tek.com/keithley

# Series 2230G
# Triple-Channel Power Supplies

## Verification and Adjustment Manual

2230G-905-01 Rev. A / August 2018

2230G-905-01A

KEITHLEY
A Tektronix Company

# Series 2230G

# Triple-Channel Power Supplies

# Verification and Adjustment Manual



These are the original instructions in English.



Document number: 2230G-905-01 Rev. A / August 2018

KEITHLEY
A Tektronix Company

# Safety precautions

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

This product is intended for use by personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product warranty may be impaired.

The types of product users are:

**Responsible body** is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

**Operators** use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

**Maintenance personnel** perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

**Service personnel** are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are measurement, control, and data I/O connections, with low transient overvoltages, and must not be directly connected to mains voltage or to voltage sources with high transient overvoltages. Measurement Category II (as referenced in IEC 60664) connections require protection for high transient overvoltages often associated with local AC mains connections. Certain Keithley measuring instruments may be connected to mains. These instruments will be marked as category II or higher.

Unless explicitly allowed in the specifications, operating manual, and instrument labels, do not connect any instrument to mains.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30 V RMS, 42.4 V peak, or 60 VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

For safety, instruments and accessories must be used in accordance with the operating instructions. If the instruments or accessories are used in a manner not specified in the operating instructions, the protection provided by the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories. Maximum signal levels are defined in the specifications and operating information and shown on the instrument panels, test fixture panels, and switching cards.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as protective earth (safety ground) connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to protective earth (safety ground) using the wire recommended in the user documentation.

The  symbol on an instrument means caution, risk of hazard. The user must refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

The  symbol on an instrument means warning, risk of electric shock. Use standard safety precautions to avoid personal contact with these voltages.

The  symbol on an instrument shows that the surface may be hot. Avoid personal contact to prevent burns.

The  symbol indicates a connection terminal to the equipment frame.

If this  symbol is on a product, it indicates that mercury is present in the display lamp. Please note that the lamp must be properly disposed of according to federal, state, and local laws.

The **WARNING** heading in the user documentation explains hazards that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

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

The **CAUTION** heading with the  symbol in the user documentation explains hazards that could result in moderate or minor injury or damage the instrument. Always read the associated information very carefully before performing the indicated procedure. Damage to the instrument may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

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

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

Unless otherwise noted in product-specific literature, Keithley instruments are designed to operate indoors only, in the following environment: Altitude at or below 2,000 m (6,562 ft); temperature 0 °C to 50 °C (32 °F to 122 °F); and pollution degree 1 or 2.

To clean an instrument, use a cloth dampened with deionized water or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., a data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Safety precaution revision as of June 2017.

# Table of contents

Section 1

# Introduction

**In this section:**



## Welcome

Thank you for choosing a Keithley Instruments product. The Series 2230G Triple-Channel Power Supplies (Models 2230G-30-3, 2230G-30-6, and 2230G-60-3) provide output power up to 195 W and 375 W. Each power supply has three isolated power channels, allowing you to power circuits with different references or polarities.

The Series 2230G supports remote sensing and has rear-panel connections to make automated test more convenient. Built in RS-232, USB, and GPIB interfaces allow multiple communication methods. The Series 2230G power supplies cover a wide range of applications in a space-saving 2U half-rack size.

## Introduction to this manual

This manual provides instructions to help you calibrate and adjust your Keithley Instruments 2230G. In this manual, the term "calibration" refers to the process of verifying that the accuracy of the instrument is within its one-year accuracy specifications. The term "adjustment" refers to the process of changing the calibration constants so that the accuracy of the instrument is within its one-year accuracy specifications.

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

NOTE

For additional command descriptions, refer to the 2230G User's Manual (part number 2230G-905-01), which is available on the Downloads, Manuals, and Documentation web page (http://www.tek.com/downloads).

## Extended warranty

Additional years of warranty coverage are available on many products. These valuable contracts protect you from unbudgeted service expenses and provide additional years of protection at a fraction of the price of a repair. Extended warranties are available on new and existing products. Contact your local Keithley Instruments office, sales partner, or distributor for details.

# Contact information

If you have any questions after you review the information in this documentation, please contact your local Keithley Instruments office, sales partner, or distributor. You can also call the corporate headquarters of Keithley Instruments (toll-free inside the U.S. and Canada only) at 1-800-935-5595, or from outside the U.S. at +1-440-248-0400. For worldwide contact numbers, visit the Keithley Instruments website (http://www.tek.com/keithley).

Section 2

# Performance verification

**In this section:**



## Introduction

Use the procedures in this section to verify that 2230G accuracy is within the limits stated in the instrument's one-year accuracy specifications. Specifications and characteristics are subject to change without notice; refer to the Product Support web page (www.tek.com/product-support) for the most recent specifications.

You can use these calibration verification procedures to:

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

**WARNING**

**The information in this section is intended for qualified service personnel only, as described by the types of product users in the Safety precautions (on page 1-1). Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.**

NOTE

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

# Factory service

***To return the instrument to Keithley Instruments for repair:***

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

# Test record

| Model | Serial number | Procedure performed by | Used as |
|---|---|---|---|
| | | | |

| Test | Passed | Failed |
|---|---|---|
| DC voltage accuracy | | |
| DC voltage readback accuracy | | |
| DC voltage line regulation | | |
| DC voltage load regulation | | |
| DC current accuracy | | |
| DC current readback accuracy | | |
| DC current line regulation | | |
| DC current load regulation | | |
| Voltage noise at 20 MHz | | |
| Current noise at 20 MHz | | |

# 2230G-30-3 test report

**2230G-30-3 DC voltage accuracy**

| Instrument test voltage | DUT voltage | Test current | Minimum | Measured | Maximum |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 0.00000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | 7.4878 V | | 7.5123 V |
| 50% | 15.0000 V | 0.5 A | 14.9855 V | | 15.0145 V |
| 75% | 22.5000 V | 0.5 A | 22.4833 V | | 22.5168 V |
| 100% | 30.0000 V | 0.5 A | 29.9810 V | | 30.0190 V |
| **Channel 2** | | | | | |
| 0% | 0.0000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | 7.4878 V | | 7.5123 V |
| 50% | 15.0000 V | 0.5 A | 14.9855 V | | 15.0145 V |
| 75% | 22.5000 V | 0.5 A | 22.4833 V | | 22.5168 V |
| 100% | 30.0000 V | 0.5 A | 29.9810 V | | 30.0190 V |
| **Channel 3** | | | | | |
| 0% | 0.0000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 1.2500 V | 0.5 A | 1.2396 V | | 1.2604 V |
| 50% | 2.5000 V | 0.5 A | 2.4893 V | | 2.5108 V |
| 75% | 3.7500 V | 0.5 A | 3.7389 V | | 3.7611 V |
| 100% | 5.0000 V | 0.5 A | 4.9885 V | | 5.0115 V |

**2230G-30-3 DC voltage readback accuracy**

| Instrument test voltage | DUT voltage | Test current | Measured voltage | Voltage readback | Absolute difference | Maximum difference |
|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | |
| 0% | 0.00000 V | 0.5 A | | | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | | | | 0.01225 V |
| 50% | 15.0000 V | 0.5 A | | | | 0.01450 V |
| 75% | 22.5000 V | 0.5 A | | | | 0.01675 V |
| 100% | 30.0000 V | 0.5 A | | | | 0.01900 V |
| **Channel 2** | | | | | | |
| 0% | 0.0000 V | 0.5 A | | | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | | | | 0.01225 V |
| 50% | 15.0000 V | 0.5 A | | | | 0.01450 V |
| 75% | 22.5000 V | 0.5 A | | | | 0.01675 V |
| 100% | 30.0000 V | 0.5 A | | | | 0.01900 V |
| **Channel 3** | | | | | | |
| 0% | 0.0000 V | 0.5 A | | | | 0.010000 V |
| 25% | 1.2500 V | 0.5 A | | | | 0.010375 V |
| 50% | 2.5000 V | 0.5 A | | | | 0.010750 V |
| 75% | 3.7500 V | 0.5 A | | | | 0.011125 V |
| 100% | 5.0000 V | 0.5 A | | | | 0.011500 V |

**2230G-30-3 DC voltage line regulation**

| Instrument | Minimum | Maximum | Nominal | Nominal minimum | Maximum nominal | Larger | Maximum value |
|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | 0.00600 V |
| **Channel 2** | | | | | | | 0.00600 V |
| **Channel 3** | | | | | | | 0.00350 V |

**2230G-30-3 DC voltage load regulation**

| Instrument | Minimum | Reference | Maximum | Reference minimum | Maximum reference | Maximum reference /0.98 | Largest | Maximum value |
|---|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | | 0.00600 V |
| **Channel 2** | | | | | | | | 0.00600 V |
| **Channel 3** | | | | | | | | 0.00350 V |

**2230G-30-3 DC current accuracy**

| Instrument test current | Test voltage | DUT current | Minimum | Measured current | Maximum |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 15 V | 0.00000 A | –0.00500 A | | 0.00500 A |
| 25% | 15 V | 0.75000 A | 0.74425 A | | 0.75575 A |
| 50% | 15 V | 1.50000 A | 1.49350 A | | 1.50650 A |
| 75% | 15 V | 2.25000 A | 2.24275 A | | 2.25725 A |
| 100% | 15 V | 3.00000 A | 2.99200 A | | 3.00800 A |
| **Channel 2** | | | | | |
| 0% | 15 V | 0.00000 A | –0.00500 A | | 0.00500 A |
| 25% | 15 V | 0.75000 A | 0.74425 A | | 0.75575 A |
| 50% | 15 V | 1.50000 A | 1.49350 A | | 1.50650 A |
| 75% | 15 V | 2.25000 A | 2.24275 A | | 2.25725 A |
| 100% | 15 V | 3.00000 A | 2.99200 A | | 3.00800 A |
| **Channel 3** | | | | | |
| 0% | 5 V | 0.00000 A | –0.00500 A | | 0.00500 A |
| 25% | 5 V | 0.75000 A | 0.74425 A | | 0.75575 A |
| 50% | 5 V | 1.50000 A | 1.49350 A | | 1.50650 A |
| 75% | 5 V | 2.25000 A | 2.24275 A | | 2.25725 A |
| 100% | 5 V | 3.00000 A | 2.99200 A | | 3.00800 A |

**2230G-30-3 DC current readback accuracy**

| Instrument test current | Test current | Measured current | Current readback | Absolute difference | Maximum difference |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 0.00000 A | | | | 0.00500 A |
| 25% | 0.75000 A | | | | 0.00575 A |
| 50% | 1.50000 A | | | | 0.00650 A |
| 75% | 2.25000 A | | | | 0.00725 A |
| 100% | 3.00000 A | | | | 0.00800 A |
| **Channel 2** | | | | | |
| 0% | 0.00000 A | | | | 0.00500 A |
| 25% | 0.75000 A | | | | 0.00575 A |
| 50% | 1.50000 A | | | | 0.00650 A |
| 75% | 2.25000 A | | | | 0.00725 A |
| 100% | 3.00000 A | | | | 0.00800 A |
| **Channel 3** | | | | | |
| 0% | 0.00000 A | | | | 0.00500 A |
| 25% | 0.75000 A | | | | 0.00575 A |
| 50% | 1.50000 A | | | | 0.00650 A |
| 75% | 2.25000 A | | | | 0.00725 A |
| 100% | 3.00000 A | | | | 0.00800 A |

**2230G-30-3 DC current line regulation**

| Instrument | Test voltage | Minimum | Maximum | Nominal | Nominal minimum | Maximum nominal | Larger | Maximum value |
|---|---|---|---|---|---|---|---|---|
| **Channel 1** | 15 V | | | | | | | 0.00330 A |
| **Channel 2** | 15 V | | | | | | | 0.00330 A |
| **Channel 3** | 5 V | | | | | | | 0.00330 A |

**2230G-30-3 DC current load regulation**

| Instrument | Minimum | Reference | Maximum | Reference minimum | Maximum reference | Larger | Maximum difference |
|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | 0.00330 A |
| **Channel 2** | | | | | | | 0.00330 A |
| **Channel 3** | | | | | | | 0.00330 A |

**2230G-30-3 voltage noise at 20 MHz**

| Instrument | Voltage test load R1 | Measured RMS | Maximum RMS | Measured pk-pk | Maximum pk-pk |
|---|---|---|---|---|---|
| **Channel 1** | 20 Ω | | 1.00 mV | | 3.0 mV |
| **Channel 2** | 20 Ω | | 1.00 mV | | 3.0 mV |
| **Channel 3** | 3.3 Ω | | 1.00 mV | | 3.0 mV |

**2230G-30-3 current noise at 20 MHz**

| Instrument | Current test load R1 | Measured RMS | Maximum RMS |
|---|---|---|---|
| **Channel 1** | 1 Ω | | 4.0 mA |
| **Channel 2** | 1 Ω | | 4.0 mA |
| **Channel 3** | 1 Ω | | 4.0 mA |

# 2230G-30-6 test report

**2230G-30-6 DC voltage accuracy**

| Instrument test voltage | DUT voltage | Test current | Minimum | Measured | Maximum |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 0.00000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | 7.4878 V | | 7.5123 V |
| 50% | 15.0000 V | 0.5 A | 14.9855 V | | 15.0145 V |
| 75% | 22.5000 V | 0.5 A | 22.4833 V | | 22.5168 V |
| 100% | 30.0000 V | 0.5 A | 29.9810 V | | 30.0190 V |
| **Channel 2** | | | | | |
| 0% | 0.0000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | 7.4878 V | | 7.5123 V |
| 50% | 15.0000 V | 0.5 A | 14.9855 V | | 15.0145 V |
| 75% | 22.5000 V | 0.5 A | 22.4833 V | | 22.5168 V |
| 100% | 30.0000 V | 0.5 A | 29.9810 V | | 30.0190 V |
| **Channel 3** | | | | | |
| 0% | 0.0000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 1.2500 V | 0.5 A | 1.2396 V | | 1.2604 V |
| 50% | 2.5000 V | 0.5 A | 2.4893 V | | 2.5108 V |
| 75% | 3.7500 V | 0.5 A | 3.7389 V | | 3.7611 V |
| 100% | 5.0000 V | 0.5 A | 4.9885 V | | 5.0115 V |

**2230G-30-6 DC voltage readback accuracy**

| Instrument test voltage | DUT voltage | Test current | Measured voltage | Voltage readback | Absolute difference | Maximum difference |
|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | |
| 0% | 0.00000 V | 0.5 A | | | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | | | | 0.01225 V |
| 50% | 15.0000 V | 0.5 A | | | | 0.01450 V |
| 75% | 22.5000 V | 0.5 A | | | | 0.01675 V |
| 100% | 30.0000 V | 0.5 A | | | | 0.01900 V |
| **Channel 2** | | | | | | |
| 0% | 0.0000 V | 0.5 A | | | | 0.01000 V |
| 25% | 7.5000 V | 0.5 A | | | | 0.01225 V |
| 50% | 15.0000 V | 0.5 A | | | | 0.01450 V |
| 75% | 22.5000 V | 0.5 A | | | | 0.01675 V |
| 100% | 30.0000 V | 0.5 A | | | | 0.01900 V |
| **Channel 3** | | | | | | |
| 0% | 0.0000 V | 0.5 A | | | | 0.010000 V |
| 25% | 1.2500 V | 0.5 A | | | | 0.010375 V |
| 50% | 2.5000 V | 0.5 A | | | | 0.010750 V |
| 75% | 3.7500 V | 0.5 A | | | | 0.011125 V |
| 100% | 5.0000 V | 0.5 A | | | | 0.011500 V |

**2230G-30-6 DC voltage line regulation**

| Instrument | Minimum | Maximum | Nominal | Nominal minimum | Maximum nominal | Larger | Maximum value |
|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | 0.00600 V |
| **Channel 2** | | | | | | | 0.00600 V |
| **Channel 3** | | | | | | | 0.00350 V |

**2230G-30-6 DC voltage load regulation**

| Instrument | Minimum | Reference | Maximum | Reference minimum | Maximum reference | Maximum reference /0.98 | Largest | Maximum value |
|---|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | | 0.00600 V |
| **Channel 2** | | | | | | | | 0.00600 V |
| **Channel 3** | | | | | | | | 0.00350 V |

**2230G-30-6 DC current accuracy**

| Instrument test current | Test voltage | DUT current | Minimum | Measured current | Maximum |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 15 V | 0.00000 A | –0.00800 A | | 0.00800 A |
| 25% | 15 V | 1.50000 A | 1.49050 A | | 1.50950 A |
| 50% | 15 V | 3.00000 A | 2.98900 A | | 3.01100 A |
| 75% | 15 V | 4.50000 A | 4.48750 A | | 4.51250 A |
| 100% | 15 V | 6.00000 A | 5.98600 A | | 6.01400 A |
| **Channel 2** | | | | | |
| 0% | 15 V | 0.00000 A | –0.00800 A | | 0.00800 A |
| 25% | 15 V | 1.50000 A | 1.49050 A | | 1.50950 A |
| 50% | 15 V | 3.00000 A | 2.98900 A | | 3.01100 A |
| 75% | 15 V | 4.50000 A | 4.48750 A | | 4.51250 A |
| 100% | 15 V | 6.00000 A | 5.98600 A | | 6.01400 A |
| **Channel 3** | | | | | |
| 0% | 5 V | 0.00000 A | –0.00500 A | | 0.00500 A |
| 25% | 5 V | 0.75000 A | 0.74425 A | | 0.75575 A |
| 50% | 5 V | 1.50000 A | 1.49350 A | | 1.50650 A |
| 75% | 5 V | 2.25000 A | 2.24275 A | | 2.25725 A |
| 100% | 5 V | 3.00000 A | 2.99200 A | | 3.00800 A |

**2230G-30-6 DC current readback accuracy**

| Instrument test current | Test current | Measured current | Current readback | Absolute difference | Maximum difference |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 0.00000 A | | | | 0.0080 A |
| 25% | 1.50000 A | | | | 0.0095 A |
| 50% | 3.00000 A | | | | 0.0110 A |
| 75% | 4.50000 A | | | | 0.0125 A |
| 100% | 6.00000 A | | | | 0.0140 A |
| **Channel 2** | | | | | |
| 0% | 0.00000 A | | | | 0.0080 A |
| 25% | 1.50000 A | | | | 0.0095 A |
| 50% | 3.00000 A | | | | 0.0110 A |
| 75% | 4.50000 A | | | | 0.0125 A |
| 100% | 6.00000 A | | | | 0.0140 A |
| **Channel 3** | | | | | |
| 0% | 0.00000 A | | | | 0.00500 A |
| 25% | 0.75000 A | | | | 0.00575 A |
| 50% | 1.50000 A | | | | 0.00650 A |
| 75% | 2.25000 A | | | | 0.00725 A |
| 100% | 3.00000 A | | | | 0.00800 A |

**2230G-30-6 DC current line regulation**

| Instrument | Test voltage | Minimum | Maximum | Nominal | Nominal minimum | Maximum nominal | Larger | Maximum value |
|---|---|---|---|---|---|---|---|---|
| **Channel 1** | 15 V | | | | | | | 0.00360 A |
| **Channel 2** | 15 V | | | | | | | 0.00360 A |
| **Channel 3** | 5 V | | | | | | | 0.00330 A |

**2230G-30-6 DC current load regulation**

| Instrument | Minimum | Reference | Maximum | Reference minimum | Maximum reference | Larger | Maximum difference |
|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | 0.00360 A |
| **Channel 2** | | | | | | | 0.00360 A |
| **Channel 3** | | | | | | | 0.00330 A |

**2230G-30-6 voltage noise at 20 MHz**

| Instrument | Voltage test load R1 | Measured RMS | Maximum RMS | Measured pk-pk | Maximum pk-pk |
|---|---|---|---|---|---|
| **Channel 1** | 20 Ω | | 1.00 mV | | 4.0 mV |
| **Channel 2** | 20 Ω | | 1.00 mV | | 4.0 mV |
| **Channel 3** | 3.3 Ω | | 1.00 mV | | 3.0 mV |

**2230G-30-6 current noise at 20 MHz**

| Instrument | Current test load R1 | Measured RMS | Maximum RMS |
|---|---|---|---|
| **Channel 1** | 1 Ω | | 5.0 mA |
| **Channel 2** | 1 Ω | | 5.0 mA |
| **Channel 3** | 1 Ω | | 4.0 mA |

# 2230G-60-3 test report

**2230G-60-3 DC voltage accuracy**

| Instrument test voltage | DUT voltage | Test current | Minimum | Measured | Maximum |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 0.00000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 15.0000 V | 0.5 A | 14.9855 V | | 15.0145 V |
| 50% | 30.0000 V | 0.5 A | 29.9810 V | | 30.0190 V |
| 75% | 45.0000 V | 0.5 A | 44.9765 V | | 45.0235 V |
| 100% | 60.0000 V | 0.5 A | 59.9720 V | | 60.0280 V |
| **Channel 2** | | | | | |
| 0% | 0.0000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 15.0000 V | 0.5 A | 14.9855 V | | 15.0145 V |
| 50% | 30.0000 V | 0.5 A | 29.9810 V | | 30.0190 V |
| 75% | 45.0000 V | 0.5 A | 44.9765 V | | 45.0235 V |
| 100% | 60.0000 V | 0.5 A | 59.9720 V | | 60.0280 V |
| **Channel 3** | | | | | |
| 0% | 0.0000 V | 0.5 A | –0.01000 V | | 0.01000 V |
| 25% | 1.2500 V | 0.5 A | 1.2396 V | | 1.2604 V |
| 50% | 2.5000 V | 0.5 A | 2.4893 V | | 2.5108 V |
| 75% | 3.7500 V | 0.5 A | 3.7389 V | | 3.7611 V |
| 100% | 5.0000 V | 0.5 A | 4.9885 V | | 5.0115 V |

**2230G-60-3 DC voltage readback accuracy**

| Instrument test voltage | DUT voltage | Test current | Measured voltage | Voltage readback | Absolute difference | Maximum difference |
|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | |
| 0% | 0.00000 V | 0.5 A | | | | 0.0100 V |
| 25% | 15.0000 V | 0.5 A | | | | 0.0145 V |
| 50% | 30.0000 V | 0.5 A | | | | 0.0190 V |
| 75% | 45.0000 V | 0.5 A | | | | 0.0235 V |
| 100% | 60.0000 V | 0.5 A | | | | 0.0280 V |
| **Channel 2** | | | | | | |
| 0% | 0.00000 V | 0.5 A | | | | 0.0100 V |
| 25% | 15.0000 V | 0.5 A | | | | 0.0145 V |
| 50% | 30.0000 V | 0.5 A | | | | 0.0190 V |
| 75% | 45.0000 V | 0.5 A | | | | 0.0235 V |
| 100% | 60.0000 V | 0.5 A | | | | 0.0280 V |
| **Channel 3** | | | | | | |
| 0% | 0.0000 V | 0.5 A | | | | 0.010000 V |
| 25% | 1.2500 V | 0.5 A | | | | 0.010375 V |
| 50% | 2.5000 V | 0.5 A | | | | 0.010750 V |
| 75% | 3.7500 V | 0.5 A | | | | 0.011125 V |
| 100% | 5.0000 V | 0.5 A | | | | 0.011500 V |

**2230G-60-3 DC voltage line regulation**

| Instrument | Minimum | Maximum | Nominal | Nominal minimum | Maximum nominal | Larger | Maximum value |
|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | 0.00900 V |
| **Channel 2** | | | | | | | 0.00900 V |
| **Channel 3** | | | | | | | 0.00350 V |

**2230G-60-3 DC voltage load regulation**

| Instrument | Minimum | Reference | Maximum | Reference minimum | Maximum reference | Maximum reference /0.98 | Largest | Maximum value |
|---|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | | 0.00900 V |
| **Channel 2** | | | | | | | | 0.00900 V |
| **Channel 3** | | | | | | | | 0.00350 V |

**2230G-60-3 DC current accuracy**

| Instrument test current | Test voltage | DUT current | Minimum | Measured current | Maximum |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 30 V | 0.00000 A | –0.00500 A | | 0.00500 A |
| 25% | 30 V | 0.75000 A | 0.74425 A | | 0.75575 A |
| 50% | 30 V | 1.50000 A | 1.49350 A | | 1.50650 A |
| 75% | 30 V | 2.25000 A | 2.24275 A | | 2.25725 A |
| 100% | 30 V | 3.00000 A | 2.99200 A | | 3.00800 A |
| **Channel 2** | | | | | |
| 0% | 30 V | 0.00000 A | –0.00500 A | | 0.00500 A |
| 25% | 30 V | 0.75000 A | 0.74425 A | | 0.75575 A |
| 50% | 30 V | 1.50000 A | 1.49350 A | | 1.50650 A |
| 75% | 30 V | 2.25000 A | 2.24275 A | | 2.25725 A |
| 100% | 30 V | 3.00000 A | 2.99200 A | | 3.00800 A |
| **Channel 3** | | | | | |
| 0% | 5 V | 0.00000 A | –0.00500 A | | 0.00500 A |
| 25% | 5 V | 0.75000 A | 0.74425 A | | 0.75575 A |
| 50% | 5 V | 1.50000 A | 1.49350 A | | 1.50650 A |
| 75% | 5 V | 2.25000 A | 2.24275 A | | 2.25725 A |
| 100% | 5 V | 3.00000 A | 2.99200 A | | 3.00800 A |

**2230G-60-3 DC current readback accuracy**

| Instrument test current | Test current | Measured current | Current readback | Absolute difference | Maximum difference |
|---|---|---|---|---|---|
| **Channel 1** | | | | | |
| 0% | 0.00000 A | | | | 0.00500 A |
| 25% | 0.75000 A | | | | 0.00575 A |
| 50% | 1.50000 A | | | | 0.00650 A |
| 75% | 2.25000 A | | | | 0.00725 A |
| 100% | 3.00000 A | | | | 0.00800 A |
| **Channel 2** | | | | | |
| 0% | 0.00000 A | | | | 0.00500 A |
| 25% | 0.75000 A | | | | 0.00575 A |
| 50% | 1.50000 A | | | | 0.00650 A |
| 75% | 2.25000 A | | | | 0.00725 A |
| 100% | 3.00000 A | | | | 0.00800 A |
| **Channel 3** | | | | | |
| 0% | 0.00000 A | | | | 0.00500 A |
| 25% | 0.75000 A | | | | 0.00575 A |
| 50% | 1.50000 A | | | | 0.00650 A |
| 75% | 2.25000 A | | | | 0.00725 A |
| 100% | 3.00000 A | | | | 0.00800 A |

**2230G-60-3 DC current line regulation**

| Instrument | Test voltage | Minimum | Maximum | Nominal | Nominal minimum | Maximum nominal | Larger | Maximum value |
|---|---|---|---|---|---|---|---|---|
| **Channel 1** | 15 V | | | | | | | 0.00330 A |
| **Channel 2** | 15 V | | | | | | | 0.00330 A |
| **Channel 3** | 5 V | | | | | | | 0.00330 A |

**2230G-60-3 DC current load regulation**

| Instrument | Minimum | Reference | Maximum | Reference minimum | Maximum reference | Larger | Maximum difference |
|---|---|---|---|---|---|---|---|
| **Channel 1** | | | | | | | 0.00330 A |
| **Channel 2** | | | | | | | 0.00330 A |
| **Channel 3** | | | | | | | 0.00330 A |

**2230G-60-3 voltage noise at 20 MHz**

| Instrument | Voltage test load R1 | Measured RMS | Maximum RMS | Measured pk-pk | Maximum pk-pk |
|---|---|---|---|---|---|
| **Channel 1** | 40 Ω | | 1.00 mV | | 4.0 mV |
| **Channel 2** | 40 Ω | | 1.00 mV | | 4.0 mV |
| **Channel 3** | 3.3 Ω | | 1.00 mV | | 3.0 mV |

**2230G-60-3 current noise at 20 MHz**

| Instrument | Current test load R1 | Measured RMS | Maximum RMS |
|---|---|---|---|
| **Channel 1** | 1 Ω | | 4.0 mA |
| **Channel 2** | 1 Ω | | 4.0 mA |
| **Channel 3** | 1 Ω | | 4.0 mA |

# Verification test requirements

Be sure that you perform these verification tests:

- Under the proper environmental conditions.
- After the specified warmup period.
- Using the correct line voltage.
- Using the proper test equipment.
- Using the specified output signal and reading limits.

## Environmental conditions

Conduct the calibration verification procedures in a test environment with:

- An ambient temperature of 18 °C to 28 °C.
- A relative humidity of less than or equal to 80 percent, unless otherwise noted.
- No direct airflow on the input terminals.

## Warmup period

Allow the 2230G to warm up for at least 30 minutes before conducting the calibration verification procedures.

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

Allow the test equipment to warm up for the amount of time recommended by the manufacturer.

## Line power

The 2230G requires:

- Line voltage of 99 V to 132 V for 2230G-30-3, or 108 V to 132 V for 2230G-30-6 and 2230G-60-3
- Line frequency of 60 Hz

or

- Line voltage of 198 V to 264 V
- Line frequency of 50 Hz

Calibration verification tests should be performed within this range.

NOTE

The instrument automatically senses the line frequency at power up.

## Recommended test equipment

The following table describes the recommended calibration verification equipment. You can also use other equipment if it meets specifications listed in the table below.

| Manufacturer | Model | Description | Used as |
|---|---|---|---|
| Kikusui | PCR2000M | Variable AC output from 90 VAC to 265 VAC with at least 750 VA capacity | AC power source |
| Keithley Instruments | 2380 series | Variable DC load capable of 6 ADC and 40 VDC | Electronic load |
| Keithley Instruments | 2000 DMM | Voltage measurement from 12 mV to 40 V, higher than 100 ppm accuracy that can multiply the result by a scalar | DC voltmeter |
| - | - | 18 AWG (minimum) connection wire assemblies:<br>■ #10 fork lug to #10 fork lug, quantity 2<br>■ Stackable banana to #10 fork lug, quantity 2<br>■ Stackable banana to bare wire, quantity 2<br>Wire lengths are not critical | High-current connection wire |
| - | - | 22 AWG (minimum) connection wires:<br>■ Banana plug to banana plug, quantity 2<br>■ Bare wire to stackable banana, quantity 2<br>■ Bare wire to banana, quantity 2<br>Wire lengths are not critical | Low-current connection wire |
| Guildline | 9230A-50 | 0.050 Ω ±100 ppm at 25 W ±4 ppm/°C temperature coefficient | 50 mΩ precision shunt resistor |
| Guildline | 92301 cable set | Kelvin 4-terminal measuring cables from shunt resistor to voltmeter | Current sense resistor cabling |
| OHMITE | 15FR050E | 0.050 Ω, 5 W<br>quantity 2<br>Both leads of each resistor require a banana jack connector | 50 mΩ resistor for remote sense testing |

| Manufacturer | Model | Description | Used as |
|---|---|---|---|
| - | - | Loading resistors for high current in voltage mode and high voltage in current mode,<br>All resistors should be rated for at least 50 W, ohms tolerance within 5%<br>Resistor composition is not critical<br>Both leads of the load resistor require a banana plug/jack (or equivalent) to connect to the power supply | Load resistor for voltage<br>noise testing |
| Vishay/Dale | RH05012R00FE02 | 2230G-60-3: 24 Ω<br>2230G-30-3: 12 Ω<br>2230G-30-6: 6 Ω | CH1 |
| Vishay/Dale | RH05012R00FE02 | 2230G-60-3: 24 Ω<br>2230G-30-3: 12 Ω<br>2230G-30-6: 6 Ω | CH2 |
| Vishay/Dale | RH05012R00FE02 | 2.5 Ω | CH3 |
| Vishay/Dale | HL10006Z1R000JJ | 1 Ω, 100 W, 5% of tolerance<br>Both leads of the load resistor require a banana plug/jack (or equivalent) to connect to the power supply | Load resistor for current<br>noise testing |
| Tektronix | DPO3012 | 20 MHz bandwidth-limited oscilloscope at 1 mV/division | Oscilloscope |
| Tektronix | P2220, 1X probe | Low capacitance,<br>1 MΩ/10 MΩ, 1X/10X<br>6 MHz/200 MHz | Oscilloscope probe |
| Tektronix | P6139A, 10X | Low capacitance, 10 MΩ, 500 MHz | Oscilloscope probe |
| Tektronix | 012-0482-00 | 50 Ω BNC, male-to-male | Coaxial cable |
| Pomona Electronics | 3073 | BNC female to banana breakout | BNC adapter |

# Verification test procedures

Use the following procedures to perform the verification tests.

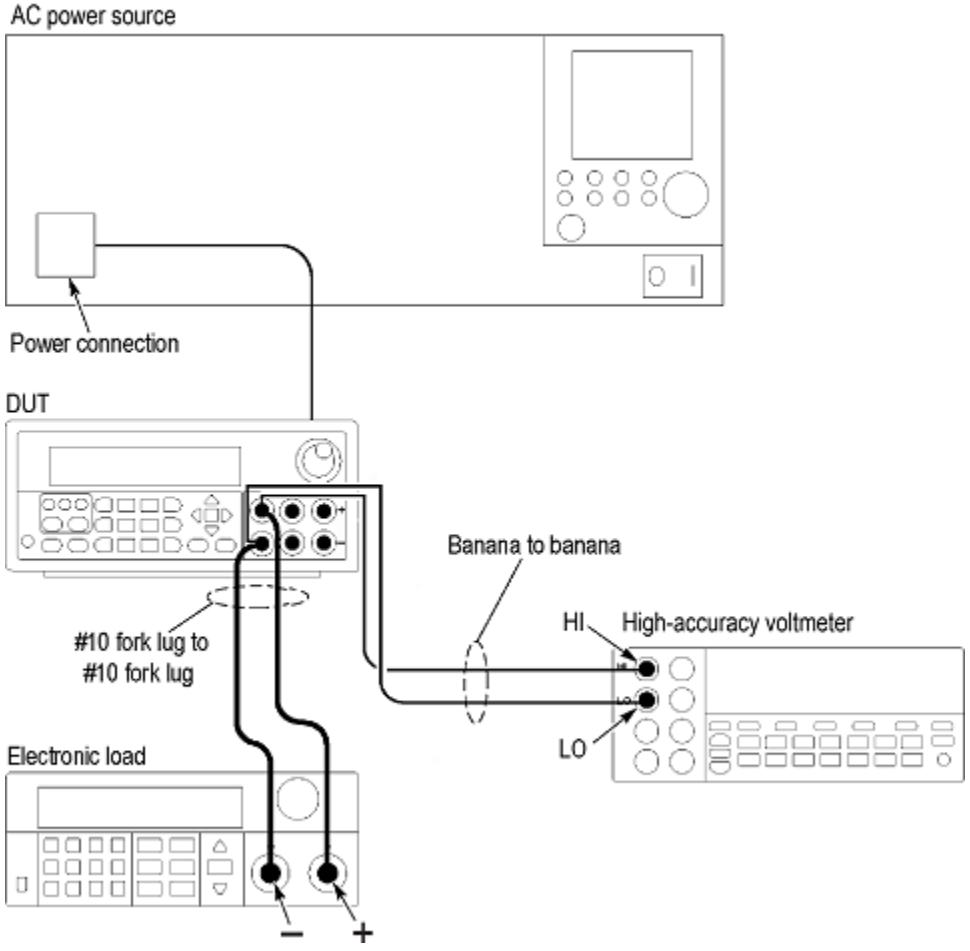
## Check DC voltage setting and DC voltage readback accuracy

| Equipment required | Comment |
|---|---|
| AC power source | High-current connection wire (bold line connections in the following figure) |
| Electronic load | Low-current connection wire (fine line connections in the following figure) |
| DC voltmeter | |

***To perform the test on each channel sequentially:***

1. Set up the equipment as shown in the following figure.

**Figure 1: Connections for checking the voltage**



## NOTE

Make sure that the equipment is properly warmed up.

To ensure accurate measurements, the voltmeter must be connected as close as possible to the front panel of the device under test (DUT). It is recommended that you use fork lugs between the electronic load and the DUT and banana plugs between the DUT and voltmeter. You can also use fork lugs for both connections to the DUT.

2. Set the voltmeter as follows:
   - Set it to measure DC volts.
   - Set it to autorange.
   - Verify that the math mx+b function is disabled (select **Shift + DC**), ensuring that volts are being read.
3. Set the electronic load as follows:
   - Set to a constant current.
   - Set to draw a constant current at the test current specified for the channel under test in the table for DC voltage accuracy.
4. Set the channel under test to the full-scale output current.
5. Set the channel under test to 0% of the full-scale output voltage (0 V).
6. Turn the DUT output on.
7. Enter the voltmeter reading in the table for DC voltage accuracy.
8. Enter the voltmeter reading in the table for DC voltage readback accuracy.
9. Enter the voltage readback of the channel under test in the table for DC voltage readback accuracy.
10. Calculate the difference between the two measurements made in steps 8 and 9 and enter the value in the appropriate column of the table. Check whether the absolute difference is within the maximum difference.
11. Increase the channel under test output voltage by 25% of the full-scale output voltage.
12. Repeat steps 7 through 11 until you complete testing at 100% of full scale.

This completes the check for one channel. If needed, return to step 1 to repeat the procedure for each additional channel.

## Check DC voltage line regulation

NOTE

Ensure the warm-up criteria have been met, as described in Warmup period (on page 2-20).

***To perform the test on each channel sequentially:***

1. Set up the equipment as shown in the figure in Check DC voltage setting and DC voltage readback accuracy (on page 2-23).
2. Change the AC power source output to the minimum voltage specified in the following table.

| DUT voltage selector switch | AC power source voltage |
|---|---|
| 110 | 99 V |
| 220 | 198 V |

3. Set the voltmeter as follows:
   - Set to measure DC volts.
   - Set to autorange.
   - Verify that the math mx+b function is disabled (select **Shift + DC**), ensuring that volts are being read.
4. Set the electronic load as follows:
   - Set to constant current.
   - Set to draw the specified test current.

| Channel | Test current |
|---|---|
| Channel 1 | 2230G-30-3: 3 A<br>2230G-30-6: 6 A<br>2230G-60-3: 3 A |
| Channel 2 | 2230G-30-3: 3 A<br>2230G-30-6: 6 A<br>2230G-60-3: 3 A |
| Channel 3 | 2230G-30-3: 3 A<br>2230G-30-6: 3 A<br>2230G-60-3: 3 A |

5. Set the channel under test to 100% of the full-scale output current.
6. Set the channel under test to 100% of the full-scale output voltage.
7. Turn the DUT output on.
8. Enter the voltmeter reading in the Minimum column of the table for DC voltage line regulation for the channel under test.
9. Change the AC power source output to the maximum voltage specified in the following table.

| DUT voltage selector switch | AC power source voltage |
|---|---|
| 110 | 132 V |
| 220 | 264 V |

10. Enter the voltmeter reading in the Maximum column of the table for checking DC voltage line regulation for the channel under test.
11. Change the AC power source output to match the voltage selector switch setting of the DUT.

| DUT voltage selector switch | AC power source voltage |
|---|---|
| 110 | 115 V |
| 220 | 230 V |

12. Enter the voltmeter reading in the Nominal column of the table for checking DC voltage line regulation for the channel under test.
13. Calculate the difference between the two values in the Nominal and Minimum columns.
14. Calculate the difference between the two values in the Nominal and Maximum columns.
15. Enter the calculated values in the appropriate columns.
16. Enter the larger of the two values calculated in steps 13 and 14 in the appropriate column.

This completes the check for one channel. If needed, repeat the procedure for each additional channel.

## Check DC voltage load regulation

NOTE

Ensure the warm-up criteria have been met, as described in Warmup period (on page 2-20).

***To perform the test on each channel sequentially:***

1. Set up the equipment as shown in the figure in Check DC voltage setting and DC voltage readback accuracy (on page 2-23).
2. Set the voltmeter as follows:
   - Set to measure DC volts.
   - Set to autorange.
   - Verify that the math mx+b function is disabled (select **Shift + DC**), ensuring that volts are being read.
3. Set the electronic load as follows:
   - Set to constant current.
   - Set to draw 0 A.
4. Set the channel under test to 100% of the full-scale output current.
5. Set the channel under test to 100% of the full-scale output voltage.
6. Turn the DUT output on.
7. Enter the voltmeter reading in the Minimum column of the table for DC voltage load regulation for the channel under test.
8. Increase the electronic load to the reference load test current value.

| Channel | Test current |
|---|---|
| Channel 1 | 2230G-30-3: 1.5 A<br>2230G-30-6: 3 A<br>2230G-60-3: 1.5 A |
| Channel 2 | 2230G-30-3: 1.5 A<br>2230G-30-6: 3 A<br>2230G-60-3: 1.5 A |
| Channel 3 | 2230G-30-3: 1.5 A<br>2230G-30-6: 1.5 A<br>2230G-60-3: 1.5 A |

9. Enter the voltmeter reading in the Reference column of the table for DC voltage load regulation for the channel under test.

10. Increase the electronic load to the maximum load test current value.

| Channel | Test current |
|---|---|
| Channel 1 | 2230G-30-3: 3 A<br>2230G-30-6: 6 A<br>2230G-60-3: 3 A |
| Channel 2 | 2230G-30-3: 3 A<br>2230G-30-6: 6 A<br>2230G-60-3: 3 A |
| Channel 3 | 2230G-30-3: 3 A<br>2230G-30-6: 3 A<br>2230G-60-3: 3 A |

11. Enter the voltmeter reading in the Maximum column of the table for DC voltage load regulation for the channel under test.
12. Calculate the three values: Ref – Min, Max – Ref, and (Max – Ref)/0.98. Enter the values in the appropriate columns.
13. Enter the largest of the three values calculated in step 12 in the appropriate column.

This completes the verification procedure for one channel. If needed, repeat the procedure for each additional channel.

## Check DC current and DC current readback accuracy

| Equipment required | Comment |
|---|---|
| AC power source | High-current connection wire (bold line connections in the following figure) |
| Electronic load | Low-current connection wire (fine line connections in the following figure) |
| DC voltmeter | |

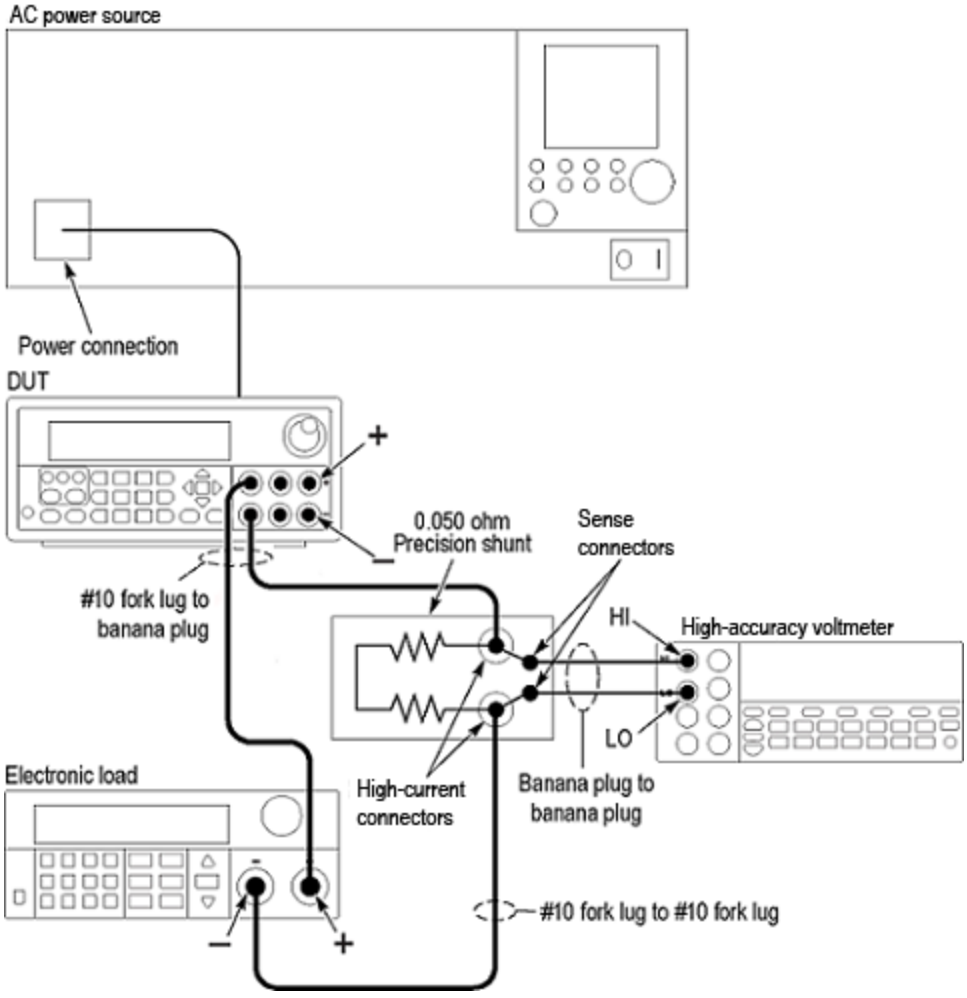
### NOTE

Ensure the warm-up criteria have been met, as described in Warmup period (on page 2-20).

***To perform the test on each channel sequentially:***

1. Set up the equipment as shown in the following figure.

**Figure 2: Connections for checking the current**



2. Set the voltmeter as follows:
   - Set to measure DC volts.
   - Set to autorange.
   - Set to show amperes (instead of volts) by multiplying the voltmeter result by 20.
     - Select **Shift + DCV** (mx+b).
     - Use the arrow key to move the cursor to the far right until it is positioned on the **^**.
     - Press the up range button once so that `M=10.00000` is displayed.
     - Press the arrow key to move the cursor to the first digit and press the up range button once so that `M=20.00000` is displayed.
     - Press the **Enter** button and check that the display shows `B=0`.
     - Press the **Enter** button and check that the display shows `UNITS`.
     - Use the arrow keys to modify the display to show `AMP`.
     - Adjust each letter individually.
3. Set the electronic load as follows:
   - Set to constant voltage.
   - Set to the specified voltage for your channel under test.
4. Set the channel under test to 0% of the full-scale output current.
5. Set the channel under test to 100% of the full-scale output voltage.
6. Turn the DUT output on.
7. Enter the voltmeter reading in the table for DC current accuracy.
8. Enter the voltmeter reading in the table for DC current readback accuracy.
9. Enter the current readback of the channel under test in the table for DC current readback accuracy.
10. Calculate the difference between the two measurements made in steps 8 and 9. Enter the value in the appropriate column of the table. Check whether the absolute difference is within the maximum difference.
11. Increase the channel under test output current by 25% of the full-scale output current.
12. Repeat steps 7 through 11 until you complete testing at 100% of the full-scale output current.

This completes the check for one channel. If needed, repeat the procedure for each additional channel.

## Check DC current line regulation

NOTE

Ensure the warm-up criteria have been met, as described in Warmup period (on page 2-20).

***To perform the test on each channel sequentially:***

1. Set up the equipment as shown in the figure in Check DC current and DC current readback accuracy (on page 2-28).
2. Change the AC power source output to the voltage specified in the following table.

| DUT voltage selector switch | AC power source voltage |
|---|---|
| 110 | 99 V |
| 220 | 198 V |

3. Set the voltmeter as follows:
   - Set to measure DC volts.
   - Set to autorange.
     - Set to show amperes (instead of volts) by multiplying the voltmeter result by 20.
     - Select **Shift + DCV** (mx+b).
     - Use the arrow key to move the cursor to the far right until it is positioned on the **^**.
     - Press the up range button once so that `M=10.00000` is displayed.
     - Press the arrow key to move the cursor to the first digit and then press the up range button once so that `M=20.00000` is displayed.
     - Press the **Enter** button and check that the display shows `B=0`.
     - Press the **Enter** button and check that the display shows `UNITS`.
     - Use the arrow keys to modify the display to show `AMP`.
     - Adjust each letter individually.
4. Set the electronic load as follows:
   - Set to constant voltage.
   - Set to the specified voltage for your channel under test.
5. Set the channel under test to 100% of the full-scale output voltage.
6. Set the channel under test to 100% of the full-scale output current.
7. Turn the DUT output on.
8. Enter the voltmeter reading in the Minimum column of the DC current line regulation table for the channel under test.
9. Change the AC power source output to the voltage specified in the following table.

| DUT voltage selector switch | AC power source voltage |
|---|---|
| 110 | 132 V |
| 220 | 264 V |

10. Enter the voltmeter reading in the Maximum column for the channel under test.
11. Change the AC power source output to the voltage specified in the following table.

| DUT voltage selector switch | AC power source voltage |
|---|---|
| 110 | 115 V |
| 220 | 230 V |

12. Enter the voltmeter reading in the Nominal column for the channel under test.

13. Calculate the two values: Nominal – Minimum and Maximum – Nominal. Enter the values in the appropriate columns.
14. Select the larger of the two calculations from step 13 and enter the value in the appropriate column.
15. Turn the DUT output off.

This completes the verification procedure for one channel. If needed, repeat the procedure for each additional channel.

## Check DC current load regulation

NOTE

Ensure the warm-up criteria have been met, as described in Warmup period (on page 2-20).

***To perform the test on each channel sequentially:***

1. Set up the equipment as shown in the figure in Check DC current and DC current readback accuracy (on page 2-28).
2. Set the voltmeter as follows:
   - Set to measure DC volts.
   - Set to autorange.
   - Set to show amperes (instead of volts) by multiplying the voltmeter result by 20.
     - Select **Shift + DCV** (mx+b).
     - Use the arrow key to move the cursor to the far right until it is positioned on the **^**.
     - Press the up range button once so that `M=10.00000` is displayed.
     - Press the arrow key to move the cursor to the first digit and then press the up range button once so that `M=20.00000` is displayed.
     - Press the **Enter** button and check that the display shows `B=0`.
     - Press the **Enter** button and check that the display shows `UNITS`.
     - Use the arrow keys to modify the display to show `AMP`.
     - Adjust each letter individually.
3. Set the electronic load as follows:
   - Set to constant voltage.
   - Set to output the minimum test voltage level.

| Channel | Minimum test voltage level |
|---|---|
| Channel 1 | 2230G-30-3: 3.0 V<br>2230G-30-6: 3.0 V<br>2230G-60-3: 6.0 V |
| Channel 2 | 2230G-30-3: 3.0 V<br>2230G-30-6: 3.0 V<br>2230G-60-3: 6.0 V |
| Channel 3 | 2230G-30-3: 0.5 V<br>2230G-30-6: 0.5 V<br>2230G-60-3: 0.5 V |

4. Set the channel under test to 100% of the full-scale output current for your product.
5. Set the channel under test to 100% of the full-scale output voltage for your product.
6. Turn the DUT output on.
7. Enter the voltmeter reading in the Minimum column of the DC current load regulation table.

8. Increase the electronic load to the reference test voltage level.

| Channel | Reference test voltage level |
|---|---|
| Channel 1 | 2230G-30-3: 15.0 V<br>2230G-30-6: 15.0 V<br>2230G-60-3: 30.0 V |
| Channel 2 | 2230G-30-3: 15.0 V<br>2230G-30-6: 15.0 V<br>2230G-60-3: 30.0 V |
| Channel 3 | 2230G-30-3: 2.5 V<br>2230G-30-6: 2.5 V<br>2230G-60-3: 2.5 V |

9. Enter the voltmeter reading in the Reference column table for DC current load regulation at the reference test voltage for the channel under test.
10. Increase the electronic load to the maximum test voltage level.

| Channel | Maximum test voltage level |
|---|---|
| Channel 1 | 2230G-30-3: 29.4 V<br>2230G-30-6: 29.4 V<br>2230G-60-3: 58.8 V |
| Channel 2 | 2230G-30-3: 29.4 V<br>2230G-30-6: 29.4 V<br>2230G-60-3: 58.8 V |
| Channel 3 | 2230G-30-3: 4.9 V<br>2230G-30-6: 4.9 V<br>2230G-60-3: 4.9 V |

11. Enter the voltmeter reading in the table for DC current load regulation at the maximum voltage for the channel under test.
12. Calculate the two values: Reference – Minimum and Maximum – Reference. Enter the values in the appropriate columns.
13. Select the larger of the two calculated values from step 12 and enter the value in the appropriate column.
14. Power off the DUT and test equipment.

This completes the verification procedure for one channel. If needed, repeat the procedure for each additional channel.

## Check voltage noise (20 MHz)

| Equipment required | Comment |
|---|---|
| High-current connection wire (bold line connections in the following figure) | Oscilloscope |
| Load resistor | Coaxial cable (BNC male-male) |
| BNC female-to-banana | |

NOTE

Ensure the warm-up criteria have been met, as described in Warmup period (on page 2-20).

***To perform the test on each channel sequentially:***

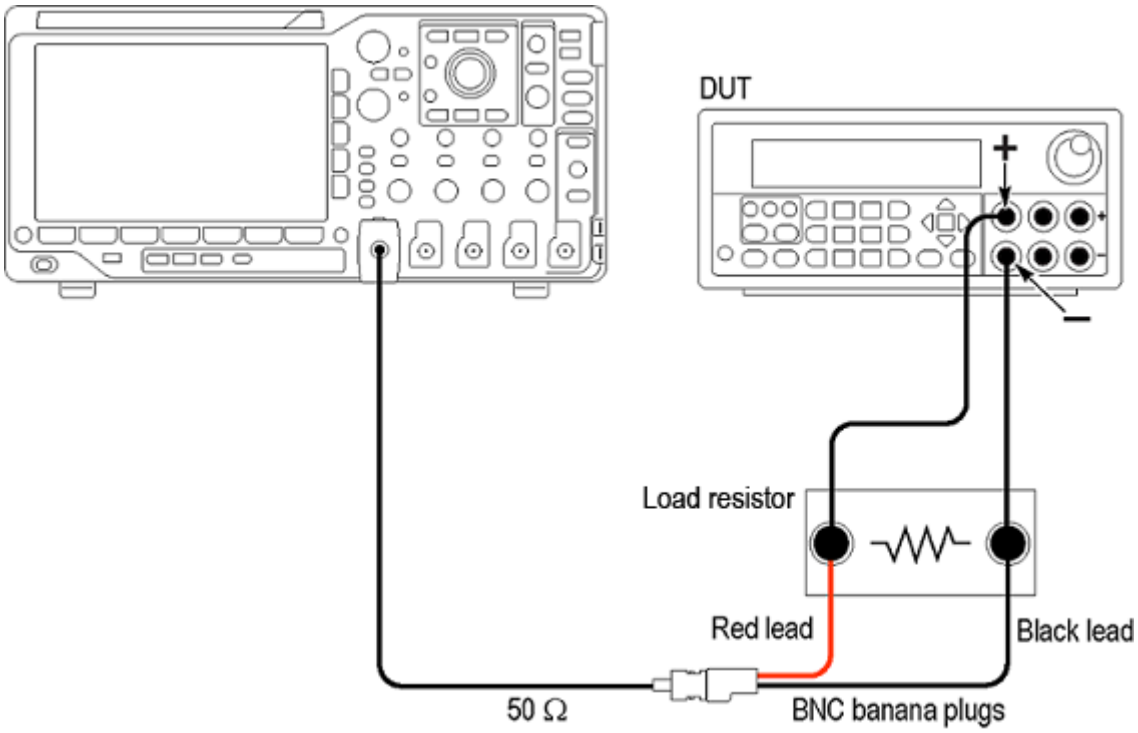
1. Plug the device under test (DUT) into your local line power from the mains.
2. Plug the test oscilloscope into the same mains outlet as the DUT.

NOTE

Some AC power sources create large amounts of high-frequency noise on the power line that the instrument may not fully reject. Noise directly on the mains is typically better controlled. Use the same mains outlet for both the DUT and test oscilloscope to avoid ground loops, which may cause noise.

3. Power on the DUT and test oscilloscope.
4. Set up the equipment as shown in the following figure. Use the appropriate load resistor depending on the channel being tested.

**Figure 3: Connections for checking voltage noise**



5. Set the oscilloscope as follows:
   - 1 mV/division
   - 1 MΩ input resistance
   - 20 MHz bandwidth limit
   - AC coupled
   - Line trigger
   - 2 ms/division
   - Set to measure $V_{pk-pk}$ and $V_{RMS}$
6. Set the channel under test to the 100% full-scale output voltage.
7. Set the channel under test to the 100% full-scale output current.
8. Turn the DUT output on.

**WARNING**

**Do not touch the load resistor. The load resistor may become hot enough to cause burns.**

9. Enter the oscilloscope measurements in the table for voltage noise at 20 MHz.

This completes the verification procedure for one channel. If needed, repeat the procedure for each additional channel.

## Check current noise (20 MHz)

| Equipment required | Comment |
|---|---|
| High-current connection wire (bold line connections) | Oscilloscope |
| 1 Ω load resistor | Oscilloscope 10X probe |

**NOTE**

Ensure the warm-up criteria have been met, as described in Warmup period (on page 2-20).

***To perform the test on each channel sequentially:***

1. Plug the device under test (DUT) into your local line power from the mains.
2. Plug the test oscilloscope into the same mains outlet as the DUT.

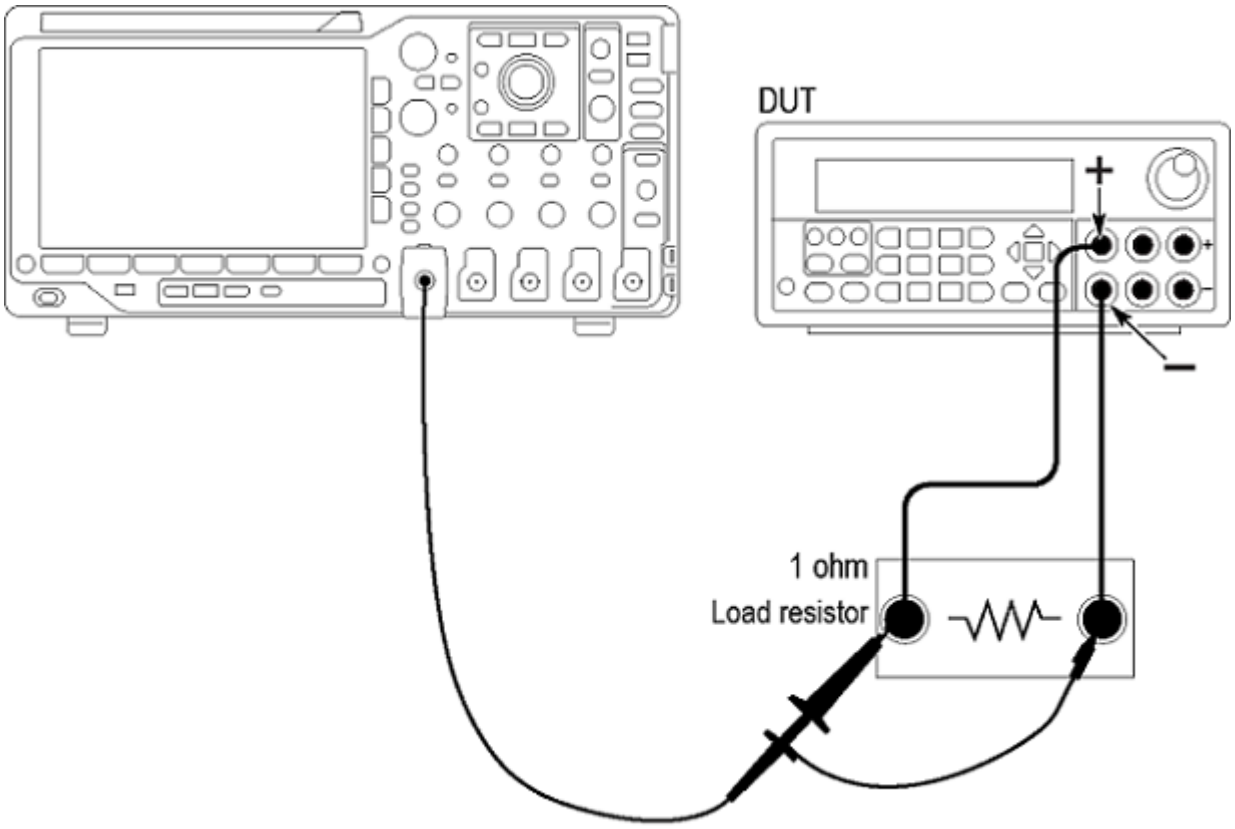
**NOTE**

Some AC power sources create large amounts of high-frequency noise on the power line that the instrument may not fully reject. Noise directly on the mains is typically better controlled. Use the same mains outlet for both the DUT and test oscilloscope to avoid ground loops which may cause noise.

3. Power on the DUT and oscilloscope.

4. Set up the equipment as shown.

**Figure 4: Connections for checking current noise**




5. Set up the oscilloscope as follows:
   - 1 mV/division
   - 1 MΩ input resistance
   - 20 MHz bandwidth limit
   - AC coupled
   - Line trigger
   - 2 ms/division
   - Set to measure $V_{pk\text{-}pk}$ and $V_{RMS}$
6. Set the channel under test to the 100% full-scale output voltage.
7. Set the channel under test to the 100% full-scale output current.
8. Turn the DUT output on.

**⚠ WARNING**

**Do not touch the load resistor. The load resistor may become hot enough to cause burns.**

9. Enter the oscilloscope measurements in the table for current noise at 20 MHz.
10. Power off the DUT and test equipment.

This completes the verification procedure for one channel. If needed, repeat the procedure for each additional channel.

Section 3

# Adjustment

**In this section:**



## Introduction

This section describes the procedures to adjust the 2230G calibration.

2230G performance is specified for one year from adjustment. Adjustment should be performed at this interval, depending on your specification requirements.

NOTE

Performance is also specified relative to calibration adjustment temperature ($T_{cal}$). Keithley factory adjustment is performed at 23 °C ± 1 °C

⚠ WARNING

**The information in this section is intended for qualified service personnel only, as described by the types of product users in the Safety precautions (on page 1-1). Do not attempt to perform these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.**

## Environmental conditions

To ensure accurate results, the environment must meet the following conditions.

### Temperature and relative humidity

Conduct the adjustment procedures in a test environment with:

- A stable ambient temperature controlled to vary less than ±1 °C during the period of adjustment.
- Keithley Instruments recommends a calibration adjustment temperature ($T_{cal}$) of 23 ± 5 °C. If a different nominal temperature is used, it should be noted on the calibration report.
- A relative humidity of less than or equal to 40 percent, unless otherwise noted.
- No direct airflow on the input terminals.

### Line power

The Model 2230G requires a line voltage and a line frequency of 99 to 132 at 60 Hz or 198 to 264 at 50 Hz.

The instrument must be adjusted within this range.

NOTE

The instrument automatically senses the line frequency at power-up.

## Warmup period

Allow the Model 2230G to warm up for at least 30 minutes before conducting the adjustment procedures.

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

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

## Recommended test equipment

The following table summarizes the recommended calibration equipment. Specified accuracy of all functions and ranges is dependent on the precision of reference signals used during the adjustment process. To achieve specified performance, adjustment reference uncertainties must be at least four times smaller than the best corresponding Model 2230G one-year accuracy specification for measuring that signal.

| Manufacturer | Model | Description | Used for: |
|---|---|---|---|
| Keithley | 2380 series | Variable DC load capable of 6 ADC and 40 VDC | Electronic load |
| Keithley | 2000 | Voltage measurement at 12 mV through 40 V to better than 100 ppm accuracy with the ability to multiply the result by a scalar | Digital multimeter |
| - | - | 18 AWG (minimum) hookup wire assemblies | High-current hookup wire (high-current connections are indicated with bold lines in the setup illustrations) |
| - | - | 22 AWG (minimum) hookup wires | Low-current hookup wire (low-current connections are indicated with light lines in the setup illustrations) |

NOTE

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

# General adjustment considerations

Model 2230G performance is sensitive to errors from thermoelectric potentials generated by test cables and connections. Be sure to use high-quality cables and connection techniques. When changing a connection during the adjustment process, be sure to allow time (up to five minutes) for thermal settling.

**⚠ WARNING**

**The information in this section is intended for qualified service personnel only, as described by the types of product users in the Safety precautions (on page 1-1). Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death if contacted. Use appropriate safety precautions when working with hazardous voltages.**

# Initial instrument setup

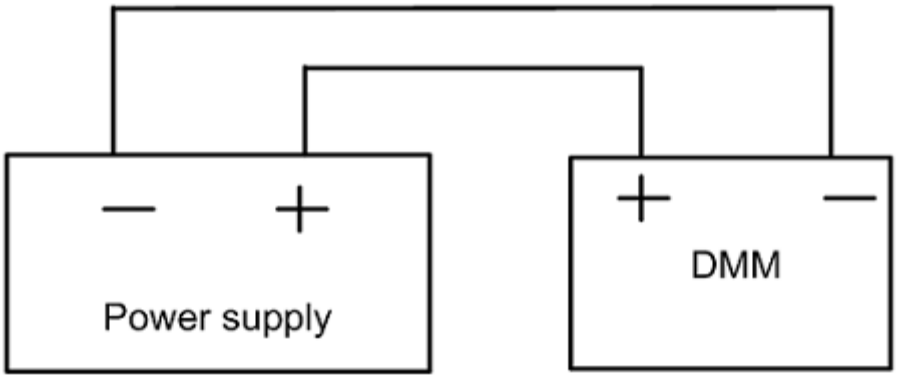
Adjust the 2230G using a remote connection through the USB interface.

For details on remote communications, refer to "Remote communications interfaces" in the *Series 2230G User's Manual* (part number 2230G-900-01).

## Connect the calibration equipment

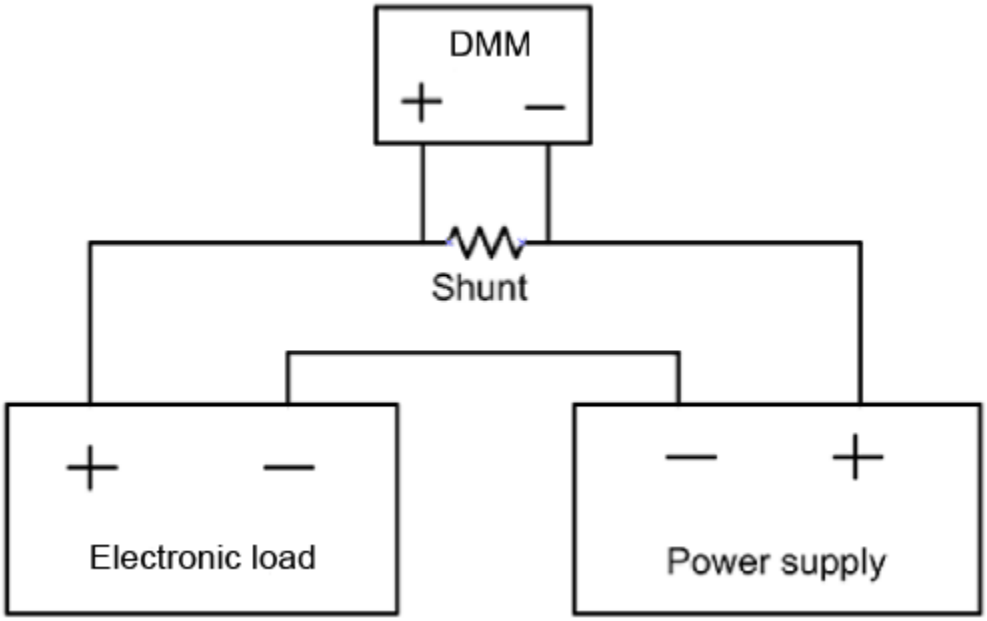
Set up the equipment for voltage calibration as follows.

**Figure 5: Adjusting voltage calibration**



Set up the equipment for current calibration as follows.

**Figure 6: Adjusting current calibration**

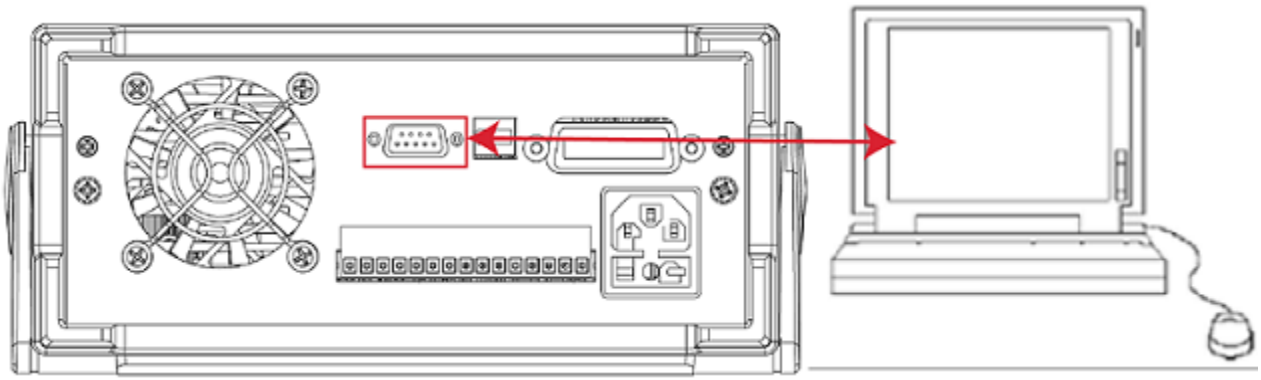



## Connect the remote communication

The 2230G has an RS-232 communication interface for communication with a computer. You can use a cable with two COM ports to connect a power supply to a computer.

You need to configure the instrument to RS-232 and its parameters for the connection. For more information about remote communication, see "RS-232 interface" in the *Series 2230G User's Manual,* part number 2230G-900-01).

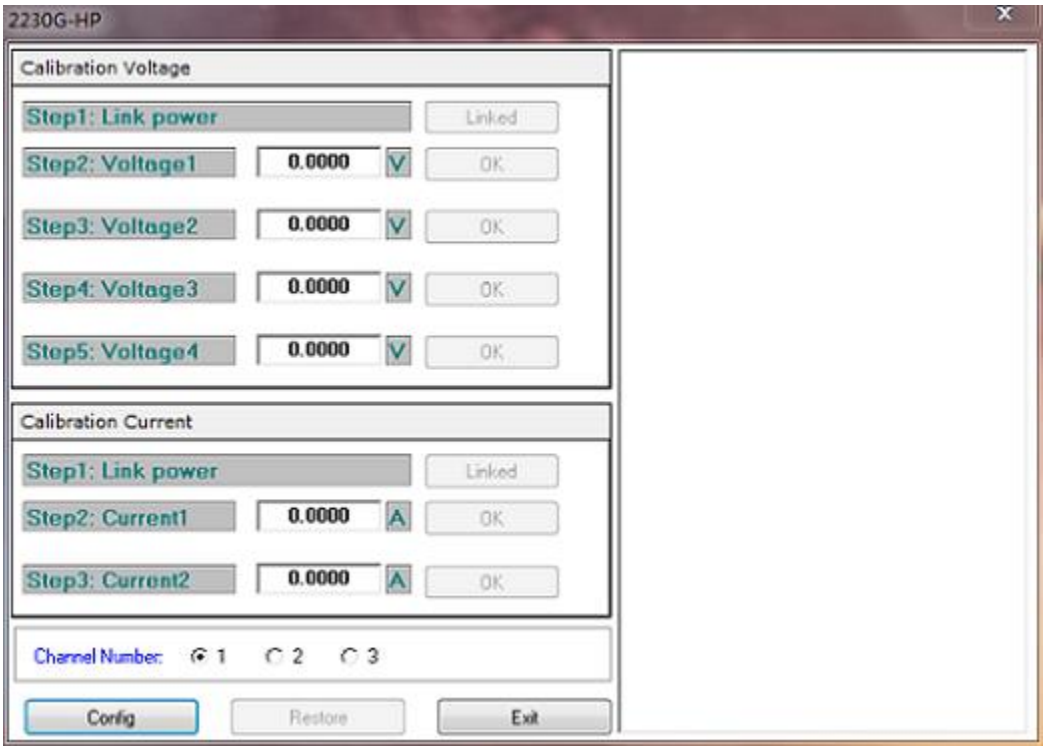
**Figure 7: Adjustment remote communication**



# Calibration adjustment procedures

Click the **2230G-HP.exe** icon on the computer. The following figure is displayed.

**Figure 8: Start calibration adjustment**



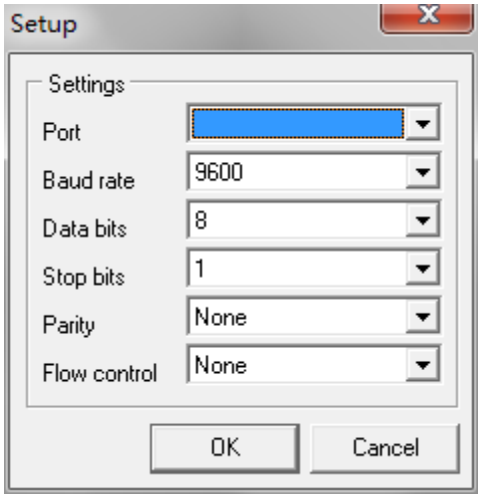

The parameters and icons in the interface are described in the following table.

| Parameter or icon | Description |
|---|---|
| **Calibration Voltage** | The procedure of calibration voltage |
| **Linked** | Link to remote control |
| **OK** | Execute the calibration |
| **Calibration Current** | The procedure of calibration current |
| **Channel Number** | Select the channel before the calibration of the equipment |
| **Config** | Configure parameters under the configuration interface of a serial communication |
| **Restore** | Revert to precalibration status |
| **Exit** | Exit the calibration software |

## Configure the serial communication interface

1. Click **Config**. The following figure is displayed.

**Figure 9: Configure the RS-232 port**



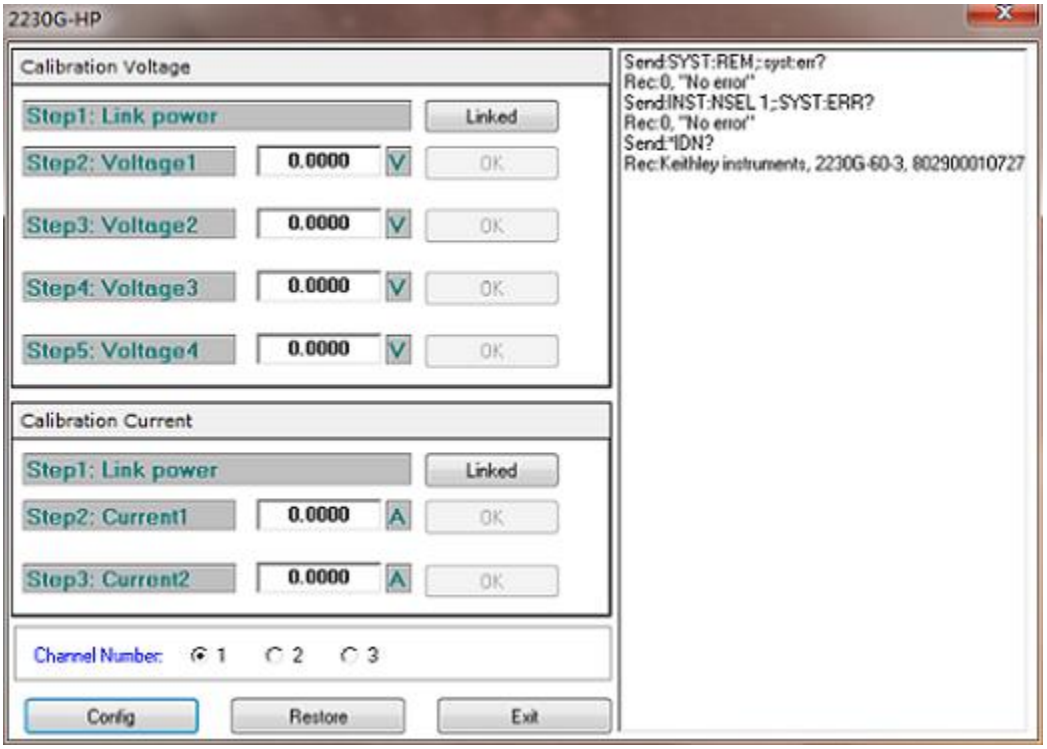

2. Enter the settings for the RS-232 port. The baud rate must agree with the settings of the power supply.

NOTE

You can set the parameters of RS-232 on the power supply by selecting **Menu > User Settings > Communication Port**.

3. Press **OK**. The following figure is displayed.

**Figure 10: Calibration adjustment interface**



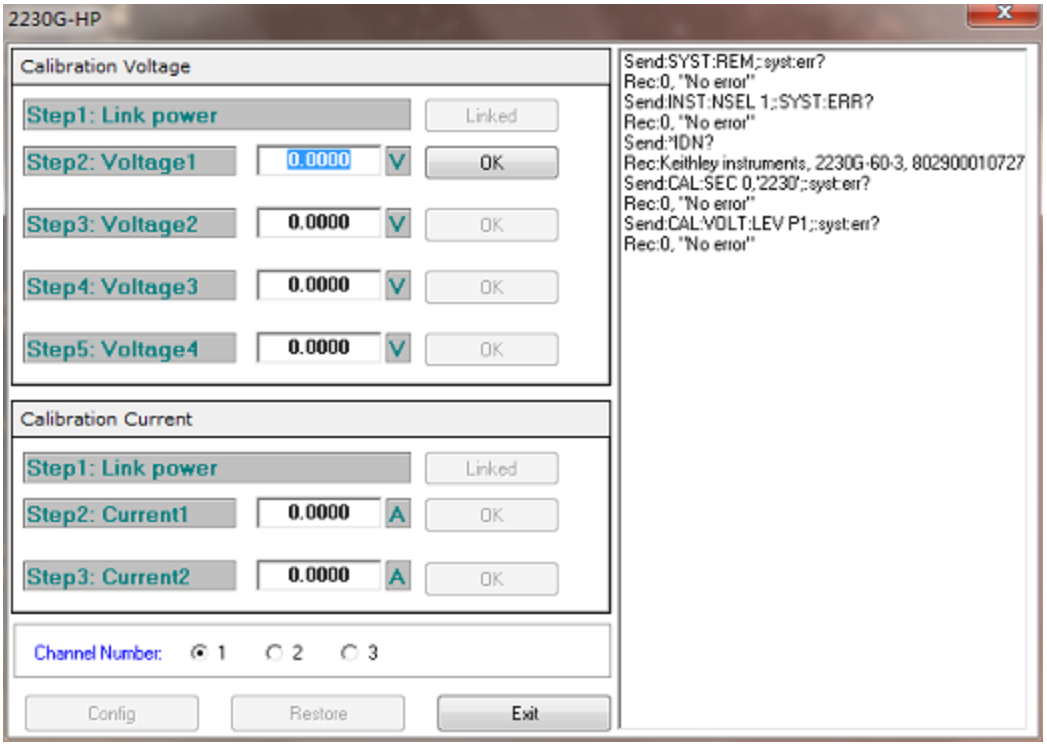

4. Configure the following:
   - Calibration voltage for every channel
   - Calibration current for every channel

## Calibrate voltage

The calibration operation of each channel is executed independently, but the calibration method is the same. The following steps provide detailed information for calibrating the voltage of channel 1:

1. Choose the channel number.
2. Select **Linked**. Information is displayed in the right panel as shown in the following figure.

**Figure 11: Voltage calibration**




## NOTE

When **Linked** is selected, the calibration of the power supply is unlocked.

3. Enter the measured voltage value under the **Step2: Voltage1**, then click **OK** to calibrate the first voltage point.
4. Enter the measured voltage value under the **Step3: Voltage2**, then click **OK** to calibrate the second voltage point.
5. Enter the measured voltage value under the **Step4: Voltage3**, then click **OK** to calibrate the third voltage point.
6. Enter the measured voltage value under the **Step5: Voltage4**, then click **OK** to calibrate the fourth voltage point.
7. The interface displays **Calibrate Voltage End** after calibrating the last point. Click **OK** and save the calibration voltage. If you need to revert to precalibration status, select **Restore**.

## Calibrate current

Before calibrating current, set the load mode to CC, and the current value to 150% for the unit under test (UUT).

The selection of current calibration points is calculated according to the following formula.

$I_{out} = V_{DMM} / R_{shunt}$

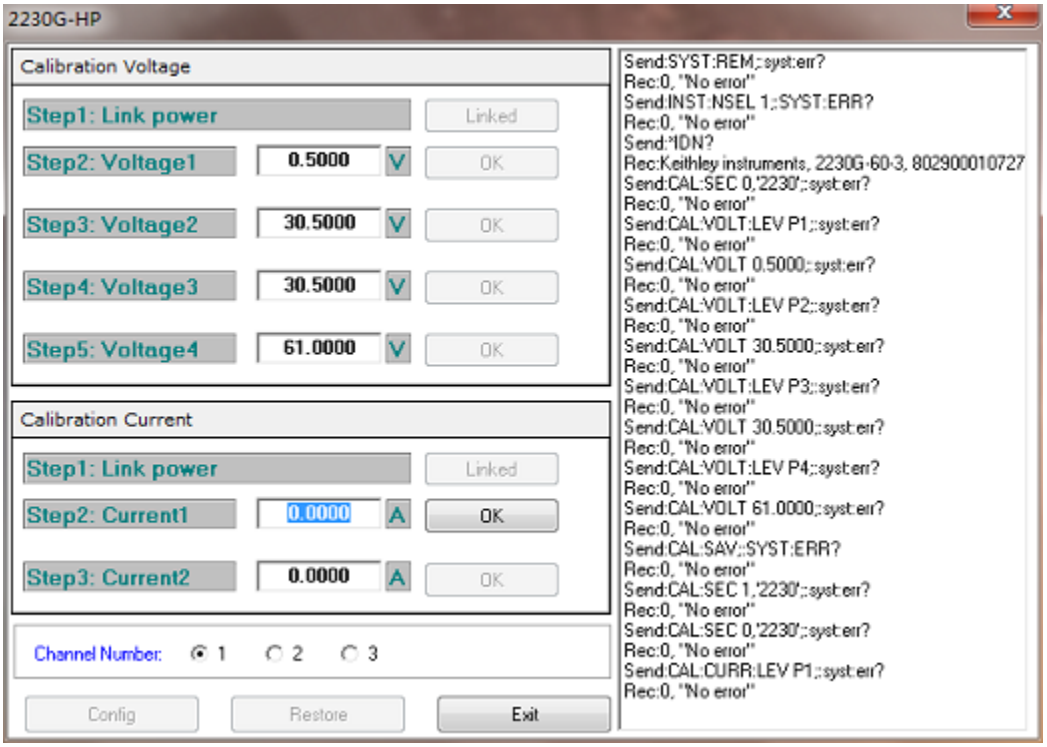
Where:

- $I_{out}$: The current calibration point.
- $V_{DMM}$: The voltage value displayed in DMM.
- $R_{shunt}$: The resistance of shunt.

The calibration operation of each channel is executed independently, but the calibration method is the same. The following steps provide detailed information for calibrating the current of channel 1:

1. Choose channel number.
2. Select **Linked** in area Calibration Current. Information is displayed in the right panel as shown in the following figure.

**Figure 12: Current calibration**




3. Enter the current calibration point under the **Step2: Current1**, then click **OK** to calibrate the first current point.
4. Enter the current calibration point under the **Step3: Current2**, then click **OK** to calibrate the second current point.

Keithley Instruments
Corporate Headquarters • 28775 Aurora Road • Cleveland, Ohio 44139 • 440-248-0400 • Fax: 440-248-6168 • 1-800-935-5595 • www.tek.com/keithley

KEITHLEY
A Tektronix Company