OFF; *RST OFF	LATC, LIVE, or OFF
Sets the Inhibit Input to Live mode: <code>OUTP:INH:MODE LIVE</code>	

### OUTPut:PROTection:CLEar

Resets any protection events that have occurred. The protection settings are specified in the [INIT:TEST](#) commands.

Parameter	Typical Return
(none)	(none)
Clear instrument protection: <code>OUTP:PROT:CLE</code>	



## Sense Commands

### SENSe:OCV:AVAIable?

Returns the availability of the open-circuit voltage measurement. This command is only applicable when used in conjunction with the **INITiate:TEST:OCV** command.

A one (1) is returned when the OCV measurement is completed. A zero (0) is returned when the OCV measurement is unavailable or if the command was used with any other INIT command besides INITiate:TEST:OCV.

Parameter	Typical Return
(none)	0 or 1
Returns the availability of OCV : SENS:OCV:AVAI?	

### SENSe:PROBecheck:AVAIable?

Returns the availability of the probe check test.

A one (1) is returned when the probe check command is completed. A zero (0) is returned when the probe check command is unavailable.

Parameter	Typical Return
(none)	0 or 1
Returns the availability of the Probe check test: SENS:PROB:AVAI?	

### SENSe:THERmistor:CONFigure <temp>, <resistance>, <beta>

#### SENSe:THERmistor:CONFigure?

Specifies the parameters for the external thermistor connected to the rear panel temperature sensor input (see **Thermistor Connections**).

Parameter	Typical Return
<temp> the nominal temperature of the thermistor in degrees C, from -272.15 to 273.15	25° C
<resistance> the nominal resistance in ohms, from 1 to 1,000,000	10,000
<beta> value from 1 to 1,000,000	4073
Specifies the nominal temperature and resistance: SENS:THER:CONF 25, 10000, 4073	

**SENSe:TTIMe:REMAining?**

Returns the remaining test time in minutes for the test that is presently running.

Parameter	Typical Return
(none)	2.200000E+02
Returns the remaining test time: <code>SENSe:TTIMe:REMAining?</code>	

**SENSe:VERification:AVAIable?**

Returns the state of the verification procedure. A one (1) is returned when the verification procedure is completed. A zero (0) is returned when the verification is in progress.

Parameter	Typical Return
(none)	0 or 1
Returns the state of the verification procedure: <code>SENSe:VERification:AVAIable?</code>	

**SENSe:WIRE:RESistance:AVAIable?**

Returns the state of the **wire resistance calibration**. A one (1) is returned when the wire resistance calibration is completed and the wire resistance values are available. A zero (0) is returned when the calibration is in progress.

Parameter	Typical Return
(none)	0 or 1
Returns the state of the wire resistance calibration: <code>SENSe:WIRE:RESistance:AVAIable?</code>	

**SENSe:WIRE:RESistance:CONFigure <resistance>, (@<chanlist>)****SENSe:WIRE:RESistance:CONFigure? (@<chanlist>)**

Specifies the resistance of the wiring of each channel. Refer to **Wire resistance calibration** for more information.

Parameter	Typical Return
<resistance> the resistance of the wire in ohms, from 0 Ω to 5 Ω; Default: 0 Ω	0
<chanlist> active channels from 1 - 32	(none)
Specifies a wire resistance of 0.188Ω for channel 1: <code>SENSe:WIRE:RESistance:CONFigure 0.188, (@1)</code>	

**NOTE**

**Wire resistance calibration** is required when all RJ45 connectors have been installed in the instrument. Wire resistance calibration is also required whenever any RJ45 connector is unplugged, reinserted, or reseated.

## Status Commands

Status commands let you determine the operating condition of the instrument at any time. Refer to [Status Tutorial](#) for more information.

### STATus:ALARm[EVEnt]?

Returns the sum of the bits in the event register for the Status Alarm Register group. An event register is a read-only register that latches events from the condition register. While an event bit is set, subsequent events corresponding to that bit are ignored. The register bits are cleared when you read the register.

Parameter	Typical Return
(none)	<bitvalue>
Read the event alarm register: STAT:ALAR?	

- Once a bit is set, it remains set until cleared by reading the event register or by sending \*CLS (clear status).
- The value returned is the binary-weighted sum of all bits set in the register.

### STATus:ALARm:CONDition?

Returns the sum of the bits in the condition register for the Status Alarm Register group. Condition register bits are updated in real time; they are neither latched nor buffered. This register is read-only; bits are not cleared when read. The alarm status group consists of the OVP, UVP, and OCP status bits in the Status Questionable registers.

Parameter	Typical Return
(none)	<bitvalue>
Read the event alarm register: STAT:ALAR:COND?	

- The condition register bits reflect the current condition. If a condition goes away, the corresponding bit is cleared in the condition register.
- The value returned is the binary-weighted sum of all bits set in the register.

### STATus:ALARm:ENABLE <value>

#### STATus:ALARm:ENABLE?

Enables bits in the condition register for the Status Alarm Register group. The selected bits are then reported to the Status Byte. An enable register defines which bits in the event register will be reported to the Status Byte register group. You can write to or read from an enable register.

Parameter	Typical Return
A decimal value that corresponds to the binary-weighted sum of the bits in the register.	+259 (bit 1, 2 and 8 set)
Enable bits 1, 2, and 8 in the enable register: STAT:ALAR:ENAB 259	

- Use the <value> parameter to specify which bits will be reported to the Status Byte. The decimal value specified corresponds to the binary-weighted sum of the bits you wish to enable in the register.
- The enable setting value is stored in nonvolatile memory.

### STATus:ALARm:CONDiton:CURRent?

Returns the sum of the bits feeding the over-current (OCP) condition bit in the Status Alarm Register group. This is a 32-bit unsigned value, where each bit represents one channel. Channel 1 is represented by bit 0; channel 32 by bit 31.

Parameter	Typical Return
(none)	<bit value>
Read the event alarm register: STAT:ALAR:COND:CURR?	

- The condition register bits reflect the current condition. If a condition goes away, the corresponding bit is cleared in the condition register.
- The value returned is the binary-weighted sum of all bits set in the register.

### STATus:ALARm:CONDiton:VOLTage?

Returns the sum of the bits feeding the over-voltage (OVP) condition bit in the Status Alarm Register group. This is a 32-bit unsigned value, where each bit represents one channel. Channel 1 is represented by bit 0; channel 32 by bit 31.

Parameter	Typical Return
(none)	<bit value>
Read the event alarm register: STAT:ALAR:COND:VOLT?	

- The condition register bits reflect the current condition. If a condition goes away, the corresponding bit is cleared in the condition register.
- The value returned is the binary-weighted sum of all bits set in the register.

### STATus:ALARm:CONDiton:VOLTage:UNDer?

Returns the sum of the bits feeding the under-voltage (UVP) condition bit in the Status Alarm Register group. This is a 32-bit unsigned value, where each bit represents one channel. Channel 1 is represented by bit 0; channel 32 by bit 31.

Parameter	Typical Return
(none)	<bit value>
Read the event alarm register: <code>STAT:ALAR:COND:VOLT:UND?</code>	

- The condition register bits reflect the current condition. If a condition goes away, the corresponding bit is cleared in the condition register.
- The value returned is the binary-weighted sum of all bits set in the register.

### **STATus:ALARm:ENABLE <value>** **STATus:ALARm:ENABLE?**

Enables bits in the condition register for the Status Alarm Register group. The selected bits are then reported to the Status Byte. An enable register defines which bits in the event register will be reported to the Status Byte register group. You can write to or read from an enable register.

Parameter	Typical Return
A decimal value that corresponds to the binary-weighted sum of the bits in the register.	+16 (bit 4 set)
Enable bit 4 (value 16) in the enable register: <code>STAT:ALAR:ENAB 16</code>	

- Use the <value> parameter to specify which bits will be reported to the Status Byte. The decimal value specified corresponds to the binary-weighted sum of the bits you wish to enable in the register. For example, to enable bit 4 (decimal value = 16) and bit 8 (decimal value = 256), the corresponding decimal value would be 272 (16 + 256).
- The enable setting value is stored in nonvolatile memory.

### **STATus:OPERation[:EVENT]?**

Returns the sum of the bits in the event register for the Standard Operation Register group. An event register is a read-only register that latches events from the condition register. While an event bit is set, subsequent events corresponding to that bit are ignored. The register bits are cleared when you read the register.

Parameter	Typical Return
(none)	<bit value>
Read the operation event status register: <code>STAT:OPER?</code>	

- Once a bit is set, it remains set until cleared by reading the event register or by sending \*CLS (clear status).
- The value returned is the binary-weighted sum of all bits set in the register.

**STATus:OPERation:CONDition?**

Returns the sum of the bits in the condition register for the Standard Operation Register group. This register is read-only; bits are not cleared when read.

A condition register continuously monitors the state of the instrument. Condition register bits are updated in real time; they are neither latched nor buffered

Parameter	Typical Return
(none)	<bitvalue>
Read the operation status condition register: STAT:OPER:COND?	

- The condition register bits reflect the current condition. If a condition goes away, the corresponding bit is cleared.
- The value returned is the binary-weighted sum of all bits set in the register.

**STATus:OPERation:ENABLE <value>****STATus:OPERation:ENABLE?**

Sets and queries bits in the enable register for the Standard Operation Register group. The enable register is a mask for enabling specific bits from the Operation Event register to set the OPER (operation summary) bit of the Status Byte register. STATus:PRESet clears all bits in the enable register.

Parameter	Typical Return
A decimal value that corresponds to the binary-weighted sum of the bits in the register.	+16 (bit 4 set)
Enable bit 4 in the enable register: STAT:OPER:ENAB 16	

- \*CLS does not clear the enable register, but does clear the **event register**.

## System Commands

**SYSTem:COMMunicate:ENABLE 0|OFF|1|ON, <interface>**

**SYSTem:COMMunicate:ENABLE? <interface>**

Disables or enables the USB or LAN interface. You must cycle power for the changes to take effect.

Parameter	Typical Return
0 OFF 1 ON Default: ON for all interfaces	0 or 1
<interface> USB LAN	(none)
Disable the USB interface: SYST:COMM:ENAB OFF,USB	

- If you disable the LAN interface, none of the associated LAN services will start at power-on.
- The interface enable settings are stored in nonvolatile memory.

### SYSTem:COMMunicate:LAN:CONTRol?

Returns the initial socket control connection port number. This connection is used to send and receive commands and queries.

Parameter	Typical Return
(none)	<port #> (0 if sockets not supported)
Query the Control connection port number: SYST:COMM:LAN:CONT?	

- Use the Control socket connection to send a Device Clear (DCL) to the instrument or to detect pending Service Request (SRQ) events.

**SYSTem:COMMunicate:LAN:DHCP 0|OFF|1|ON**

**SYSTem:COMMunicate:LAN:DHCP?**

Disables or enables instrument's use of DHCP. DHCP stands for Dynamic Host Configuration Protocol, a protocol for assigning dynamic IP addresses to networked devices. With dynamic addressing, a device can have a different IP address every time it connects to the network.

**ON** - the instrument tries to obtain an IP address from a DHCP server. If a DHCP server is found, it assigns a dynamic IP address, Subnet Mask, and Default Gateway to the instrument.

**OFF or DHCP unavailable** - the instrument uses the static IP address, Subnet Mask, and Default Gateway during power-on.

Parameter	Typical Return
0 OFF 1 ON, Default: ON	0 or 1
Disable DHCP: SYST:COMM:LAN:DHCP OFF	

- If a DHCP LAN address is not assigned by a DHCP server, then an Auto-IP address is obtained after approximately 2 minutes. An Auto-IP address has the form 169.254.nnn.nnn.
- The DHCP setting is stored in non-volatile memory.

**NOTE**

If you change this setting, you must send SYSTem:COMMunicate:LAN:UPDate to activate the new setting.

**SYSTem:COMMunicate:LAN:DNS[1|2] "<address>"****SYSTem:COMMunicate:LAN:DNS[1|2]? [CURRent|STATic]**

Assigns the static IP addresses of Domain Name System (DNS) servers. A primary and a secondary server address may be assigned. If DHCP is available and enabled, DHCP will auto-assign these server addresses. These auto-assigned server addresses take precedence over the static addresses assigned with this command. Contact your LAN administrator for details.

The optional query **CURRent** parameter returns the address currently being used by the instrument. The optional query **STATic** parameter returns the static address from non-volatile memory. This address is used if DHCP is disabled or unavailable.

Parameter	Typical Return
Command: "nnn.nnn.nnn.nnn". Default: "0.0.0.0".	(none)
Query: [CURRent STATic]. Default: CURRent	"198.105.232.4"
To set a static primary DNS address: SYST:COMM:LAN:DNS "198.105.232.4"	

- The assigned DNS server addresses are used if DHCP is disabled or unavailable. Otherwise, the DNS server addresses are auto-assigned by DHCP.
- The DNS server addresses are stored in non-volatile memory.

**NOTE**

If you change this setting, you must send SYSTem:COMMunicate:LAN:UPDate to activate the new setting.

**SYSTem:COMMunicate:LAN:DOMain?**

Returns the domain name assigned to the instrument.

Parameter	Typical Return
(none)	"example.com"
Return the domain name used by the instrument: SYST:COMM:LAN:DOM?	

- If Dynamic Domain Name System (DNS) is available on your network and your instrument uses DHCP, the domain name is assigned by the Dynamic DNS service at power-on.
- A null string ("") indicates that no domain name is assigned.



**SYSTem:COMMunicate:LAN:GATeway "<address>"**  
**SYSTem:COMMunicate:LAN:GATeway? [CURRent|STATic]**

Assigns a default gateway for the instrument. The specified IP Address sets the default gateway, which allows the instrument to communicate with systems that are not on the local subnet. Thus, this is the default gateway where packets are sent that are destined for a device not on the local subnet, as determined by the Subnet Mask setting. Contact your LAN administrator for details.

The optional query **CURRent** parameter returns the address currently being used by the instrument. The optional query **STATic** parameter returns the static address from non-volatile memory. This address is used if DHCP is disabled or unavailable.

Parameter	Typical Return
Command: "nnn.nnn.nnn.nnn". Default: "0.0.0.0".	(none)
Query: [CURRent STATic]. Default: CURRent	"198.105.232.1"
To set a static primary DNS address: SYST:COMM:LAN:GAT "198.105.232.1"	

- If DHCP is enabled, the specified default gateway is not used. However, if the DHCP server fails to assign a valid IP address, the currently configured default gateway is used.
- The gateway address is stored in non-volatile memory.

**NOTE**

If you change this setting, you must send SYSTem:COMMunicate:LAN:UPDate to activate the new setting.

**SYSTem:COMMunicate:LAN:HOSTname "<name>"**  
**SYSTem:COMMunicate:LAN:HOSTname? [CURRent|STATic]**

Assigns a hostname to the instrument. A hostname is the host portion of the domain name, which is translated into an IP address. If Dynamic Domain Name System (Dynamic DNS) is available on your network and your instrument uses DHCP, the hostname is registered with the Dynamic DNS service at power-on. If DHCP is enabled, the DHCP server can change the specified hostname. Contact your LAN administrator for details.

The optional query **CURRent** parameter returns the name currently being used by the instrument. The optional query **STATic** parameter returns the name from non-volatile memory. This may not be the actual name used by the instrument if DHCP is enabled.

Parameter	Typical Return
String of up to 15 characters. Must start with letter (A-Z) May contain letters, numbers (0-9), or dashes ("-").	(none)
Query: [CURRent STATic]. Default: CURRent	"Keysight BT2152A"
To define a hostname: SYST:COMM:LAN:HOST "Keysight BT2152A "	

- If no hostname exists, the query returns a null string ("").
- The hostname is stored in non-volatile memory.

**NOTE**

If you change this setting, you must send `SYSTem:COMMunicate:LAN:UPDate` to activate the new setting.

---

### **SYSTem:COMMunicate:LAN:IPADdress "<address>"** **SYSTem:COMMunicate:LAN:IPADdress? [CURRent|STATic]**

Assigns a static Internet Protocol (IP) address for the instrument. If DHCP is enabled, the specified static IP address is not used. Contact your LAN administrator for details.

The optional query **CURRent** parameter returns the address currently being used by the instrument. The optional query **STATic** parameter returns the static address from non-volatile memory. This address may not be the actual address used by the instrument if DHCP is enabled.

Parameter	Typical Return
Command: "nnn.nnn.nnn.nnn".	(none)
Query: [CURRent STATic]. Default: CURRent	"169.254.149.35"
To set a static IP address: <code>SYST:COMM:LAN:IPAD "169.254.149.35"</code>	

- The IP address is stored in non-volatile memory.

**NOTE**

If you change this setting, you must send `SYSTem:COMMunicate:LAN:UPDate` to activate the new setting.

---

### **SYSTem:COMMunicate:LAN:MAC?**

Returns the instrument's Media Access Control (MAC) address as an ASCII string of 12 hexadecimal characters (0-9 and A-F) enclosed in quotation marks.

Parameter	Typical Return
(none)	"0030D3001041"
To return the MAC address: <code>SYST:COMM:LAN:MAC?</code>	

- The MAC address is also known as the link-layer address, the Ethernet (station) address, LANIC ID or Hardware Address. This is an unchangeable 48-bit address assigned by the manufacturer to each unique Internet device.

**NOTE**

Your LAN administrator may need the MAC address to assign a static IP address for this device.

---

## **SYSTem:COMMunicate:LAN:SMASk "<mask>"**

### **SYSTem:COMMunicate:LAN:SMASk? [CURRent|STATic]**

Assigns a subnet mask for the instrument to use in determining whether a client IP address is on the same local subnet. When a client IP address is on a different subnet, all packets must be sent to the Default Gateway. Contact your LAN administrator for details.

The optional query **CURRent** parameter returns the address currently being used by the instrument. The optional query **STATic** parameter returns the static address from non-volatile memory. This address is used if DHCP is disabled or unavailable..

Parameter	Typical Return
Command: "nnn.nnn.nnn.nnn". Default: "255.255.0.0".	(none)
Query: [CURRent STATic]. Default: CURRent	"255.255.0.0"
To set a subnet mask: SYST:COMM:LAN:IPAD "255.255.0.0"	

- If DHCP is enabled (SYSTem:COMMunicate:LAN:DHCP ON), the specified subnet mask is not used. However, if the DHCP server fails to assign a valid IP address, the instrument uses the Auto-IP subnet mask.
- A value of "0.0.0.0" or "255.255.255.255" indicates that subnetting is not being used.
- The subnet mask setting is stored in non-volatile memory.

#### **NOTE**

If you change this setting, you must send SYSTem:COMMunicate:LAN:UPDate to activate the new setting.

## **SYSTem:COMMunicate:LAN:TELNet:PROMpt "<string>"**

### **SYSTem:COMMunicate:LAN:TELNet:PROMpt?**

Specifies the command prompt seen when communicating with the instrument via Telnet.

Parameter	Typical Return
Quoted string of up to 15 characters. Default: "BT2152A".	"BT2152A"
To set a command prompt: SYST:COMM:LAN:TELN:PROM "BT2152A"	

- The instrument uses LAN port 5024 for SCPI Telnet sessions and port 5025 for SCPI Socket sessions.
- Telnet sessions are typically started from a host computer shell (telnet <IP\_address> <port>).  
For example: telnet 169.254.4.10 5024  
To exit a Telnet session, press <Ctrl-D>.
- This setting is stored in non-volatile memory.

## **SYSTem:COMMunicate:LAN:TELNet:WMESsage "<string>"**

### **SYSTem:COMMunicate:LAN:TELNet:WMESsage?**

Specifies the welcome message seen when communicating with the instrument via Telnet.

Parameter	Typical Return
Quoted string of up to 63 characters. Default: "Welcome to the Telnet Session".	"Welcome to the Telnet Session"
To set a command prompt: SYST:COMM:LAN:TELN:WMES "Welcome to the Telnet Session"	

- The instrument uses LAN port 5024 for SCPI Telnet sessions and port 5025 for SCPI Socket sessions.
- This setting is stored in non-volatile memory.

## **SYSTem:COMMunicate:LAN:UPDate**

Stores any changes made to the LAN settings into non-volatile memory and restarts the LAN driver with the updated settings.

Parameter	Typical Return
(none)	(none)
The following configures the instrument to use statically assigned LAN settings: SYST:COMM:LAN:DHCP OFF SYST:COMM:LAN:DNS "198.105.232.4" SYST:COMM:LAN:DNS2 "198.105.232.5" SYST:COMM:LAN:GAT "198.105.232.1" SYST:COMM:LAN:HOST "LAB1-DMM" SYST:COMM:LAN:IPAD "198.105.232.101" SYST:COMM:LAN:SMAS "255.255.255.0" SYST:COMM:LAN:WINS "198.105.232.4" SYST:COMM:LAN:WINS "198.105.232.5" SYST:COMM:LAN:UPD	
The following configures the instrument back to use DHCP: SYST:COMM:LAN:DHCP ON SYST:COMM:LAN:UPD	

- This command must be sent after changing the settings for DHCP, DNS, gateway, hostname, IP address, subnet mask, or WINS.
- Make all changes to the LAN settings before sending this command.

## **SYSTem:COMMunicate:LAN:WINS[1|2] "<address>"**

### **SYSTem:COMMunicate:LAN:WINS[1|2]? [CURRENT|STATIC]**

Assigns the static IP addresses of the Windows Internet Name System (WINS) servers. A primary and a secondary server address may be assigned. If DHCP is available and enabled, DHCP will auto-assign these server addresses. These auto-assigned server addresses take precedence over the static addresses assigned with this command. Contact your LAN administrator for details.

The optional query **CURRent** parameter returns the address currently being used by the instrument. The optional query **STATic** parameter returns the static address from non-volatile memory. This address is used if DHCP is disabled or unavailable.

Parameter	Typical Return
Command: "nnn.nnn.nnn.nnn". Default: "0.0.0.0".	(none)
Query: [CURRent STATic]. Default: CURRent	"198.105.232.4"
To set a static primary WINS address: SYST:COMM:LAN:DNS "198.105.232.4"	

- The WINS addresses are stored in non-volatile memory.

**NOTE**

If you change this setting, you must send SYSTem:COMMunicate:LAN:UPDate to activate the new setting.

**SYSTem:DATE <yyyy>, <mm>, <dd>**

**SYSTem:DATE?**

**SYSTem:TIME <hh>, <mm>, <ss>**

**SYSTem:TIME?**

SYSTem:DATE - Sets the date of the system clock. Specify the year (2000 to 2099), month (1 to 12), and day (1 to 31).

SYSTem:TIME - Sets the time of the system clock. Specify hours (0 to 23), minutes (0 to 59), and seconds (0 to 59).

Parameter	Typical Return
<yyyy>,<mm>,<dd>	+2017,+06,+30
<hh>,<mm>,<ss>	20,30,00.000
Set the date to June 30, 2017: SYST:DATE 2017,06,30	
Set the clock to 8:30 PM: SYST:TIME 20,30,0	

- The real-time clock does not adjust itself for time zone changes or daylight savings time.

**SYSTem:ERRor?**

Reads and clears one error from the error queue.

Parameter	Typical Return
(none)	+0,"No error"
Reads and clears the first error in error queue: SYST:ERR?	

- Error retrieval is first-in-first-out (FIFO), and errors are cleared as you read them.
- If more have accumulated than the queue can hold, the last error stored in the queue (the most recent error) is replaced with -350,"Error queue overflow". No additional errors are stored until you remove errors from the queue. If no errors have occurred when you read the error queue, the instrument responds with +0,"No error".
- The error queue is cleared when power is cycled. It is not cleared by a \*RST.
- Errors have the following format (the error string may contain up to 80 characters).  
`<error code>,<error string>` For a list of error codes and message strings, see [SCPI Error Messages](#).

### SYSTem:TEMPerature? EXTernal

Returns the temperature sensed across a 10 kΩ thermistor, which must be connected to the rear panel TEMP input in °C (see [Rear View](#)).

Parameter	Typical Return
EXTernal	+2.41923802E+001
Return the temperature of the external thermistor: SYST:TEMP? EXT	

- Same as [FETCh:TEMPerature:LATest?](#)
- If nothing is connected to the external temperature connector, the command will return 9.91E37.

## Status Tutorial

### Status Registers

### Alarm Channel Groups

### Alarm Status Group

### Standard Operation Group

### Status Byte Register

### Error and Output Queues

### Status Diagram

This section provides a detailed description of the individual registers and register groups. The status diagram at the end of this topic shows how the status registers and groups are interconnected.

## Status Registers

The Alarm Channel, Alarm Status, and Standard Operation groups use three different type of registers to track qualify, flag, and enable instrument events.

- A Condition register continuously monitors the state of the instrument. The bits in the condition register are updated in real time and the bits are not latched or buffered.
- An Event register latches the various events from the condition register. There is no buffering in this register; while an event bit is set, subsequent events corresponding to that bit are ignored. This is a read-only register.
- An Enable register defines which bits in the event register will be reported to the Status Byte register group. You can write to or read from an enable register.

To program individual bits in any register group, you must send a value that corresponds to the binary-weighted value of all the bits that you wish to enable. For example, to enable bit 2 (decimal value = 4) and bit 4 (decimal value = 16), the corresponding decimal value would be 20 (4 + 16). Similarly, any register queries return the binary-weighted value of the bits that have been set. For example, with bit 3 (value 8) and bit 5 (value 32) being set, the query returns +40.

## Alarm Channel Groups

These registers record signals that indicate abnormal conditions on specific channels. There are three condition groups - one for each abnormal condition: over-voltage, over-current, and under-voltage.

The group channel assignments are 32-bit unsigned values where each bit represents one channel. Channel 1 is represented by bit 0; channel 32 by bit 32. A "1" in a bit position indicates that the indicated alarm condition is true. When true, the affected channel is shut down.

The channel bits are logically-ORed into bits 0, 1, and 9 of the Alarm Status Group. The following table describes the bit assignments.

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Bit	Bit Name	Decimal Value
0	Channel 1	1
1	Channel 2	2
2	Channel 3	4
.	.	.
.	.	.
.	.	.
29	Channel 30	536870912
30	Channel 31	1073741824
31	Channel 32	2147483648

### Alarm Status Group

These register groups record signals that indicate abnormal operation. The group consists of a Condition, Event, and Enable register. The outputs of the Alarm Status group are logically-ORed into the QUEStionable summary bit (3) of the Status Byte register. Refer to **Status Registers** for a description of each register. The following table describes the bit assignments.

Bit	Bit Name	Decimal Value	Definition
0	OVP	1	Over-voltage protection
1	OCP	2	Over-current protection
2-8	not used	not used	0 is returned
9	UVP	512	Under-voltage protection
10-15	not used	not used	0 is returned

### Standard Operation Group

These register groups record signals that indicate the present operating status of the instrument. The group consists of a Condition, Event, and Enable register. The Standard Operation event register latches events relating to the operation of the unit. It is a read-only register that is cleared when read. The Standard Operation enable register functions similarly to the enable registers of the Alarm Status group. Refer to **Status Registers** for a description of each register. The following table describes the bit assignments.

Bit	Bit Name	Decimal Value	Definition
0	Calibrating	1	Instrument calibration has been initiated.
1	Warm Up	2	The instrument is warming up.



Bit	Bit Name	Decimal Value	Definition
2	Emergency Stop	4	An emergency stop condition has been activated.
3	not used	not used	0 is returned
4	Measuring	16	A cell measurement is in progress.
5-7	not used	not used	0 is returned
8	Config changed	256	The cell configuration has changes since the previous test has run.
9-11	not used		
12	Temperature unregulated	4096	The reference temperature of the instrument cannot be maintained within specifications during the execution of an INIT command.
13	Global Error	8192	A remote interface has errors in the error queue. <code>SYSTem:ERRor?</code> reads and deletes errors.
14-15	not used	not used	0 is returned

## Status Byte Register

This register summarizes the information from all other status groups as defined in the IEEE 488.2 Standard Digital Interface for Programmable Instrumentation. The following table describes the bit assignments.

Bit	Bit Name	Decimal Value	Definition
0	not used	not used	0 is returned
1	Alarm Status Summary	2	One or more Status Alarm conditions have occurred. Use <code>STATus:ALARm:EVENT?</code> to read and delete errors.
2	Error Queue	4	One or more errors in the Error Queue. <code>SYSTem:ERRor?</code> reads and deletes errors.
3	not used	not used	0 is returned
4	Message Available	16	Data is available in the instrument's output buffer.
5	not used	not used	0 is returned
6	Master Status Summary	64	One or more bits are set in the Status Byte Register and may generate a Service Request. Bits must be enabled, see *SRE.
7	Operation Status Summary	128	One or more bits are set in the Operation Status Register. Bits must be enabled, see <code>STATus:OPERation:ENABLE</code> .

## Error and Output Queues

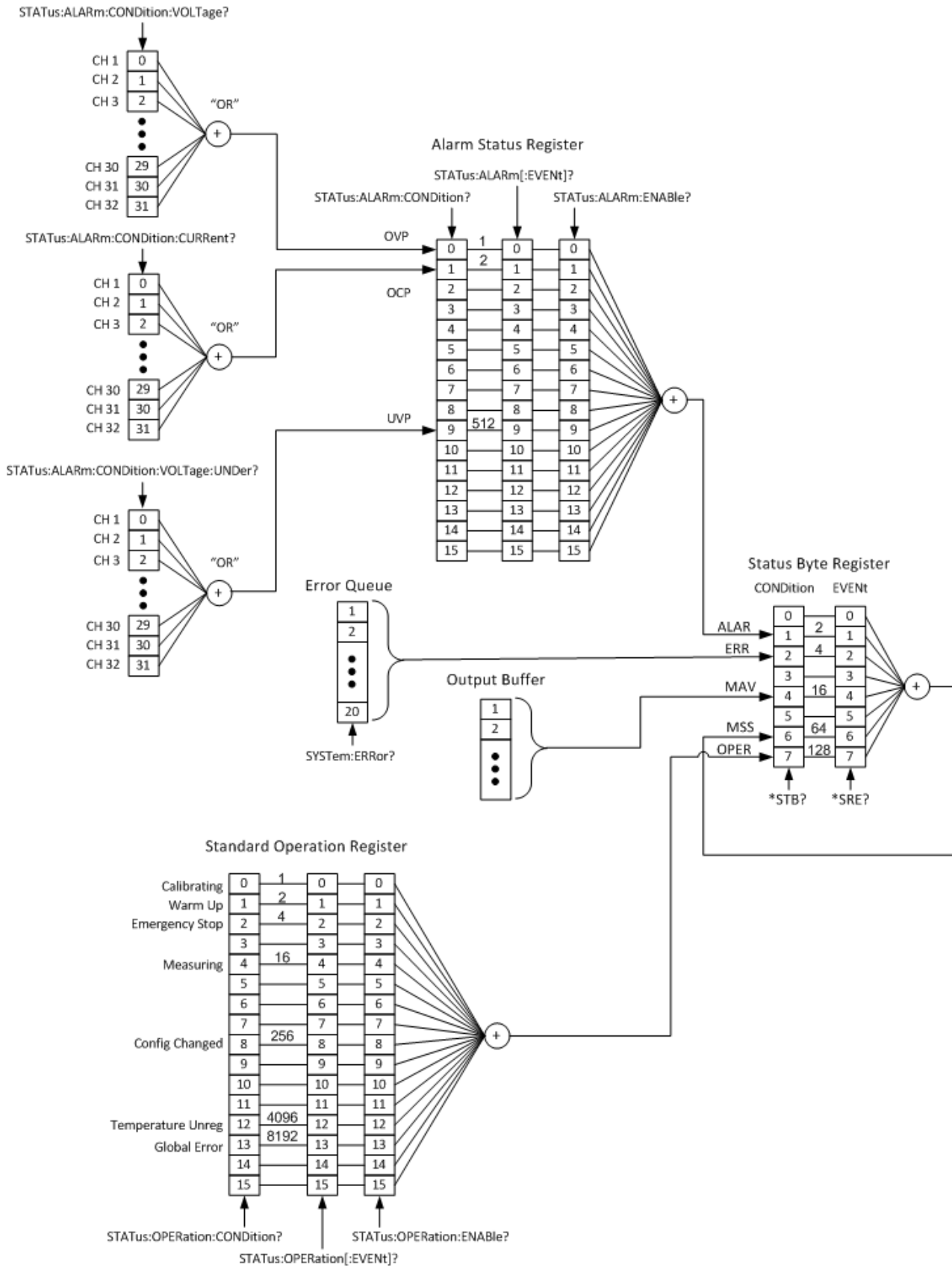
The Error Queue is a first-in, first-out (FIFO) data register that stores numerical and textual description of an error or event. Error messages are stored until they are read with **SYSTem:ERRor?** If the queue overflows, the last error/event in the queue is replaced with error -350, "Queue overflow".

The Output Queue is a first-in, first-out (FIFO) data register that stores instrument-to-controller messages until the controller reads them. Whenever the queue holds messages, it sets the MAV bit (4) of the Status Byte register.

## MSS Bit

MSS is a real-time (unlatched) summary of all Status Byte register bits that are enabled by the Service Request Enable register. MSS is set whenever the instrument has one or more reasons for requesting service. \*STB? reads the MSS in bit position 6 of the response but does not clear any of the bits in the Status Byte register.

## Status Diagram



## Reset (\*RST) and Interface Settings

Reset State settings are set when the unit is reset.

Parameter	Setting
Over-current protection:	1.00e-2
Over-voltage protection:	4.0
Under-voltage protection:	3.0
Output resistance:	1.0
Open-circuit voltage:	3.5
Initial cell current:	1.00e-3
Output inhibit mode:	OFF
Test duration:	5 minutes
Time interval <tint>:	1 second

Interface Settings are the default factory settings.

Parameter	Setting
LAN interface:	enabled
USB interface:	enabled
DHCP:	On
Auto IP:	On
IP Address:	169.254.4.61
Subnet Mask:	255.255.0.0
Default Gateway:	0.0.0.0
DNS Server:	0.0.0.0
Host Name:	K-2152A-nnnnn (where nnnnn is last 5 digits of the serial number)
LAN Services:	All enabled
Telnet prompt:	"BT2152A> "
IP addresses of Windows Internet Name System	0.0.0.0

Power must be cycled for interface enable or LAN service changes to take effect. LAN settings changes require a LAN restart.

## SCPI Error Messages

- Up to 20 errors can be stored in the error queue.
- A global error queue holds all power-on and hardware-related errors (example: over-temperature).
- Error retrieval is first-in-first-out (FIFO), and errors are cleared as you read them. Once you have read all interface-specific errors, the errors in the global error queue are retrieved.
- If more than 20 errors have occurred, the last error stored in the queue (the most recent error) is replaced with -350,"Error queue overflow". No additional errors are stored until you remove errors from the queue. If no errors have occurred when you read the error queue, the instrument responds with +0,"No error".
- Error conditions are also summarized in the Status Byte Register. See [Status Subsystem](#) for details.
- Interface-specific error queues are cleared by power cycles. The error queue is not cleared by \*RST.
- The SYSTem:ERRor? query reads and clears one error from the error queue. Errors have the following format -113,"Undefined header". The error string may contain up to 255 characters.

## Error List

### Device-dependent Errors (these errors set Standard Event Status register bit #3)

201, "Memory lost: time and date";

Internal calibration time and date is lost

202, "Selftest failed";

The power-on self-test has failed

204, "NVRAM checksum error";

A non-volatile RAM checksum error has occurred in the instrument

205, "NVRAM full";

The non-volatile RAM memory in the instrument is full

206, "File not found";

The internal calibration file was not found in NVRAM

207, "Power rail fault";

One or more of the internal power rails have failed

208, "Power supply fault";

One or more of the internal power supplies have failed

210, "diagnostic error";

An internal diagnostic error has occurred in the instrument

#### 4 Programming Reference

220, "data is not available";

Measurement data is not available. No measurement readings have occurred

230, "External temperature sensor not connected.";

The external temperature sensor is not connected to the TEMP input

231, "Internal temperature not within limits.";

The internal reference temperature is not within the specified limit

250, "Error during self-discharge measurement";

A self-discharge measurement error has occurred. Error condition specific messages will be appended to this generic message.

270, "Readings not being collected";

Measurement readings are not being collected as the collection engine is not running.

271, "Not enough reading points collected";

Not enough reading points have been collected to return a measurement

309, "Incorrectly formatted channel list";

The channel list is incorrectly formatted. Check channel syntax - should be (@1:32) or similar.

316, "Mass storage error";

The mass storage memory has been exceeded

320, "Exceeded max number of licensed channels";

The command is specifying more channels than are supported by the installed license.

610, "Self Test Failure: Multiple errors during self test";

Multiple errors have occurred during self-test

611, "Self Test Failure: Voltage reference failed";

The internal reference voltage has failed during self-test.

612, "Self Test Failure: 10 mA Reference failed";

The internal 10 mA reference has failed during self-test.

613, "Self Test Failure: 100 mA Reference failed";

The internal 100 mA reference has failed during self-test.

680, "Incorrect cal password";

An incorrect calibration password has been entered

700, "Unknown calibration error occurred";

An unknown calibration error occurred

701, "Calibration has not been started.";

The command used requires the instrument to be in calibration mode.

702, "The calibration result is out of the expected range.";

The calibration value entered from the DVM is outside of the expected range

703, "Error during auto calibration.";

An error has occurred during transfer calibration. Try running auto calibration again

800, "Nonvolatile memory write failure";

The instrument could not write to nonvolatile memory

#### **Command Errors (these errors set Standard Event Status register bit #5)**

-123, "Numeric overflow"

The numeric value returned is larger than the expected value

-203, "Command protected; instrument must be unsecured";

Calibration mode requires a password to unsecure the instrument

-213, "INIT ignored";

The INIT:TEST command is ignored. There is already an init running.

-221, "Settings conflict; invalid tint. ";

A test could not be executed because of invalid time interval parameter.

-221, "Settings conflict; invalid test duration. ";

A test could not be executed because of invalid test duration parameter.

-221, "Settings conflict; lower limit > upper limit. ";

A test could not be executed because the lower limit is greater than the upper limit parameter.

-221, "Settings conflict; cell open circuit voltage must be between over and under voltage. ";

A test did not execute because the open circuit voltage must be between the over and under voltage.

-222, "Data out of range; value clipped to upper limit";

The measured data is out of range; the returned value is clipped to the upper limit.

-222, "Data out of range; value clipped to lower limit";

The measured data is out of range; the returned value is clipped to the lower limit.

-222, "Parameter 1 out of range";

The command could not be executed because the 1st parameter is out of range.

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-222, "Parameter 2 out of range";

The command could not be executed because the 2nd parameter is out of range.

-222, "Parameter 3 out of range";

The command could not be executed because the 3rd parameter is out of range.

-222, "Parameter 4 out of range";

The command could not be executed because the 4th parameter is out of range.

-222, "Parameter 5 out of range";

The command could not be executed because the 5th parameter is out of range.

-222, "Parameter 6 out of range";

The command could not be executed because the 6th parameter is out of range.

-222, "Parameter 7 out of range";

The command could not be executed because the 7th parameter is out of range.

-222, "Parameter 8 out of range";

The command could not be executed because the 8th parameter is out of range.

-222, "Parameter 9 out of range";

The command could not be executed because the 9th parameter is out of range.

-250, "Mass storage error; internal file system could not be opened";

The command could not be executed because the internal file system could not be opened

-250, "Mass storage error; USB file system could not be opened";

The command could not be executed because the USB file system could not be opened

-253, "Corrupt media; internal file system scan failed";

The command could not be executed because the internal file system scan failed

-253, "Corrupt media; internal file system format failed";

The command could not be executed because the internal file system format failed

-253, "Corrupt media; file system corruption detected; reformat needed";

The command could not be executed because the internal file system is corrupted

-253, "Corrupt media; USB file system scan failed";

The command could not be executed because the USB file system scan failed

-350, "Error queue overflow";

The error queue is full. No additional errors can be stored until errors are removed from the queue.



# 5

## Verification and Calibration

**Verification Procedure**

**Reference Calibration**

**Channel Calibration**

**Wire Resistance Calibration**

**Calibration Security Reset**

**Maintenance**

## Verification Procedure

### Introduction

The verification procedures verify that the BT2152A is operating normally and is within published specifications. Verification commands are used to set the channels to a specific level, which can then be used for verify the specified accuracy of the channel. **All procedures verify one channel at a time.**

While verifying all channels can provide 100% assurance that all channels are within specification, the procedure can be time consuming. An alternative verification strategy would be to perform channel calibration first. Because channel calibration self-tests each output, it can be used to provide a high level of confidence that the channel is good. After channel calibration has been performed, verifying a single channel to confirm that it is within specification will give very high confidence that the remaining channels are also within specification as well.

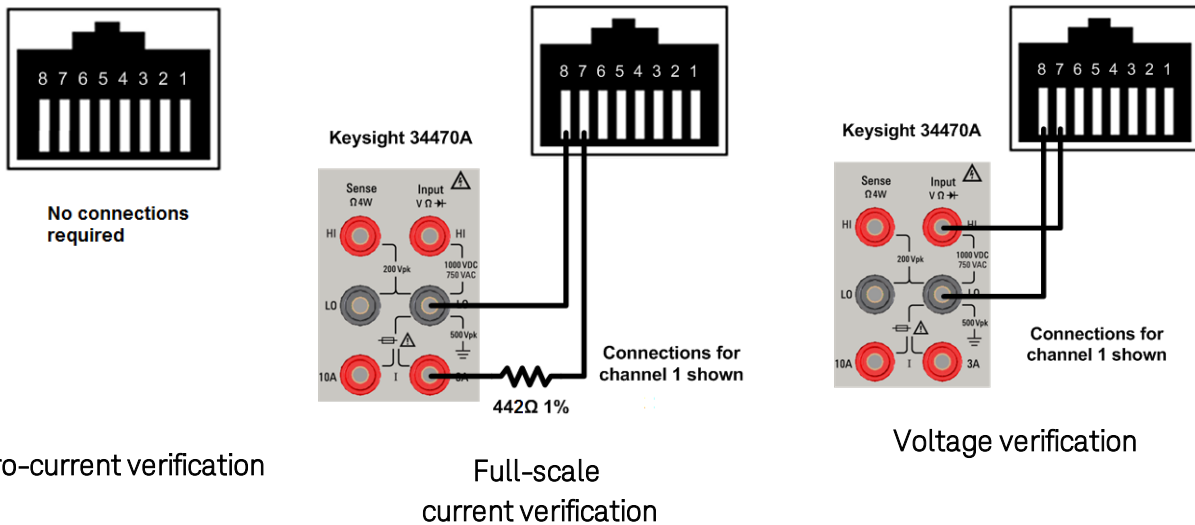
If the instrument fails any of the verification tests, try fully recalibrating the unit. If full calibration is unsuccessful, return the unit to a Keysight Technologies Service Center.

### Verification Equipment and Considerations

- A 7½-digit DMM, Keysight 34470A  
(Run auto-calibration on the DMM prior to starting the verification procedure)
- A 442-ohm ¼ watt through-hole resistor, Keysight P/N 0698-4591 or equivalent
- The ambient temperature is stable and between 23 °C ±2 °C. Relative humidity is <80%
- The BT2152A must be warmed up for at least 1 hour prior to verification tests

### External DMM Connections and Setup

The setup for verifying current and voltage measurement accuracies are depicted as follows for channel 1 on a single RJ45 connector. Channels are verified one at a time. Channels are in groups of four, each group connected to one RJ45 connector.



Building a multi-channel breakout board assembly can simplify verification, especially when planning to verify all the channels. This can be constructed by wiring all BT2152A channels in parallel at the breakout board. Only one channel can be tested at a time with this arrangement (see [Optional Verification Assembly](#)).

## Zero-Scale Current Accuracy Verification

Verifying the measurement system at zero, the bottom of the range, verifies contribution due to offset errors in the system. A significant consideration here is verifying the extremely low + 1  $\mu\text{A}$  offset specification of BT2152A's current measurement system. Noise inherent in the BT2152's output typically requires a 1-minute measurement integration time be used with the DMM to average the noise out down to a + 1  $\mu\text{A}$  level. However, this can be circumvented by testing the channel at zero by using an open circuit. For this reason, the BT2152A's zero-scale current measurement is verified **prior** to making any connection to any channel.

The zero-scale current measurement accuracy procedure is as follows:

### NOTE

No channel connections are required for the zero-scale current accuracy verification.

**Step 1.** Start the verification. Send **CAL:VER:STAR <channel>**

Verification Step 1	Setting
Select the channel to verify	1

**Step 2.** Wait 15 seconds for the unit to settle before proceeding with measurements

**Step 3.** Start the zero-scale current verification. Send **CAL:VER:MEAS:INIT <time>, <tint>**. The front panel TEST light flashes orange when this command is executed.

Verification Step 3	Setting
Set the time for the measurement in seconds	<time> = 10
Set the interval the measurement in seconds	<tint> = 10

**Step 4.** Wait for the measurement time set in step 3 to complete. Either send **SENS:VER:AVAI?** until the query returns a "1", or wait until the front panel TEST light turns off.

**Step 5.** Fetch the measurement reading from the BT2152A. Send **FETC:CURR:LAT? (@channel)**

Verification Step 5	Setting
Return the measurement data from a channel	@1

**Step 6.** Verify that the zero-scale current error is within the specified accuracy provided in the Quick Reference section of this guide.

**Step 7.** If verifying multiple channels, repeat steps 1 through 7 for the remainder of the channels in the BT2152A.

**Step 8.** End the voltage verification. Send **CAL:VER:END**

### Full-Scale Current Accuracy Verification

Current measurement accuracy is verified near or at the 10-mA full-range current. Gain error is significant at the top of the range and adds to any offset error in the system.

**Step 1.** Connect a 7.5 digit (or better) DMM to the RJ45 connector as shown under the Full-scale current verification figure. Place the external resistor in series with the DMM.

**Step 2.** Set the DMM for DC current measurement, 10 mA range, and 10 PLCs (to integrate noise).

**Step 3.** Start the verification. Send **CAL:VER:STAR <channel>**

Verification Step 3	Setting
Select the channel to verify	1

**Step 4.** Set an output voltage. Send **CAL:VER:VOLT <voltage>**

Verification Step 4	Setting
Set the top-end current measurement range. (4.5 V provides approximately 10 mA with the 442-ohm resistor in place.)	<voltage> = 4.5
Specify the channel to be tested	channel 1

**Step 5.** Wait 15 seconds for the BT2152A to settle before proceeding with measurements.

**Step 6.** Initiate a measurement. Send **CAL:VER:MEAS:INIT <time>, <tint>**. The front panel TEST light flashes orange when this command is executed.

Verification Step 6	Setting
Set the time for the measurement in seconds	<time> = 10
Set the interval the measurement in seconds	<tint> = 10

**Step 7.** While the BT2152A is performing its measurements, take a current reading with the DMM and record this value.

**Step 8.** Wait for the measurement time set in step 6 to complete. Either send **SENS:VER:AVAI?** until the query returns a "1", or wait until the front panel TEST light turns off.

**Step 9.** Fetch the measurement reading from the BT2152A. Send **FETC:CURR:LAT? (@channel)**

Verification Step 9	Setting
Return the measurement data from a channel	@1

**Step 10.** Subtract the reference reading from the DMM obtained in step 7 from the reading from the BT2152A measurement obtained in step 9. Verify if it within the specified accuracy provided in the Quick Reference section of this guide.

**Step 11.** If verifying multiple channels, repeat steps 3 through 10 for the remainder of the channels in the BT2152A.

**Step 12.** End the current verification. Send **CAL:VER:END**

### Voltage Accuracy Verification

The voltage measurement accuracy is verified near or at the top and bottom of the scale. Offset error dominates at the bottom of the scale while gain error becomes significant at the top of the scale.

**Step 1.** Connect a 7.5 digit (or better) DMM to the RJ45 connector as shown under the Voltage verification figure.

**Step 2.** Set the DMM for DC voltage measurement, 10 V range, and 10 PLCs (to integrate noise).

**Step 3.** Start the verification. Send **CAL:VER:STAR <channel>**

Verification Step 3	Setting
Select the channel to verify	1

**Step 4.** Set an output voltage. Send **CAL:VER:VOLT <voltage>**

Verification Step 4	Setting
Set the bottom-end measurement range voltage	<voltage> = 0.5

**Step 5.** Wait 15 seconds for the BT2152A to settle before proceeding with measurements.

**Step 6.** Initiate a measurement. Send **CAL:VER:MEAS:INIT <time>, <tint>**. The front panel TEST light flashes orange when this command is executed.

Verification Step 6	Setting
Set the time for the measurement in seconds	<time> = 10
Set the interval the measurement in seconds	<tint> = 10

**Step 7.** While the BT2152A is performing its measurements, take a voltage reading with the DMM and record this value.

**Step 8.** Wait for the measurement time set in step 6 to complete. Either send **SENS:VER:AVAI?** until the query returns a "1", or wait until the front panel TEST light turns off.

**Step 9.** Fetch the measurement reading from the BT2152A. Send **FETC:VOLT:LAT? (@channel)**

Verification Step 9	Setting
Return the measurement data from a channel	@1

**Step 10.** Subtract the reference reading from the DMM obtained in step 7 from the reading from the BT2152A measurement obtained in step 9. Verify if it within the specified accuracy provided in the Quick Reference section of this guide.

**Step 11.** Repeat steps 4 through 10 with the voltage set to 4.5 V, to test the top end of the voltage measurement scale.

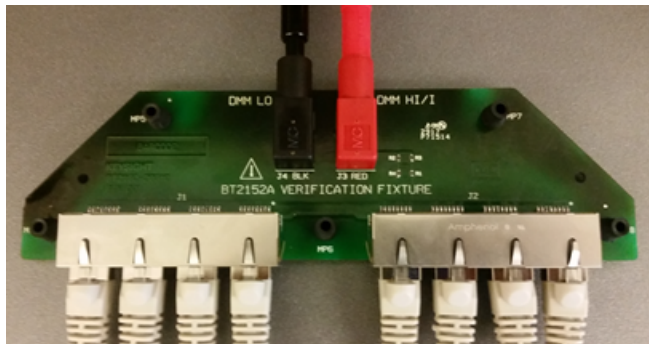
**Step 12.** If verifying multiple channels, repeat steps 3 through 11 for the remainder of the channels in the BT2152A.

**Step 13.** End the voltage verification. Send **CAL:VER:END**

### Optional Verification Assembly

A multi-channel breakout board assembly can simplify verification when planning to verify all the channels. This can be constructed by wiring all BT2152A channels in parallel at the breakout board. Only one channel at a time can be tested with this arrangement. When selected, that channel is electrically connected. The remaining channels have internal switches keeping them disconnected

A verification board assembly, Keysight part number BT2152-66510, will be available soon for quickly verifying full range current accuracy and voltage accuracy on a BT2152A. This is used in conjunction with eight off-the-shelf RJ45 CAT6+ shielded cables to connect it to the 32 channels of the BT2152A (refer to the figure under **RJ45 to RJ45**). A pair of wires with banana plugs are used to connect the verification assembly to the 7 ½-digit DMM.



## Reference Calibration

### Introduction

The instrument features closed-case electronic calibration; no internal mechanical adjustments are required. The instrument calculates correction factors based on reference values that you enter and stores correction factors in non-volatile memory until the next calibration is performed.

### Calibration Interval

The instrument should be calibrated on a regular interval determined by the accuracy requirements of the application.

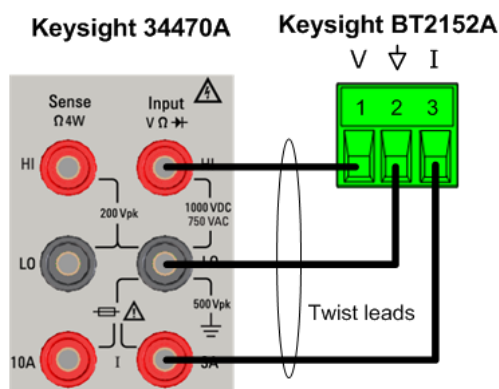
- **Reference Calibration** - Perform annually, once per year
- **Channel Calibration** - Perform monthly, once per month

### Calibration Considerations

- The following equipment is recommended for calibration: 7½-digit DMM; Keysight 34470A (Run auto-calibration on the DMM prior to starting the reference calibration)
- The calibration ambient temperature is stable and between 23 °C ±2 °C. Relative humidity is <80%.
- If set, the correct password is required to enter calibration mode. The password is factory-set to 0 (zero). You can change the password once calibration mode is entered to prevent unauthorized access to the calibration mode (See **CALibration:SECure:CODE**).
- You can calibrate any one of the four calibrations steps independently of the other steps and then store those results. The other existing calibration values will not be affected.
- A warm up time of **1 hour** is required before the unit can be calibrated.

### External DMM Connections and Setup

The following figure illustrates the connections between the **CAL** connector on the rear panel of the BT2152A and the DMM. Shielded, twisted-pair, interconnect cables of minimum length are recommended between the instrument and the DMM to reduce settling and noise errors.



## 5 Verification and Calibration

**Step 1.** Connect a 7.5 digit (or better) DMM to the calibration connector using three wires, twisted together, according to the pin-out shown in the previous figure.

**Step 2.** Power-on the DMM and allow it to warm-up, as required.

**Step 3.** Plug the connector into the Cal port on the rear of the BT2152A to be calibrated.

### Enter Calibration Mode

The following SCPI command starts the calibration. It aborts any other instrument process that is running and prepares the instrument for reference calibration.

Send **CAL:STAR**

The front panel **Test** indicator flashes orange when calibration is running. The Test indicator turns off when calibration is complete.

### Voltage Calibration

**Step 1.** Put the DMM in voltage measurement mode in AUTO range, with a minimum of 100 PLC averaging, auto input impedance (not 10M).

**Step 2.** Start the voltage calibration. Send **CAL:STEP 1**

**Step 3.** Trigger a voltage measurement on the DMM. Measure the voltage between V and Com.

Cal Step 1	Calibration Limits
Begins voltage calibration	3.3 to 3.7

**Step 4.** Send the valid measurement to the instrument. Send **CAL:RES? <value>**

**Step 5.** Start the voltage offset calibration. Send **CAL:STEP 2**

**Step 6.** Trigger a voltage measurement on the DMM. Measure the voltage between V and Com.

Cal Step 2	Calibration Limits
Begins voltage offset calibration	-0.001 to 0.001

**Step 7.** Send the valid measurement to the instrument. Send **CAL:RES? <value>**

#### NOTE

If **CAL:RES?** returns a value other than zero (0), an error has occurred. Send **SYST:ERR?** to return the error. Check the calibration setup; then re-run the step.

### Current Calibration

**Step 1.** Put the DMM in current measurement mode on the 10 mA range with a minimum of 100 PLC averaging. Make sure the DMM's current input terminal is connected to cal port pin 3 as shown in the previous figure.



**Step 2.** Start the 10 mA current calibration. Send **CAL:STEP 3**

**Step 3.** Trigger a current measurement on the DMM. Measure the current between Com and I.

Cal Step 3	Calibration Limits
Begins 10 mA current calibration	0.008 to 0.011

**Step 4.** Send the valid measurement to the instrument. Send **CAL:RES? <value>**

**NOTE**

If **CAL:RES?** returns a value other than zero (0), an error has occurred. Send **SYST:ERR?** to return the error. Check the calibration setup; then re-run the step.

## End Calibration and Store Results

**Step 1.** End calibration. This returns the instrument to the \*RST/Power-on state and sets the CAL:STEP to 0. Send **CAL:END**

**Step 2.** Store the calibration results. This step overwrites the previous calibration constants. Send **CAL:STOR**

**Step 3.** Disconnect the DMM from the instrument.

## Channel Calibration

**NOTE**

**IMPORTANT** Remove all connections from the **CAL** connector on the rear panel of the BT2152A before performing the transfer calibration.

---

During channel calibration, each individual channel is sequentially connected to the internal reference and gain and offset corrections are calculated and stored in non-volatile memory.

### Prerequisites

- The unit must pass self-test, which is run at the start of channel calibration. If self-test (\*TST?) does not pass, channel calibration (\*CAL?) will abort.
- The unit must be warmed up. A warm up time of **1 hour** is required before the unit can be calibrated. The **Ready** indicator must be green, otherwise \*CAL? will abort.
- The unit must stay with its temperature limits. If the unit exceeds the temperature limits, \*CAL? will abort

### Running Channel Calibration

Send **\*CAL?**

This calibration is automatic and takes up to 1 hour.

The front panel **Test** indicator flashes orange when channel calibration is running. The Test indicator turns off when calibration is complete.

### If Problems Occur with Channel Calibration

If the calibration value of a specific channel is out of the accepted tolerance, that channel will fail. The remaining channels will continue to calibrate, with the calibration results being stored when calibration completes.

An error will be placed in the error queue with the channel number that failed, along with measurement information detailing the issue. Use **SYSTEM:ERRor?** to read the error queue. See **SCPI Error Messages** for more information.

### Aborting Channel Calibration

If you need to abort channel calibration, either press the **Abort** button on the front panel for one second, or send a device clear.

The Test indicator turns off when channel calibration stops.

**NOTE**

You can also query the status register via a different connection and check when the cal bit returns to 0.

---

## Wire Resistance Calibration

### Benefits of Wire Resistance Calibration

The Keysight BT2152A Self-Discharge Analyzer can measure and compensate for cable resistance with the wire resistance calibration procedure.

- Using wire resistance calibration lets you run discharge measurements with better performance when using programmable resistance, because the cable wiring will be taken into account.

#### NOTE

This only applies if the RJ45 cables on the back of the BT2152A have not been removed or reseated. Otherwise, programmable output resistance cannot be guaranteed.

- With wire resistance calibration, the voltage measurement is adjusted to reflect the voltage at the end of the cable (the actual cell voltage) instead of the voltage at the RJ45 connector.
- After running wire resistance calibration and saving the values, you can query the present resistance values using the `SENS:WIRE:RES:CONF? (@<chanlist>)` query. If you have previously saved wire resistance values to non-volatile memory, you can now compare the present values to the previous values. This method lets you capture any resistance drifts over time. When the contact resistances of a specific channel/cell probe becomes too high (indicating overuse) it should be replaced.

#### NOTE

To query the previously saved resistance values, you must first load them into the instrument using `CAL:WIRE:RES:LOAD <1|2|3|4|5>`. As this overwrites the present values, you will need to save the present values before you load any previous values.

### Wire Resistance Compensation Constraints

The cable resistance measurement error is bounded by  $\pm 20 \text{ m}\Omega$  over the supported range of  $0\Omega$  to  $5\Omega$ . Note that the wire resistance compensation only holds for the insertion of the RJ-45 at the instrument end and for the contact probes that are used to short the wires at the DUT end. If the DUT contact probes change and/or the RJ45 on the instrument end is unplugged, reinserted, or reseated, the specifications will not hold because of varying contact resistance.

### Wire Resistance Calibration Procedure

#### NOTE

**IMPORTANT** Disconnect all LI cells from the cell cables before performing the wire resistance calibration.

For convenience, you can program the BT2152A to measure the cell wire resistances and enter the resistance measurements. This is the recommended method of wire resistance calibration, which requires you to disconnect all LI cells from the cell wires and then short the ends of the cell wires.

If, for some reason you cannot disconnect and short the ends of the cell wires, you have the option of measuring the cable resistances using an external DMM and the entering the results into the BT2152A using the `SENS:WIRE:RES:CONF <value>, (@<chanlist>)` command. You still need to disconnect the LI

## 5 Verification and Calibration

cells from the cell cables. Note that this method can be tedious and time consuming, and increases the likelihood of measurement errors.

**Step 1.** Make sure all RJ45 cell cables are installed at the back of the BT2152A.

**Step 2.** Disconnect any LI cells that are connected to the RJ45 cables.

**Step 3.** If you are using the BT2152A to make and enter the resistance measurement, short the ends of each wire-pair that would normally be connected to the cell together. Otherwise you must use an external DMM to measure the resistance across the wire ends.

Skip steps 4 - 7 if you are using an external DMM.

**Step 4.** To start the wire resistance calibration procedure, send **CAL:WIRE:RES:AUTO**

**Step 5.** Watch the front panel **Test** indicator. It flashes orange when wire resistance calibration is running, and turns off when calibration is complete (in about 18 minutes or so). If you are not near the front panel, query the instrument using **SENS:WIRE:RES:AVAI?** until the instrument returns a 1.

**Step 6.** Check the error queue to make sure there are no errors using **SYST:ERR?** Errors would indicate a cell was not disconnected, or a low resistance short was not detected at the end of the cable.

**Step 7.** Save the resistance values found to non-volatile memory using **CAL:WIRE:RES:SAVE <1|2|3|4|5>**. Then, if an instrument reboot or reset occurs, you can load the saved resistance values into the instrument without having to recalibrate.

Steps 8 and 9 only apply if you are using an external DMM to make resistance measurements.

**Step 8.** Measure the resistances of each cell cable pair using an external DMM and record the results..

**Step 9.** Enter the results into the BT2152A using the **SENS:WIRE:RES:CONF <value>, (@<chanlist>)** command.

**Step 10.** Remove the shorts at the end of the cable wires and reconnect the wires to the LI cells.

## Calibration Security Reset

**WARNING** SHOCK HAZARD Only qualified, service-trained personnel who are aware of the hazards involved should remove covers. Always disconnect external power.

---

### Electrostatic Discharge (ESD) Precautions

Almost all electrical components can be damaged by electrostatic discharge (ESD) during handling. Component damage can occur at electrostatic discharge voltages as low as 50 V.

The following guidelines will help prevent ESD damage during service operations:

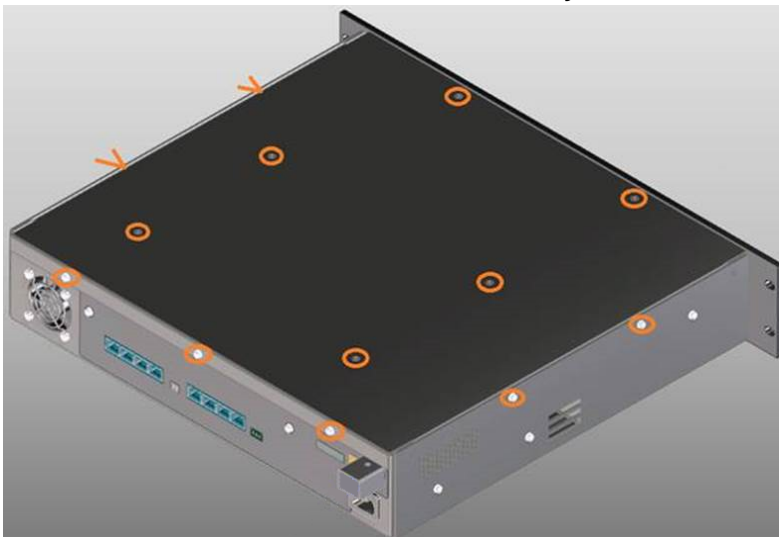
- Disassemble instruments only in a static-free work area.
- Use a conductive work area to reduce static charges.
- Use a conductive wrist strap to reduce static charge accumulation.
- Remove all plastic, foam, vinyl, paper, and other static-generating materials from the immediate work area.

### Tools Required

- T10 Torx driver - for cover removal
- Clip leads - for shorting connector pins

### Cover Removal

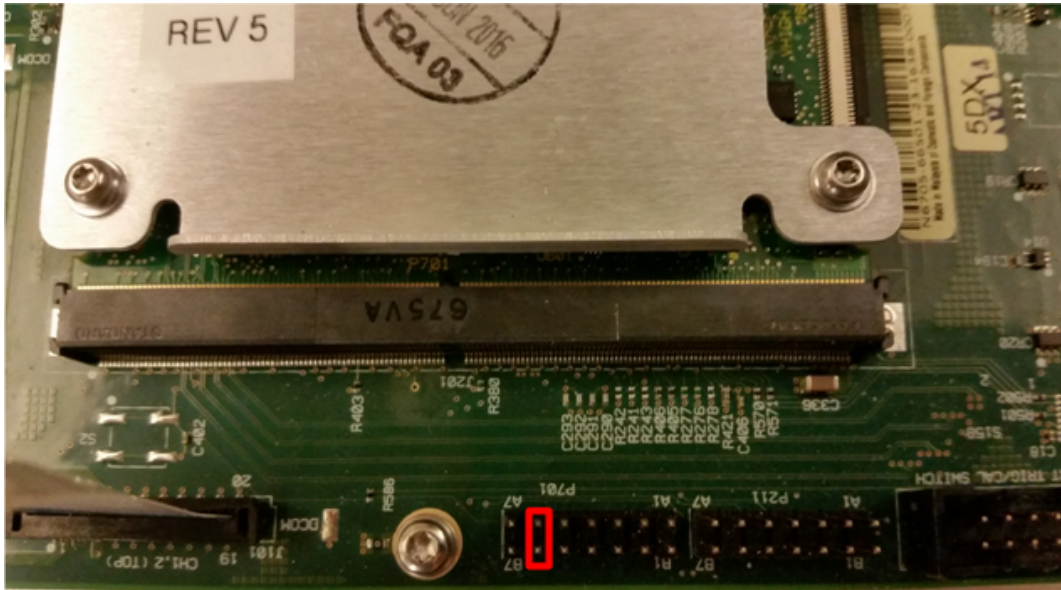
1. Turn off the power. Remove all cables from the instrument.
2. Remove the 6 flat-head screws located on the top and the 7 pan-head screws along the sides (see below). Place the screws in a container so that you do not lose them.



3. Remove the instrument cover.

## Password Reset

1. Locate the controller PC board in the right rear corner of the instrument (as viewed from the back of the unit).
2. On the controller board, locate connector P701. Use a clip lead and short pins A6 to pin B6 as shown in the red rectangle.



↑ Short pin A6 to pin B6

3. Turn the instrument ON, allow it to boot-up, wait 3 minutes, then turn the instrument OFF again.
4. Remove the clip lead from pins A6/B6.
5. Reassemble the cover.
6. Turn the unit on. The security code will now be reset to the default value of 0 (zero).

## Maintenance

No maintenance other than calibration is required. See [Calibration Interval](#).

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