Series 2200

Multichannel Programmable DC Power Supplies

Specifications and Performance Verification Technical Reference

2220S-905-01 Rev. B / Dec 2013

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Safety precautions

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

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

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

The types of product users are:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The ⏛ symbol indicates a connection terminal to the equipment frame.

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

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

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

Instrumentation and accessories shall not be connected to humans.

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

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

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

Safety precaution revision of January 2013.

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Preface

Welcome

Thank you for using a Keithley Instruments product. The Series 2200 Multichannel Programmable DC Power Supplies are flexible DC sources designed to power a wide range of applications. The model 2230-30-1 and its variants offer three power channels and the model 2220-30-1 and its variants provide two channels. The output channels on both models are independent and isolated, allowing you to power circuits with different references or polarities. Each channel can be enabled or disabled as your application requires. All outputs feature remote sense capability which can be used to reduce the effect of lead resistance, delivering 0.03% basic voltage accuracy even when using long leads. Basic current accuracy is 0.1% for all channels and linear regulation delivers low noise – less than 3 mVp-p. Flexible display modes make it easy to use the two 30 V outputs in combination, and the USB interface makes it easy to build PC-based systems without converters or special cables. The G versions of each model include a GPIB interface in combination with the USB interface.

These compact power supplies cover a wide range of applications without covering a lot of bench space. Versions of these power supplies are available for use at 100 VAC nominal line voltage which is common in Japan. These versions are indicated by the "J" suffix.

Products

This manual contains information about the following products:

Model	Description
2220-30-1	Programmable Dual Channel DC Power Supply
2220G-30-1	Programmable Dual Channel DC Power Supply with GPIB Interface
2220J-30-1	Programmable Dual Channel DC Power Supply for Japan
2220GJ-30-1	Programmable Dual Channel DC Power Supply with GPIB Interface for Japan
2230-30-1	Triple Channel Programmable DC Power Supply
2230G-30-1	Programmable Triple Channel DC Power Supply with GPIB Interface
2230J-30-1	Triple Channel Programmable DC Power Supply for Japan
2230GJ-30-1	Programmable Triple Channel DC Power Supply with GPIB Interface for Japan

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 representative for details.

Contact Information

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

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

Specifications

This section contains specifications for the Series 2200 Multichannel Programmable DC Power Supplies. All specifications are guaranteed unless noted as "typical." Typical specifications are provided for your convenience but are not guaranteed. Specifications that are marked with the ✓ symbol are checked in *Performance Verification*.

Table 1: Series 2220 Dual Channel specifications

Parameter	Description
Channel 1 and 2, nominal	Channels 1 and 2 are symmetrical and isolated. They are primarily targeted at powering analog circuits operating around ground.
Constant voltage operation, nominal	The unit may be set to a constant voltage over a range of currents
Voltage range This is the range over which the output voltage is adjustable	0 to 30 V
Remote sense voltage range	The total voltage from the – terminal to the + terminal may not exceed the rated full scale (FS) voltage + 0.2 V, allowing a minimum of 0.1 V/line for remote sense. The maximum voltage difference between a terminal and its associated sense line may not exceed 1 V. The available overhead above full scale voltage to support remote sense is limited to 0.1 V/line. However, this widens as the output voltage decreases to the ultimate limit of 1 V/line. Thus, the maximum difference specification controls operation except for the 2 V of output below full scale output.
Voltage resolution, nominal	1 mV
✓ Voltage setting accuracy with remote sense	±(0.03% of settling + 10 mV) at 25 °C ±5 °C with remote sense.
✓ Voltage setting accuracy without remote sense	±(0.05% of settling + 10 mV) at 25 °C ±5 °C without remote sense.
Current limit, nominal	Defined by the constant current setting. The changeover is automatic.
Voltage temperature coefficient, typical	±(0.03% + 10 mV) per °C outside the 25 °C ±5 °C standard range
Constant current operation, nominal	The unit may be set to a constant current over a range of voltages.
Current range This is the range over which the output current is adjustable	0 A to 1.5 A

Table 1: Series 2220 Dual Channel specifications (cont.)

Parameter	Description
Current resolution, nominal	1 mA
✓ Current setting accuracy	±(0.1% + 5 mA) at 25 °C ±5 °C
Voltage limit, nominal	0 to 30 V
Current temperature coefficient, typical	±(0.1% + 5 mA) per °C outside the 25 °C ±5 °C standard range
Meter, nominal	Internal readback capability. Voltage and current can be measured internally.
Current readback resolution, nominal	1 mA
✓ Current readback accuracy	±(0.1% of reading + 5 mA) at 25 °C ±5 °C
Current readback temperature coefficient, typical	±(0.1% + 5 mA) per °C outside of the 25 °C ±5 °C standard range
✓ Voltage readback accuracy	±(0.03% of reading + 10 mV) at 25 °C ±5 °C standard range
Voltage readback resolution, nominal	1 mV
Voltage readback temperature coefficient, typical	±(0.03% of reading + 10 mV) per °C outside the 25 °C ±5 °C standard range
✓ Line regulation – voltage	Change over the full rated line voltage range: ±(0.01% + 3 mV)
✓ Line regulation – current	Change over full rated line voltage range: ±(0.1% + 3 mA)
✓ Load regulation – voltage	Change from 0 to 100% of full scale current: ±(0.01% + 3 mV)
✓ Load regulation – current	Change from 10 to 90% of full scale voltage: ±(0.01% + 3 mA)
✓ Voltage ripple, 20 MHz bandwidth	< 3 mV_{RMS} and 20 mV_{p-p} < 1.5 mV_{RMS} and 12 mV_{p-p}, typical
✓ Voltage ripple, 7 MHz bandwidth	< 1 mV_{RMS} and 3 mV_{p-p}
✓ Current ripple, 20 MHz bandwidth	< 5 mA_{RMS}
Common Mode Current Noise	< 1.5 μA_{RMS}, 700 Hz bandwidth.

Table 1: Series 2220 Dual Channel specifications (cont.)

Parameter	Description				
Voltage transient response settling time, load change, typical	<150 ms to within 75 mV following a change from 0.1 A to 1 A.				
Voltage transient response settling time, setting change, rising, typical	<150 ms from beginning of excursion to within 75 mV of terminal value following a change from 1 V to 11 V into a 10 Ω resistor.				
Voltage transient response settling time, setting change, falling, typical	<150 ms from beginning of excursion to within 75 mV of terminal value following a change from 11 V to 1 V into a 10 Ω resistor.				
Unit Specific Mains Requirements	2220-30-1 and 2220G-30–1				
	Line Selection Switch	Voltage	Frequency	Fuse Rating	Max VA +
	110V	110/115/120	50/60 Hz	6.3A TH 250V	350
	220V	220/230/240	50/60 Hz	3.15A TH 250V	350
	2220J-30-1 and 2220GJ-30–1				
	Line Selection Switch	Voltage	Frequency	Fuse Rating	Max VA +
	110V	100	50/60 Hz	6.3A TH 250V	350
	220V	200	50/60 Hz	3.15A TH 250V	350
Maximum Input VA, typical	350 VA				

Table 2: Series 2230 Triple Channel specifications for Channels 1 and 2

Parameter	Description
Channel 1 and 2, nominal	Channels 1 and 2 are symmetrical and isolated. They are primarily targeted at powering analog circuits operating around ground.
Constant Voltage Operation, nominal	The unit may be set to be a constant voltage over a range of currents.
Voltage Range	The output voltage may be adjusted from 0V to 30V.

Table 2: Series 2230 Triple Channel specifications for Channels 1 and 2 (cont.)

Parameter	Description
Remote Sense Voltage Range	The total voltage from - terminal to + terminal may not exceed the rated full scale voltage +0.2V, allowing a minimum of 0.1V/line for remote sense. The Maximum voltage difference between a terminal and its associated sense line may not exceed 1V. The available overhead above full scale voltage to support remote sense is limited to 0.1 V/line. However, this widens as the output voltage decreases to the ultimate limit of 1 V/line. Thus, the maximum difference specification controls operation except for the 2 V of output below full scale output.
Voltage Resolution, nominal	1 mV
√ Voltage Setting Accuracy with Remote Sense	+/-(0.03% of setting + 10 mV) at 25 °C ±5 °C with Remote Sense
√ Voltage Setting Accuracy without Remote Sense	+/-(0.05% of setting + 10 mV) at 25 °C ±5 °C without Remote Sense
Current Limit, nominal	Defined by Constant Current setting. Changeover is automatic.
Voltage Temperature Coefficient, typical	+/-(0.03% of setting + 10 mV) per °C outside of the 25 °C ±5 °C standard range
Constant Current Operation, nominal	The unit may be set to be a constant current over a range of voltages.
Current Range	The output voltage may be adjusted from 0 A to 1.5 A.
Current Resolution, nominal	1 mA
√ Current Setting Accuracy	+/-(0.1% + 5 mA) at 25 °C ±5 °C.
Voltage Limit, nominal	0 to 30 V.
Current Temperature Coefficient, typical	+/-(0.1% + 5 mA) per °C outside of the 25 °C ±5 °C standard range
Meter, nominal	Internal readback capability. Voltage and current are measured internally.
Current Readback Resolution, nominal	1 mA
✓ Current Readback Accuracy	±(0.01% of reading + 5 mA) at 25 °C ±5 °C
Current Readback Temperature Coefficient, typical	±(0.01% + 5 mA) per °C outside the 25 °C ±5 °C standard range
✓ Voltage Readback Accuracy	±(0.03% of reading + 10 mV) at 25 °C ±5 °C
Voltage Readback Resolution, nominal	1 mV
Voltage Readback Temperature Coefficient, typical	±(0.03% of reading + 10 mV) per °C outside the 25 °C ±5 °C standard range
✓ Line regulation – Voltage	Change over the full rated line voltage range: ±(0.01% + 3 mV)
✓ Line regulation – Current	Change over full rated line voltage range: ±(0.1% + 3 mA)
✓ Load regulation – Voltage	Change from 0 to 100% of full scale. Voltage: ±(0.01% + 3 mV)

Table 2: Series 2230 Triple Channel specifications for Channels 1 and 2 (cont.)

✓ Load regulation – Current	Change from 10 to 90% of full scale. Current: ±(0.01% + 3 mA) While not readily testable, similar performance is expected over the 0% to 100% of full scale range of the product.
✓ Voltage Ripple, 20 MHz bandwidthh	< 3 mV_{RMS} and 20 mV_{p-p} < 1.5 mV_{RMS} and 12 mV_{p-p}, typical
Voltage Ripple, 7 MHz bandwidth	< 1 mV_{RMS} and 3 mV_{p-p}
✓ Current Ripple, 20 MHz bandwidth	< 5 mA_{RMS}
Common Mode Current Noise	< 1.5 μA_{RMS}. 700 Hz bandwidth.
Voltage Transient Response Settling Time, Load Change, typical	<150 ms to within 75 mV following a change from 0.1 A to 1 A.
Voltage Transient Response Settling Time, Setting Change, Rising, typical	<150 ms from beginning of excursion to within 75 mV of terminal value following a change from 1 V to 11 V into a 10 Ω resistor.
Voltage Transient Response Settling time, Setting Change, Falling, typical	<150 ms from beginning of excursion to within 75 mV of terminal value following a change from 11 V to 1 V into a 10 Ω resistor.

Table 3: Series 2230 Triple Channel specifications for Channel 3

Parameter	Description
Channel 3, nominal	A third channel is provided. It is primarily targeted at logic power.
Constant Voltage Operation, nominal	The unit may be set to be a constant voltage over a range of currents.
Voltage Range	The output voltage may be adjusted from 0 V to 6 V.
Remote Sense Voltage Range	The total voltage from - terminal to + terminal may not exceed the rated full scale voltage +0.2V, allowing a minimum of 0.1V/line for remote sense. The maximum voltage difference between a terminal and its associated sense line may not exceed 1V. The available overhead above full scale voltage to support remote sense is limited to 0.1 V/line. However, this widens as the output voltage decreases to the ultimate limit of 1 V/line. Thus, the maximum difference specification controls operations except for the 2 V of output below full scale output.
Voltage Resolution, nominal	1 mV
√ Voltage Setting Accuracy with Remote Sense	+/-(0.03% of setting + 10 mV) at 25 °C ±5 °C with Remote Sense
√ Voltage Setting Accuracy without Remote Sense	+/-(0.05% of setting + 10 mV) at 25 °C ±5 °C without Remote Sense
Current Limit, nominal	Defined by Constant Current setting. Chageover is automatic.
Voltage Temperature Coefficient, typical	+/-(0.03% of setting + 10 mV) per °C outside of the 25 °C ±5 °C standard range

Table 3: Series 2230 Triple Channel specifications for Channel 3 (cont.)

Constant Current Operation, nominal	The unit may be set to be a constant current over a range of voltages.
Current Range	The output voltage may be adjusted from 0 A to 5 A.
Current Resolution, nominal	1 mA
√ Current Setting Accuracy	+/-(0.1% + 5 mA) at 25 °C ±5 °C.
Voltage Limit, nominal	0 to 6 V.
Current Temperature Coefficient, typical	+/-(0.1% + 5 mA) per °C outside of the 25 °C ±5 °C standard range
Meter, nominal	Internal readback capability. Voltage and current can be measured internally. DVM connections exist to allow measuring external voltages.
Current Readback Resolution, nominal	1 mA
✓ Current Readback Accuracy	±(0.1% of reading + 5 mA) at 25 °C ±5 °C
Current Readback Temperature Coefficient, typical	±(0.1% +5mA) per °C outside of the 25 °C ±5 °C standard range
✓ Voltage Readback Accuracy	±(0.03% of reading + 10 mV) at 25 °C ±5 °C
Voltage Readback Resolution, nominal	0.1 mV
Voltage Readback Temperature Coefficient, typical	±(0.03% of reading + 10 mV) per °C outside of the 25 °C ±5 °C standard range
✓ Line Regulation – Voltage	Change over the full rated line voltage range: ±(0.01% + 3 mV)
✓ Line Regulation – Current	Change over full rated line voltage range: ±(0.1% + 3 mA)
✓ Load Regulation – Voltage	Change from 0 to 100% of full scale. Voltage: ±(0.01% + 3 mV)
✓ Load Regulation – Current	Change from 10 to 90% of full scale. Current: ±(0.01% + 3 mA)
✓ Voltage Ripple, 20 MHz Bandwidthh	< 3 mV_{RMS} and 20 mV_{p-p}. < 1.5 mV_{RMS} and 12 mV_{p-p}, typical
✓ Voltage Ripple, 7 MHz bandwidth	< 1 mV_{RMS} and 3 mV_{p-p}
✓ Current Ripple, 20 MHz Bandwidth	Less than 6 mA_{RMS}
Common Mode Current Noise	< 1.5 μA_{RMS}. 700 Hz bandwidth.
Voltage Transient Response Settling Time, Load Change, typical	<150 ms to within 75 mV following a change from 0.1 A to 1 A.
Voltage Transient Response Settling Time, Setting Change, Rising, typical	<150 ms from beginning of excursion to within 75 mV of terminal value following a change from 0.4 V to 4 V into a 4Ω resistor.
Voltage Transient Response Settling Time, Setting Change, Falling, typical	<150 ms from beginning of excursion to within 75 mV of terminal value following a change from 0.4 V to 4 V into a 4Ω resistor. The specification does not include Command Decode Time.

Table 4: Combined channel characteristics

Characteristic	Description
Combined Channel Characteristics, nominal	The unit can be configured to provide functionality on Channel 1 and Channel 2 together.
Series Combinations, nominal	Deliver up to 60 V when CH1 and CH2 are wired in series. Voltage Readback is the combined voltage. Settings changes are to the combined voltage. Current Readback is for Channel 1 only. If the currents in the two channels are significantly different there is no indication of CC/CV status for Channel 2.
Available Series Configurations, nominal	Channels 1 and 2 are connected in series. Either channel 1 or channel 2 may be the most positive source.
Series Combination Voltage Accuracy, typical	±(0.10% of the setting + 50 mV) at 25 °C ±5 °C
Series Combination Current Accuracy, typical	±(0.1% + 5 mA) at 25 °C ±5 °C for Channel 1's current. The current is only measured for Channel 1. The error is the same as for the Current Measurement Accuracy.
Parallel Combination, nominal	Delivers up to 3 A when CH1 and CH2 are wired in parallel. The meter reads back the combined current.
Available Parallel Configurations, nominal	CH1 and CH2 are connected in parallel (+ to + and – to –)
Parallel Combination Voltage Accuracy (typical)	±(0.05% of setting + 10 mV) at 25 °C ±5 °C
Parallel Combination Current Accuracy, typical	±(0.2% +10 mA) at 25 °C ±5 °C

Table 5: Series 2230 Triple Channel unit characteristics

Characteristic	Description				
Unit Characteristics, nominal	Characteristics and specifications of features unique to this product, but unrelated to a particular channel.				
Unit Specific Mains Requirements	2230-30-1 and 2230G-30–1				
	Line Selection Switch	Voltage	Frequency	Fuse Rating	Max VA
	110V	110/115/120	50/60 Hz	6.3A TH 250V	450
	220V	220/230/240	50/60 Hz	3.15A TH 250V	450
	2230J-30-1 and 2230GJ-30–1				
	Line Selection Switch	Voltage	Frequency	Fuse Rating	Max VA
	110V	100	50/60 Hz	6.3A TH 250V	450
	220V	200	50/60 Hz	3.15A TH 250V	450
Maximum Input VA, typical		450 VA			

Table 6: Mains power characteristics

Characteristic	Description		
Source Voltage	The 2220-30-1, 2220G-30-1, 2230-30-1, and 2230G-30-1 each have two ranges, selectable with a bottom panel switch. Each range is capable of ±10% excursions.		
	Marked		Allowed nominal voltages
	110		110/115/120 VAC_{RMS}
	220		220/230/240 VAC_{RMS}
	The 2220J-30-1, 2220GJ-30-1, 2230J-30-1, and 2230GJ-30-1 each have two ranges, selectable with a bottom panel switch. Each range is capable of ±10% excursions.		
	Marked		Allowed nominal voltage
	110		100 VAC_{RMS}
	220		200 VAC_{RMS}
Source Frequency	50/60 Hz		
Fuse Rating, nominal	Model	110 VAC setting	220 VAC setting
	2230, 2230G and 2220, 2220G	6.3A T 250V 159-0399-00	3.15A T 250V 159-0493-00

Table 7: Common characteristics

Item	Description
Setup Memory, nominal	30 setup memory locations
Output Timer, nominal	The product includes a timer that can be used to disable the output after a predetermined period of time.
Timer Set Time, nominal	The Timer may be set to any value between 1 and 999,999 seconds.
Timer Accuracy	±100 ppm
Software Voltage Limit, nominal	The product offers the opportunity to change the maximum settable voltage on a temporary basis. The MAX VOLT menu entry, when set below hardware maximum limit, disallows adjusting the product to voltages in excess of the MAX VOLT limit.
Cleaning Requirements, nominal	Inspect the power supply as often as operating conditions require. To clear the exterior surface, perform the following steps: 1. Remove loose dust on the outside of the power supply with a lint free cloth. Use care to avoid scratching the display. 2. Use a soft cloth dampened with water to clear the power supply. Use an aqueous solution of 75% isopropyl alcohol for more efficient cleaning. Caution: To avoid damage to the surface of the power supply, do not use any abrasive or chemical cleaning agents. Caution: Avoid getting moisture inside the unit during external cleaning. Use only enough cleaning solution to dampen the cloth or swab.

Table 7: Common characteristics (cont.)

Item	Description
Isolation Voltage, Output to Chassis	Any output can be floated up to 240 V (DC + peak AC with AC limited to a maximum 3 $V_{pk\text{-}pk}$ and maximum of 60 Hz) relative to the Earth Ground terminal. Note that remote sense terminals should remain within 1 V of their respective outputs to avoid possible damage.
Isolation Voltage, Output to Output	Any output can be floated up to 240 V (DC + pk AC with AC limited to a maximum of 3 $V_{pk\text{-}pk}$ and a maximum of 60 Hz) relative to any other output terminal. Remote sense terminals should remain within 1 V of their respective outputs to avoid possible damage.

Table 8: Terminal strip

Item	Description
The rear panel has a customer accessible terminal strip. This strip is comprised of a board-mounted section and a technician-removeable section. The technician-removeable section offers the customer a safe set of screw terminals to connect to various instrument functions detailed below.	

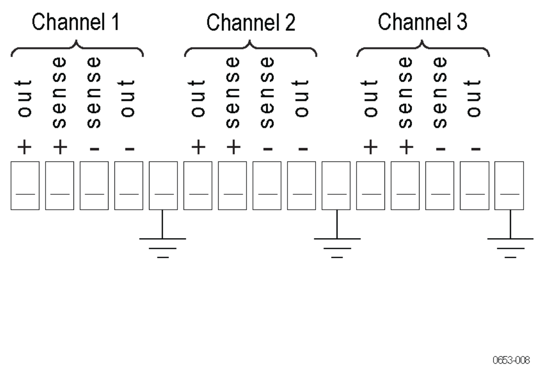


Table 9: Interfaces and output ports

Parameter (instrument model)	Description
USB device, nominal (All models)	USB 2.0 Full Speed device. 12 Mb/sec maximum.
GPIB interface (G models only)	IEEE-488.2 compliant
Command processing time, typical (All models)	About 400 ms per command.

Table 10: Mechanical characteristics

Parameter		
Weight, instrument, nominal	9 kg (19.8 lbs)	
Dimensions, nominal	Model	Dimensions (Width * Height * Depth
	2230	214 mm * 88 mm * 355 mm (8.45” * 3.47” * 13.9”)
Cooling method, nominal	Fan	
Required cooling clearance	Rear of instrument must be separated by at least 5 cm (2 in) from any airflow restrictions to assure adequate cooling. Bottom of instrument must have 1 cm (0.4 in) from any airflow restrictions. The protective boot maintains the proper bottom clearance. For rackmount configuration, follow the clearance requirements provided with the rackmount installation instructions.	
Construction materials, nominal	Chassis – Aluminum Front Panel Plastics – PC/ABS blend	

Table 11: Environment performance

Parameter	All models
Temperature	Operating: +0 °C to +40 °C Nonoperating: -20 °C to 70 °C
Humidity	Operating: 5% to 95% relative humidity (% RH) at up to 40 °C, noncondensing Nonoperating: 5% to 95% RH (relative humidity) at up to +40 °C, 5% to 60% RH above +40 °C up to +70 C, noncondensing
Altitude	Operating: 100% capability up to 2,000 meters. Nonoperating: Up to 4,000 meters

Table 12: Keypad special operations

Characteristic	Description
Display the heat sink temperature	Enter + Esc + 1
Reset the unit to the factory default settings	Enter + Esc + 2

Table 13: Safety characteristics

Item	Description
Safety Certifications	**U.S. Nationally Recognized Testing Laboratory (NRTL) Listing** UL61010-1–2004 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
	Canadian Certification CAN/CSA C22.2 No. 61010-1-2004 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
	European Union Compliance Low Voltage Directive 2006/95/EC EN61010-1 2001 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
	Additional Compliance IEC61010-1 2001 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
Channel to Channel Isolation Voltage	Any output can be floated up to 240 V (DC + peak AC with AC limited to a maximum $3V_{pk-pk}$ and maximum of 60 Hz) relative to any other channel terminal. Remote sense terminals should remain within 1 V of their respective outputs to avoid possible damage.
Channel to Ground Isolation Voltage	Any output can be floated up to 240 V (DC + peak AC with AC limited to a maximum $3V_{pk-pk}$ and maximum of 60 Hz) relative to the Earth Ground terminal. Remote sense terminals should remain within 1 V of their respective outputs to avoid possible damage.

Table 14: Electromagnetic Compatibility (EMC) — Measurement, laboratory, and control product family

Item	Description
Regional Certifications, Classifications, and Standards List	
European Union	EC Council EMC Directive 2004/108/EC Demonstrated using: **EN 61326-1:2006 Electrical Equipment for Measurement, Control, and Laboratory** [1, 2] Emissions CISPR 11, Class A Immunity IEC 61000-4-2 IEC 61000-4-3 IEC 61000-4-4 IEC 61000-4-5 IEC 61000-4-6 IEC 61000-4-8 IEC 61000-4-11 EN 61000-3-2 EN 61000-3–3 [1] [1] Emissions that exceed the levels by this standard may occur when this equipment is connected to a test object. [2]. Use high quality shielded cables to maintain compliance
Australia	EMC Framework, demonstrated per Emission Standard CISPR11 in accordance with EN 61326-1
Immunity	
Immunity, Electrostatic Discharge (ESD), Enclosure Port	IEC 61000-4-2 EN 61326-1, Performance Criterion “B”
Immunity, Conducted Radio Frequency	IEC 61000-4-6 EN 61326-1, Performance Criterion “A”

Performance Verification

This section contains performance verification procedures for the specifications marked with the ✓ symbol. Additional test equipment is required to complete the verification procedures. (See Table 27 on page 24.)

These procedures cover all models of the Series 2200 Programmable DC Power Supplies. Ignore checks that do not apply to the specific model you are testing.

Print the test record on the following pages, and use it to record the performance test results for your power supply.

NOTE. *Each individual performance test must be done for each channel. This means two times for the 2220-30-1, 2220G-30-1, 2220J-30-1, and 2220GJ-30-1. It means three times for the 2230-30-1, 2230G-30-1, 2230J-30-1, and 2230GJ-30-1.*

NOTE. *Completion of the performance verification procedure does not update the stored time and date of the latest successful adjustment. The date and time are updated only when the factory adjustment procedures are successfully completed.*

The performance verification procedures verify the performance of your instrument. They do not adjust your instrument. If your instrument fails any of the performance verification tests, you should contact Keithley service.

WARNING. *Observe all safety precautions listed in this manual before using this product and any associated instrumentation. Although some instruments and accessories are used with nonhazardous voltages, there are situations where hazardous conditions may be present. This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Before using the product, carefully read and follow all installation, operation, and maintenance information. Refer to this manual for complete product specifications. Before performing any maintenance, disconnect the line cord and all test cables. Operators of this instrument must be protected from electric shock at all times. The responsible body must make sure 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 can operate at or above 1000 volts, no conductive part of the circuit may be exposed.*

WARNING. *Do not loosen any screw on this product. There are no user serviceable components inside.*

CAUTION. *Use properly rated load wires. All load wires must be heavy enough not to overheat when carrying the maximum short-circuit output current of the power supply. If there is more than one load, then any pair of load wires must be capable of safely carrying the full-rated short-circuit output current of the power supply.*

Test Record

Model	Serial	Procedure performed by	Date

Test	Passed	Failed
Self test		
DC voltage accuracy with remote sense		
DC voltage accuracy without remote sense		
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 7 MHz		
Voltage noise at 20 MHz		
Current noise at 20 MHz		

Table 15: DC voltage accuracy with remote sense

Instrument test voltage	DUT voltage	Test current	Min	Measured	Max
Channel 1					
0%	0.00000 V	0.5 A	-0.01000 V	__________	0.01000 V
25%	7.5000 V	0.5 A	7.48775 V	__________	7.51225 V
50%	15.00000 V	0.5 A	14.98550 V	__________	15.01450 V
75%	0.00000 V	2.5 A	-0.01000 V	__________	0.01000 V
100%	30.0000 V	0.5 A	29.98100 V	__________	30.01900 V
Channel 2					
0%	0.00000 V	0.5 A	-0.01000 V	__________	0.01000 V
25%	7.5000 V	0.5 A	7.48775 V	__________	7.51225 V
50%	15.00000 V	0.5 A	14.98550 V	__________	15.01450 V
75%	22.50000 V	0.5 A	22.48325 V	__________	22.51675 V
100%	30.00000 V	0.5 A	29.98100 V	__________	30.01900 V
Channel 3					
0%	0.00000 V	2.5 A	-0.01000 V	__________	0.01000 V
25%	1.5000 V	0.5 A	14.98550 V	__________	15.01450 V
50%	3.00000 V	2.5 A	2.98910 V	__________	3.01090 V
75%	4.50000 V	2.5 A	4.48865 V	__________	4.51135 V
100%	6.00000 V	2.5 A	5.98820 V	__________	6.01180 V

Table 16: DC voltage accuracy without remote sense

Instrument test voltage	DUT voltage	Test current	Min	Measured	Max
Channel 1					
0%	0.00000 V	0.5 A	-0.01000 V	__________	0.01000 V
25%	7.50000 V	0.5 A	7.48625 V	__________	7.51375 V
50%	15.00000 V	0.5 A	14.98250 V	__________	15.01750 V
75%	22.50000 V	0.5 A	22.47875 V	__________	22.52125 V
100%	30.00000 V	0.5 A	29.975000 V	__________	30.02500 V
Channel 2					
0%	0.00000 V	0.5 A	-0.01000 V	__________	0.01000 V
25%	7.500000 V	0.5 A	7.48625 V	__________	7.51375 V
50%	15.00000 V	0.5 A	14.98250 V	__________	15.01750 V
75%	22.50000 V	0.5 A	22.47875 V	__________	22.52125 V
100%	30.00000 V	0.5 A	29.97500 V	__________	30.02500 V
Channel 3					
0%	0.00000 V	2.5 A	-0.01000 V	__________	0.01000 V
25%	1.50000 V	2.5 A	1.48925 V	__________	1.51075 V
50%	3.00000 V	2.5 A	2.98850 V	__________	3.01150 V
75%	4.50000 V	2.5 A	4.48775 V	__________	4.51225 V
100%	6.00000 V	2.5 A	5.98700 V	__________	6.01300 V

Table 17: DC voltage readback accuracy

Instrument test voltage	DUT voltage	Test current	Measured voltage	Voltage readout	Absolute difference	Maximum difference
Channel 1						
0%	0.00000 V	0.5 A	________	________	________	0.01000 V
25%	7.50000 V	0.5 A	________	________	________	0.01225 V
50%	15.00000 V	0.5 A	________	________	________	0.01450 V
75%	22.50000 V	0.5 A	________	________	________	0.01675 V
100%	30.00000 V	0.5 A	________	________	________	0.01900 V
Channel 2						
0%	0.00000 V	0.5 A	________	________	________	0.01000 V
25%	7.50000 V	0.5 A	________	________	________	0.01225 V
50%	15.00000 V	0.5 A	________	________	________	0.01450 V
75%	22.50000 V	0.5 A	________	________	________	0.01675 V
100%	30.00000 V	0.5 A	________	________	________	0.01900 V
Channel 3						
0%	0.00000 V	2.5 A	________	________	________	0.01000 V
25%	1.50000 V	2.5 A	________	________	________	0.010375 V
50%	3.00000 V	2.5 A	________	________	________	0.010750 V
75%	4.50000 V	2.5 A	________	________	________	0.011125 V
100%	6.00000 V	2.5 A	________	________	________	0.01150 V

Table 18: DC voltage line regulation

Instrument	Min line	Max line	Nom line	Nom – Min	Max – Nom	Largest	Max value
Channel 1	________	________	________	________	________	________	0.0120000 V
Channel 2	________	________	________	________	________	________	0.0120000 V
Channel 3	________	________	________	________	________	________	0.0072000 V

Table 19: DC voltage load regulation

Instrument	Min load	Ref load	Max load	Ref – Min	Max – Ref	(Max – Ref) / 0.98	Largest	Max value
Channel 1	______	______	______	_______	_______	_______	______	0.0120000 V
Channel 2	______	______	______	_______	_______	_______	______	0.0120000 V
Channel 3	______	______	______	_______	_______	_______	______	0.0072000 V

Table 20: DC current accuracy

Instrument test current	Test voltage	DUT current	Min	Measured current	Max
Channel 1					
0%	15 V	0.00000000 A	-0.00500000 A	__________	0.00500000 A
25%	15 V	0.3750 A	0.36963 A	__________	0.38037 A
50%	15 V	0.75000 A	0.74425 A	__________	0.75575 A
75%	15 V	1.1250 A	1.11888 A	__________	1.13113 A
100%	15 V	1.5000 A	1.49350 A	__________	1.50650 A
Channel 2					
0%	15 V	0.00000000 A	-0.00500000 A	__________	0.00500000 A
25%	15 V	0.3750 A	0.36963 A	__________	0.38037 A
50%	15 V	0.75000 A	0.74425 A	__________	0.75575 A
75%	15 V	1.1250 A	1.11888 A	__________	1.13113 A
100%	15 V	1.5000 A	1.49350 A	__________	1.50650 A
Channel 3					
0%	3 V	0.00000000 A	-0.00500000 A	__________	0.00500000 A
25%	3 V	1.25000000 A	1.24375000 A	__________	1.25625000 A
50%	3 V	2.50000000 A	2.49250000 A	__________	2.50750000 A
75%	3 V	3.75000000 A	3.74125000 A	__________	3.75875000 A
100%	3 V	5.00000 A	4.99000 A	__________	5.01000 A

Table 21: DC current readback accuracy

Instrument test current	Test current	Measured current	Current readout	Absolute difference	Maximum difference
Channel 1					
0%	0 A	________	________	________	0.00500000 A
25%	0.375 A	________	________	________	0.0053750 A
50%	0.75 A	________	________	________	0.00575000 A
75%	1.125 A	________	________	________	0.00612500 A
100%	1.5 A	________	________	________	0.00650000 A
Channel 2					
0%	0 A	________	________	________	0.00500000 A
25%	0.375 A	________	________	________	0.0053750 A
50%	0.75 A	________	________	________	0.00575000 A
75%	1.125 A	________	________	________	0.00612500 A
100%	1.5 A	________	________	________	0.00650000 A
Channel 3					
0%	0 A	________	________	________	0.00500000 A
25%	1.25 A	________	________	________	0.00625000 A
50%	2.5 A	________	________	________	0.00550000 A
75%	3.75 A	________	________	________	0.00875000 A
100%	5 A	________	________	________	0.01000000 A

Table 22: DC current line regulation

Instrument	Test voltage	Min line	Max line	Nom line	Nom – Min	Max – Nom	Largest	Max value
Channel 1	15 V	______	______	______	______	______	______	0.004500A
Channel 2	15 V	______	______	______	______	______	______	0.004500A
Channel 3	3 V	______	______	______	______	______	______	A

Table 23: DC current load regulation

Instrument	Meas @ min volts	Meas @ ref volts	Meas @ max volts	Ref - Min	Max - Ref	Largest	Maximum difference
Channel 1	______	______	______	______	______	______	0.003120 A
Channel 2	______	______	______	______	______	______	0.003120 A
Channel 3	______	______	______	______	______	______	0.003400 A

Table 24: Voltage noise at 7 MHz

Instrument	Voltage test load R [1]	Measured rms	Maximum rms	Measured pk - pk	Maximum pk - pk
Channel 1	40 Ω	______	1 mV	______	3 mV
Channel 2	40 Ω	______	1 mV	______	3 mV
Channel 3	2.5 Ω	______	1 mV	______	3 mV

1 Load R must be rated at 100 W minimum.

Table 25: Voltage noise at 20 MHz

Instrument	Voltage test load R [1]	Measured rms	Maximum rms	Measured pk - pk	Maximum pk - pk
Channel 1	40 Ω	______	3 mV	______	20 mV
Channel 2	40 Ω	______	3 mV	______	20 mV
Channel 3	2.5 Ω	______	3 mV	______	20 mV

1 Load R must be rated at 100 W minimum.

Table 26: Current noise at 20 MHz

Instrument	Current test load R [1]	Measured rms	Maximum rms
Channel 1	1 Ω	______	3 mVA
Channel 2	1 Ω	______	3 mA
Channel 3	1 Ω	______	3 mA

1 Load R must be rated at 100 W minimum.

Performance Verification Procedures

Performance Verification Conditions

The following conditions must be met before performing these procedures:

1. The Device Under Test (DUT) and all test equipment must have been operating continuously for 20 minutes in an environment that meets the operating range specifications for temperature and humidity.

   Test setup changes affecting the remote sense require an additional 20 minute warm-up period.

2. The procedures are intended to be used in sequence. If it is necessary to partially test the DUT using an individual test, a 20 minute warm-up period is required for the individual test.

3. You must connect the DUT and the test equipment to the same AC power circuit. Connect the DUT and test instruments into a common power strip if you are unsure of the AC power circuit distribution. Connecting the DUT and test instruments into separate AC power circuits can result in offset voltages between the equipment, which can invalidate this performance verification procedure.

4. The AC Power Source for the DUT must match the Voltage Selector switch setting located on the bottom of the DUT.

DUT voltage selector switch	AC source voltage	AC source voltage for Japan products
110	115 V	100 V
220	230 V	200 V

Equipment Required

These procedures use external equipment to directly check warranted characteristics. The following table lists the required equipment.

Table 27: Test equipment

Item	Minimum requirements	Example
1. Connectors	Connectors for hook up wire assemblies and test resistors, item numbers 5, 6, 9, 10, and 11. ■ (Qty. 6) #10 fork lugs similar to Tyco part number 52951 ■ (Qty, 14) Stackable, gold plated, banana plugs/jacks similar to Pomona model 4897-0. Used for lower current connections, and connection to the load resistors (items 10 and 11) used for noise testing. ■ (Qty. 4) Sheathed Banana Jacks similar to Pomona model 4834 to put connectors on the Resistors (item 9).	
2. AC power source	Variable AC output from 90 to 265 VAC with at least 750 VA capacity	Kikusui PCR2000M
3. Electronic load	Variable DC Load capable of 6 ADC and 40 VDC	B&K Precision 8510
4. DC voltmeter	Voltage measurement at 12 mV through 40 V to better than 100 ppm accuracy with the ability to multiply the result by a scalar.	Keithley 2000 DMM
5. High current hook up wire (High current connections are indicated with bold lines in the setup illustrations)	18 AWG (minimum) hookup wire assemblies. To perform all tests, the following wire assemblies need to be created: ■ #10 fork lug to #10 fork lug, Qty 2, (included in Guildline 92301 if used) ■ Stackable Banana to #10 fork lug, Qty 2 ■ Stackable Banana to Bare Wire Qty 2. Wire lengths are not critical.	
6. Low current hook up wire (Low current connections are indicated with light lines in the setup illustrations)	22 AWG (minimum) hookup wires To perform all tests, the following wire assemblies need to be created: ■ Banana plug to Banana plug, Qty 2 ■ Bare Wire to stackable Banana, Qty 2 ■ Bare Wire to Banana, Qty 2 Wire lengths are not critical.	
7. 50 mΩ precision shunt resistor	0.050 Ω ±100 ppm at 25 W ±4 ppm/°C temperature coefficient	Guildline 9230A-50
8. Current sense resistor cabling	Kelvin 4 terminal measuring cables for shunt resistor to voltmeter	Guildline 92301 cable set

Table 27: Test equipment (cont.)

Item		Minimum requirements	Example
9.	50 mΩ resistor for Remote Sense testing (2 required) One of these 50 mΩ resistors may be substituted with item 7.	0.050 Ω, 5 W. To perform the tests as illustrated, both leads of each resistor require a Banana Jack connector (e.g. Pomona model 4834).	OHMITE 15FR050E
10.	Load resistor for Voltage Noise testing	Loading resistors for high current in voltage mode, and high voltage in current mode All resistors should be rated for at least 50 W. Ohms tolerance within 5%. Resistor composition is not critical. To perform the tests as illustrated, both leads of the load resistor require a Banana plug/jack (or equivalent) to connect to the power supply.	
	Channel 1	12 Ω	Vishay/Dale RH05012R00FE02
	Channel 2	12 Ω	Vishay/Dale RH05012R00FE02
	Channel 3 (2230-30-1 and 2230J-30-1 only)	2.5 Ω	Vishay/Dale RH0502R500FE02
11.	Load Resistor for Current Noise testing	1 Ω, 100 W, 5% To perform the tests as illustrated, both leads of the load resistor require a Banana plug/jack (or equivalent) to connect to the power supply.	Vishay/Dale HL10006Z1R000JJ
12.	Oscilloscope	20 MHz bandwidth limited oscilloscope at 1 mV/division	Tektronix DPO3012
13.	Oscilloscope probe	Low capacitance 1 MΩ/10 MΩ 1X/10X 6 MHz/200 MHz probe	Tektronix P2220, 1X probe
14.	Oscilloscope probe	Low capacitance 10 MΩ 500 MHz probe	Tektronix P6139A, 10X probe
15.	Coaxial cable	50 Ω BNC, male-to-male	Tektronix part number: 012-0482-00
16.	BNC adapter	BNC female to banana breakout	Pomona Electronics 3073

Self Test

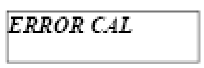
This procedure uses internal routines to verify that the DUT functions and passes its internal self tests. No test equipment or hookups are required.

1. Disconnect all cables from the DUT outputs.
2. Power on the DUT. The front-panel display will light up briefly while the DUT performs its power-on self test. All the display annunciators will light up at once.
3. Review the display with all the annunciators. Visually check if there are any strokes lost on any annunciator.

0480-005

4. If the EEPROM is damaged or the latest operation data in the EEPROM is missing, the display appears as follows:

5. If the calibration data in the EEPROM is missing, the display appears as follows:



6. If the latest operating state of the power supply in the EEPROM is missing, the display appears as follows:

7. If there is no response when you power on the DUT, verify that there is AC power to the power supply, verify the power-line voltage settings, and verify that the correct power-line fuse is installed. If you need more help, contact Keithley.
8. Power off the DUT.

Check DC Voltage Accuracy with Remote Sense

Equipment required	
(Item 2) AC Power Source	(Item 5) High current hook up wire (bold line connections)
(Item 3) Electronic Load	(Item 6) Low current hook up wire (fine line connections)
(Item 4) DC Voltmeter	(Item 9) 0.050 Ω, 5 W Resistor (Qty 2)

For each of the channels sequentially.

1. Power off the DUT.
2. Remove the shorting clip from the Remote Sense connector on the rear panel for the channel being tested. Be sure to retain the clip or clips for the channels not being tested.

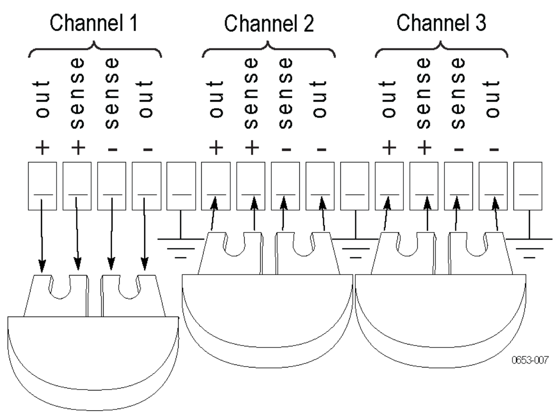


Figure 1: Configuring the shorting clips on a Remote Sense connector to test channel 1 on a 2230-30-1

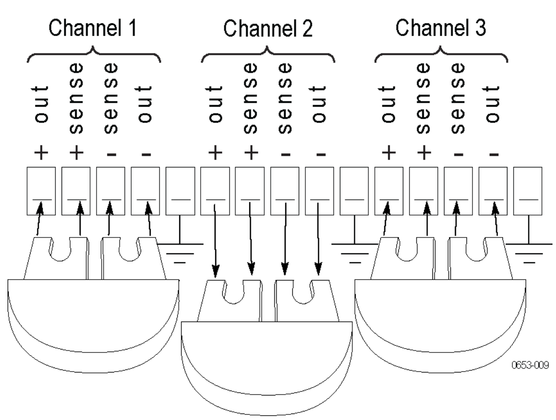


Figure 2: Configuring the shorting clips on a Remote Sense connector to test channel 2 on a 2230-30-1

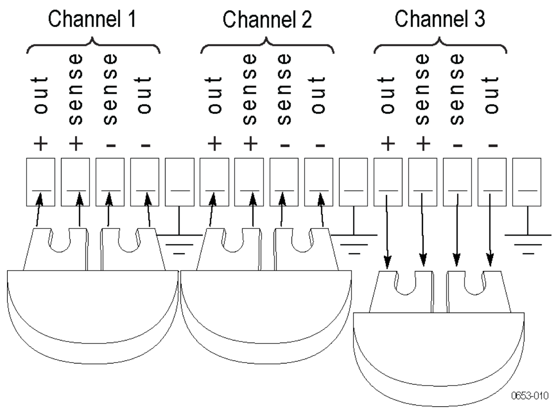


Figure 3: Configuring the shorting clips on a Remote Sense connector to test channel 3 on a 2230-30-1

3. Set up the equipment as shown. (See Figure 4.)

NOTE. *To assure accurate measurements, it is important that a significant amount of current does not flow through the sense leads. For this reason, we recommend that the wiring of the remote sense and the voltmeter be away from the high current connections between the electronic load and the DUT.*

A solution is a pair fork lugs with all three wires crimped in. Another alternative is a fork lug between the DUT and the load, and separate connections (probably also fork lugs) holding the wiring for one or both of the voltmeter and remote sense. A third alternative is to stack banana jacks at the voltmeter, with the remote sense toward the voltmeter, and the two high current connections on the outside.

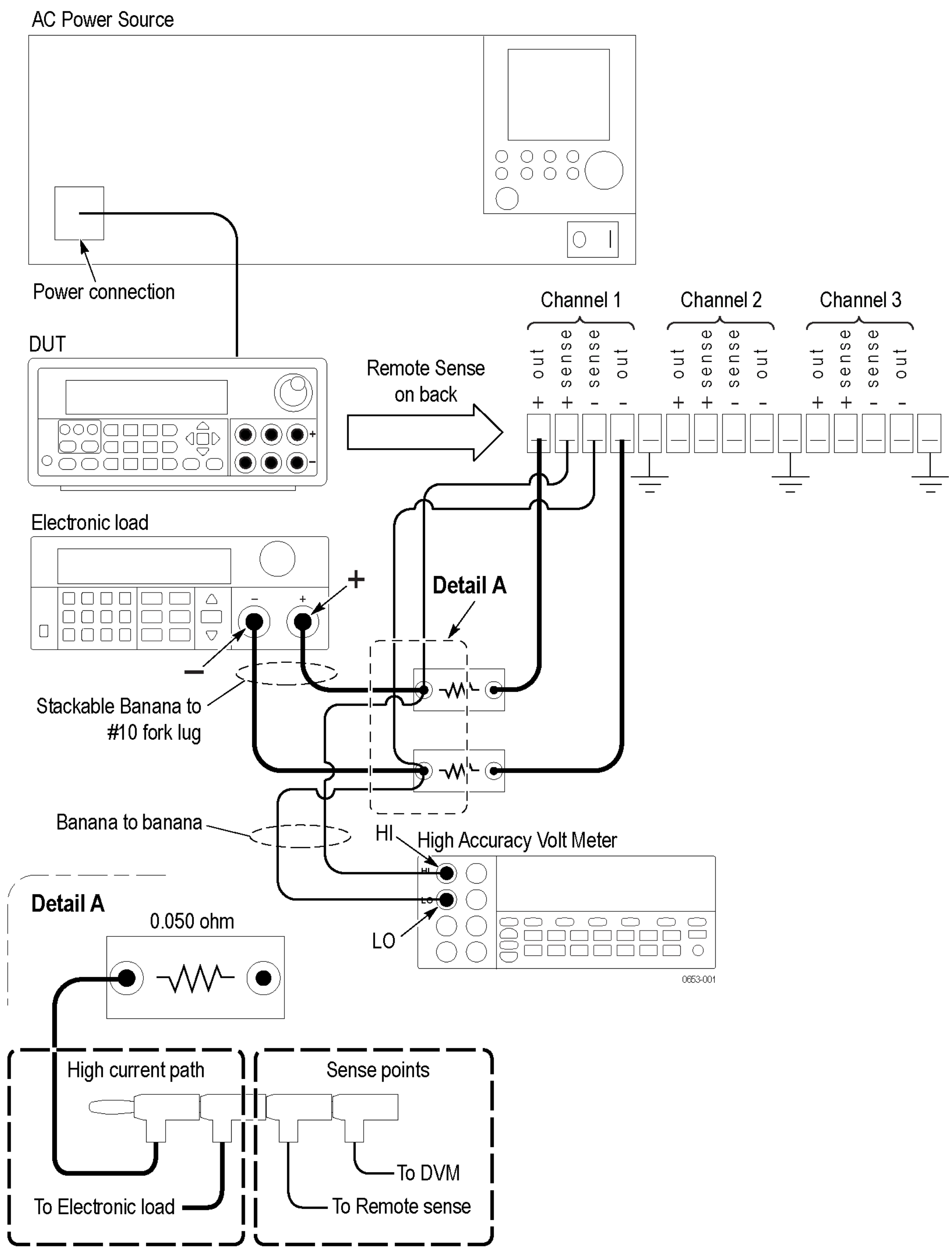


Figure 4: DC voltage accuracy with remote sense test setup. The channel 1 test setup is shown.

4. Power on the DUT.

NOTE. *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

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5. Set the voltmeter as follows:
   a. Set to measure DC volts.
   b. Set to auto range.
   c. Verify that the Math mx+b function is disabled (shift DCV), assuring that volts are being read.
6. Set the electronic load as follows:
   a. Set to Constant Current.
   b. Set the to draw a constant current at the test current specified for the DUT in the table for checking DC Voltage Accuracy With Remote Sense. (See Table 15 on page 16.)
7. Set the channel under test (CUT) to the full scale (FS) output current.
8. Set the CUT to 0% of the FS output voltage (0 V).
9. Turn the DUT output on.
10. Enter the voltmeter reading into the table for checking DC voltage accuracy with remote sense. (See Table 15 on page 16.)
11. Increase the CUT output voltage by 25% of the FS output voltage.
12. Repeat steps 10 and 11 until you complete testing at 100% of the FS.
13. Power off the DUT.
14. Disconnect the hook up wires from the Remote Sense connector and reinstall the shorting clip on the channel you just tested.
15. Power on the DUT.

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check DC Voltage Setting Accuracy Without Remote Sense and Voltage Readback Accuracy

Equipment required	
(Item 2) AC Power Source	(Item 5) High current hook up wire (bold line connections)
(Item 3) Electronic Load	(Item 6) Low current hook up wire (fine line connections)
(Item 4) DC Voltmeter	

For each channel sequentially.

1. Set up the equipment as shown. (See Figure 5.)

NOTE. *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

NOTE. *To assure accurate measurements, the voltmeter must connect as close as possible to the front panel of the DUT. A solution is to use fork lugs between the electronic load and the DUT, and banana plugs between the DUT and voltmeter. An alternative solution is to use fork lugs for both connections at the DUT.*

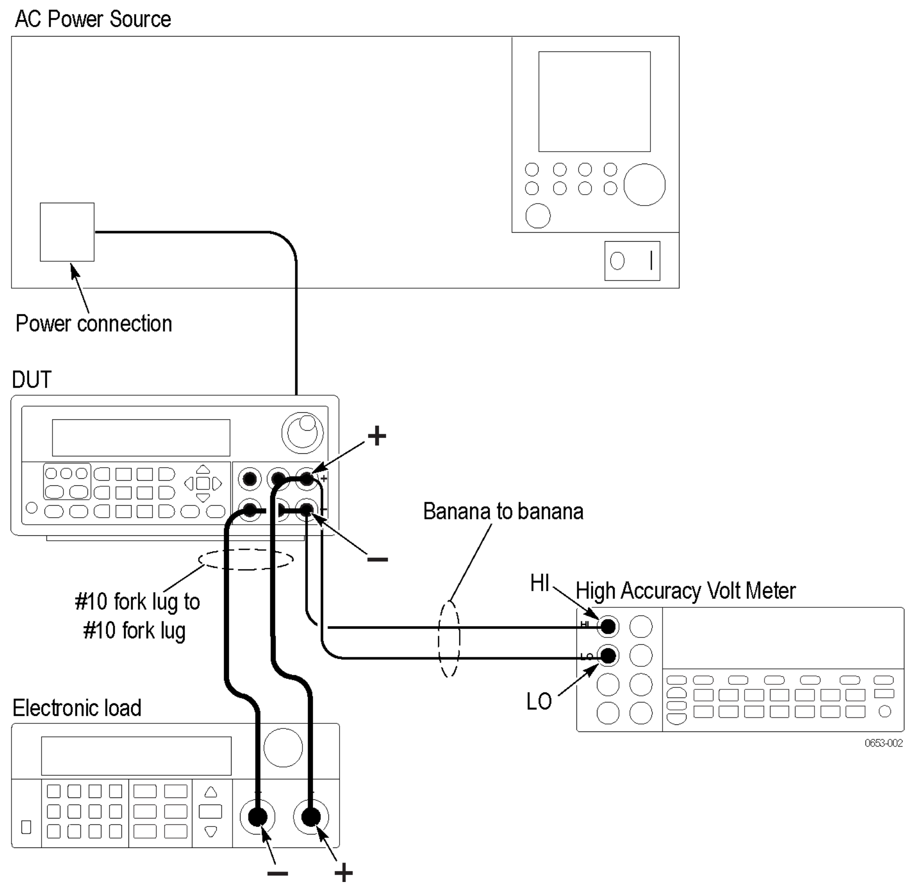


Figure 5: Voltage accuracy, regulation, and protection test setup. The channel 1 test setup is shown.

2. Set the voltmeter as follows:

a. Set to measure DC volts.

b. Set to auto range.

c. Verify that the Math mx+b function is disabled (shift DCV), assuring that volts are being read.

3. Set the electronic load as follows:

a. Set to Constant Current.

b. Set to draw a constant current at the test current specified for the channel under test (CUT) in the table for checking DC Voltage Accuracy without Remote Sense. (See Table 16 on page 17.)

4. Set the CUT to the full scale (FS) output current.

5. Set the CUT to 0% of the FS output voltage (0 V).

6. Turn the DUT output on.

7. Enter the voltmeter reading into the table for checking DC voltage accuracy without remote sense. (See Table 16 on page 17.)

8. Enter the voltmeter reading into the table for checking DC voltage readback accuracy. (See Table 17 on page 18.)

9. Enter the CUT Readback Voltage into the table for DC voltage readback accuracy. (See Table 17 on page 18.)

10. Calculate the difference of the two measurements taken in steps 8 and 9 and enter the absolute value into the difference column of the table. (See Table 17 on page 18.)

11. Increase the CUT output voltage by 25% of the FS output voltage.

12. Repeat steps 7 through 11 until you complete testing at 100% of FS.

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

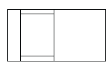
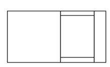
Check DC Voltage Line Regulation

This check procedure uses the same test setup as the previous procedure. (See Figure 5.)

For each channel sequentially.

1. Change the AC Power Source output to the minimum voltage specified in the following table.

> ***NOTE.*** *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

DUT voltage selector switch	AC Power Source voltage	Japan configured units
110 110V/220V 	99 V	90
220 110V/220V 	198 V	180

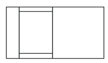
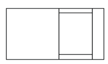
2. Set the voltmeter as follows:
   a. Set to measure DC volts.
   b. Set to auto range.
   c. Verify that the Math mx+b function is disabled (shift DCV), assuring that volts are being read.
3. Set the electronic load as follows:
   a. Set to Constant Current.
   b. Set to draw the specified test current.

Instrument	Test current
Channel 1	0.5 A
Channel 2	0.5 A
Channel 3	2.5 A

4. Set the channel under test (CUT) to 100% of the full scale (FS) output current.
5. Set the CUT to 100% of the FS output voltage.
6. Turn the DUT output on.

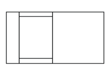
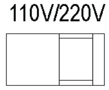
7. Enter the voltmeter reading into the table for checking DC Voltage Line Regulation under the min column for the CUT. (See Table 18 on page 19.)

8. Change the AC Power Source output to the maximum voltage specified in the following table.

DUT voltage selector switch	AC Power Source voltage	Japan configured units
110 110V/220V 	132 V	110 V
220 110V/220V 	264 V	220 V

9. Enter the voltmeter reading into table for checking DC Voltage Line Regulation under the Max column for the CUT. (See Table 18 on page 19.)

10. Change the AC Power Source output to match the Voltage Selector switch setting of the DUT.

DUT voltage selector switch	AC Power Source voltage	Japan configured units
110 110V/220V 	115 V	100 V
220 110V/220V 	230 V	200 V

11. Enter the voltmeter reading into table for checking DC Voltage Line Regulation under the Nom column for the CUT. (See Table 18 on page 19.)

12. Calculate the two values: Nom – Min and Max – Nom. Enter the values into the appropriate columns. (See Table 18 on page 19.)

13. Enter the largest of the two values calculated in step 12 into the Largest column. (See Table 18 on page 19.)

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check DC Voltage Load Regulation

This check procedure uses the same test setup as the previous procedure. (See Figure 5.)

For each channel sequentially.

NOTE. *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

---

1. Set the voltmeter as follows:
   a. Set to measure DC volts.
   b. Set to auto range.
   c. Verify that the Math mx+b function is disabled (shift DCV), assuring that volts are being read.
2. Set the electronic load as follows:
   a. Set to Constant Current.
   b. Set to draw 0 Amps.
3. Set the channel under test (CUT) to 100% of the full scale (FS) output current.
4. Set the CUT to 100% of the FS output voltage.
5. Turn the DUT output on.
6. Enter the voltmeter reading into the table for checking DC Voltage Load Regulation under the minimum load column for the CUT. (See Table 19 on page 19.)
7. Increase the electronic load to the reference load test current value.

Instrument	Reference load test current
Channel 1	0.75 A
Channel 2	0.75 A
Channel 3	2.5 A

8. Enter the voltmeter reading into the table for checking DC Voltage Load Regulation under the reference load column for the CUT. (See Table 19 on page 19.)

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

Channel	Maximum load test current
Channel 1	1.47 A
Channel 2	1.47 A
Channel 3	4.9 A

10. Enter the voltmeter reading into the table for checking DC Voltage Load Regulation under the maximum load column for the channel. (See Table 19 on page 19.)

11. Calculate the three values: Ref – Min, Max – Ref, and (Max – Ref)/0.98. Enter the values into the appropriate columns. (See Table 19 on page 19.)

12. Enter the largest of the three values calculated in step 11 into the Largest column.

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check DC Current and DC Current Readback Accuracy

Equipment required

(Item 2) AC Power Source	(Item 5) High current hook up wire (bold line connections)
(Item 3) Electronic Load	(Item 7) High Accuracy 0.05 Ω Resistor
(Item 4) DC Voltmeter	(Item 8) Current Shunt Resistor Cabling

For each channel sequentially.

1. Set up the equipment as shown. (See Figure 6.)

NOTE. Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.

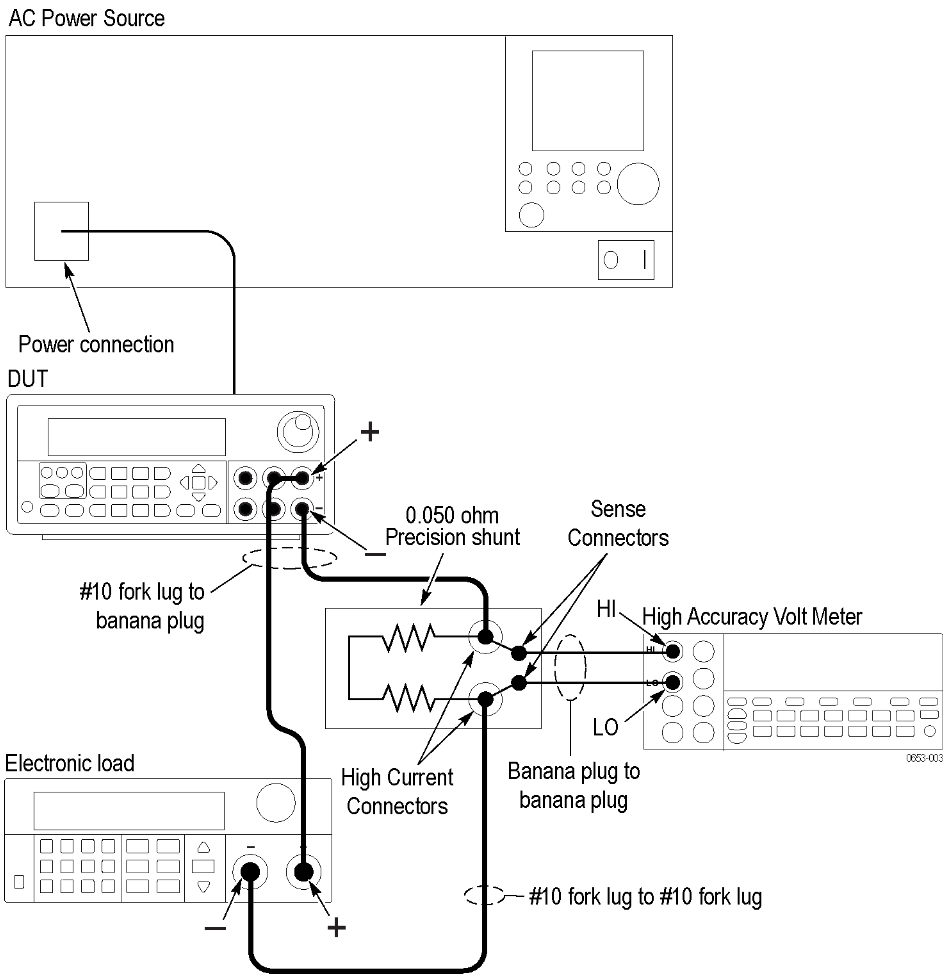


Figure 6: DC current accuracy and regulation test setup. The channel 1 test setup is shown.

2. Set the voltmeter as follows:

a. Set to measure DC volts.

b. Set to auto range.

c. Set to show amps (instead of volts) by multiplying the voltmeter result by 20.

- Press Shift DC V (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.
- Press the arrow key to move the cursor to the 1's digit and then press the up range button once so that M=20.00000.
- 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:

a. Set to Constant Voltage.

b. Set to the specified voltage for your channel under test (CUT). (See Table 20 on page 20.)

4. Set the channel under test (CUT) to 0% of the full scale (FS) output current.

5. Set the CUT to 100% of the FS output voltage.

6. Turn the DUT output on.

7. Enter the voltmeter reading into the table for checking DC current accuracy. (See Table 20 on page 20.)

8. Enter the voltmeter reading into the table for checking DC current readback accuracy. (See Table 21 on page 21.)

9. Enter the CUT readback current readout into the table for checking current readback accuracy under the current readout column. (See Table 21 on page 21.)

10. Calculate the difference of the two measurements taken in steps 8 and 9. Enter the absolute value of the calculated value into the difference column of the table. (See Table 21 on page 21.)

11. Increase the CUT output current by 25% of the FS output current.

12. Repeat steps 7 through 11 until you complete testing at 100% of the FS output current.

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check DC Current Line Regulation

This check procedure uses the same test setup as the previous procedure.(See Figure 6.)

For each channel sequentially.

1. Change the AC Power Source output to the voltage specified in the following table.

DUT voltage selector switch	AC power source voltage	Japan configured units
110	99 V	90 V
220	198 V	180 V

NOTE. *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

2. Set the voltmeter as follows:
   a. Set to measure DC volts.
   b. Set to auto range.
   c. Set to show amps (instead of volts) by multiplying the voltmeter result by 20.
      - Press Shift DC V (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.
      - Press the arrow key to move the cursor to the 1's digit and then press the up range button once so that M=20.00000.
      - 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:
   a. Set to Constant Voltage.
   b. Set to the specified voltage for your channel under test (CUT). (See Table 22 on page 22.)
4. Set the channel under test (CUT) to 100% of the full scale (FS) output voltage.
5. Set the CUT to 100% of the full scale (FS) output current.

6. Turn the DUT output on.

7. Enter the voltmeter reading into the table for checking current line regulation under the minimum line for the CUT. (See Table 22 on page 22.)

8. Change the AC Power Source output to the voltage specified in the following table.

DUT voltage selector switch	AC power source voltage	Japan configured units
110	132 V	110
220	264 V	220

9. Enter the voltmeter reading into the Max line for the CUT. (See Table 22 on page 22.)

10. Change the AC Power Source output to the voltage specified in the following table.

DUT voltage selector switch	AC power source voltage	Japan configured units
110	115 V	100 V
220	230 V	200 V

11. Enter the voltmeter reading into the Nom line for the CUT. (See Table 22 on page 22.)

12. Calculate the two values: Nom – Min and Max – Nom. Enter the values into the appropriate columns. (See Table 22 on page 22.)

13. Select the largest of the two calculations from step 12 and enter the value into the Largest column. (See Table 22 on page 22.)

14. Turn the DUT output off.

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check DC Current Load Regulation

This check procedure uses the same test setup as the previous procedure. (See Figure 6.)

***NOTE.** Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

For each channel sequentially.

1. Set the voltmeter as follows:
   a. Set to measure DC volts.
   b. Set to auto range.
   c. Set to show amps (instead of volts) by multiplying the voltmeter result by 20.
      - Press Shift DC V (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.
      - Press the arrow key to move the cursor to the 1's digit and then press the up range button once so that M=20.00000.
      - 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.
2. Set the electronic load as follows:
   a. Set to Constant Voltage.
   b. Set to output the minimum test voltage level.

Channel	Minimum test voltage
Channel 1	3.0 V
Channel 2	3.0 V
Channel 3	0.6 V

3. Set the channel under test (CUT) to 100% of the FS output current for your product.
4. Set the CUT to 100% of the FS output voltage for your product.
5. Turn the DUT output on.

6. Enter the voltmeter reading into the table for checking current load regulation at the minimum voltage for your product. (See Table 23 on page 22.)

7. Increase the electronic load to the Reference test voltage level.

Channel under test	Reference test voltage
Channel 1	15.0 V
Channel 2	15.0 V
Channel 3	3.0 V

8. Enter the voltmeter reading into the table for checking current load regulation at the reference test voltage the CUT. (See Table 23 on page 22.)

9. Increase the electronic load to the Maximum test voltage level.

Channel under test	Maximum test voltage
Channel 1	29.4 V
Channel 2	29.4 V
Channel 3	5.88 V

10. Enter the voltmeter reading into the table for checking current load regulation at the maximum voltage for the CUT. (See Table 23 on page 22.)

11. Calculate the two values: REF – Min and Max – REF. Enter the values into the appropriate columns. (See Table 23 on page 22.)

12. Select the larger of the two calculated values from step 11 and enter the value into the Largest column. (See Table 23 on page 22.)

13. Power off the DUT and test equipment.

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check Voltage Noise (7 MHz)

Equipment required

(Item 5) High current hook up wire (bold line connections)	(Item 12) Oscilloscope
(Item 10) Load Resistor	(Item 13) Oscilloscope 1X probe

For each channel sequentially.

1. Plug the 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.

NOTE. *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

4. Set up the equipment as shown. (See Figure 7.)

   Use the appropriate load resistor depending on the channel being tested. (See Table 24 on page 22.)

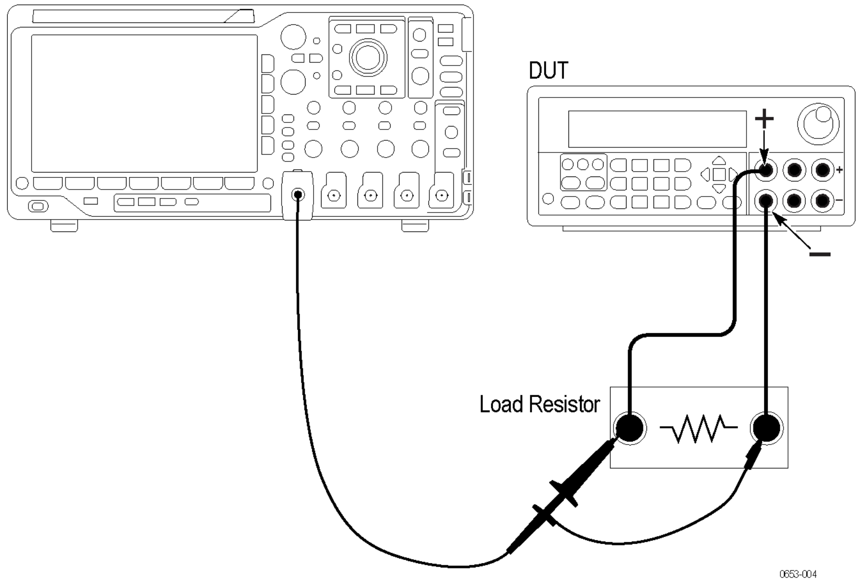


Figure 7: 7 MHz test setup. The channel 1 test setup is shown.

5. Set the oscilloscope as follows:
   a. 1 mV/division
   b. 1 MΩ input resistance
   c. 20 MHz bandwidth (BW) limit
   d. AC Coupled
   e. Line trigger
   f. 2 ms/div
   g. Set to measure $V_{p\text{-}p}$ and V_{RMS}
6. Set the oscilloscope probe to 1X mode.
7. Set the channel under test (CUT) to the 100% FS output voltage.
8. Set the CUT to the 100% FS output current.
9. Turn the DUT output on.

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

10. Enter the oscilloscope measurements into the table for checking Noise at 7 MHz. (See Table 24 on page 22.)

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check Voltage Noise (20 MHz)

Equipment required

(Item 5) High current hook up wire (bold line connections)	(Item 15) Coaxial cable (BNC M-M)
(Item 10) Load Resistor	(Item 16) BNC F-to-Banana
(Item 12) Oscilloscope	

For each channel sequentially.

1. Plug the 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.

NOTE. *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

4. Set up the equipment as shown. (See Figure 8.)

   Use the appropriate load resistor depending on the channel under test. (See Table 25 on page 22.)

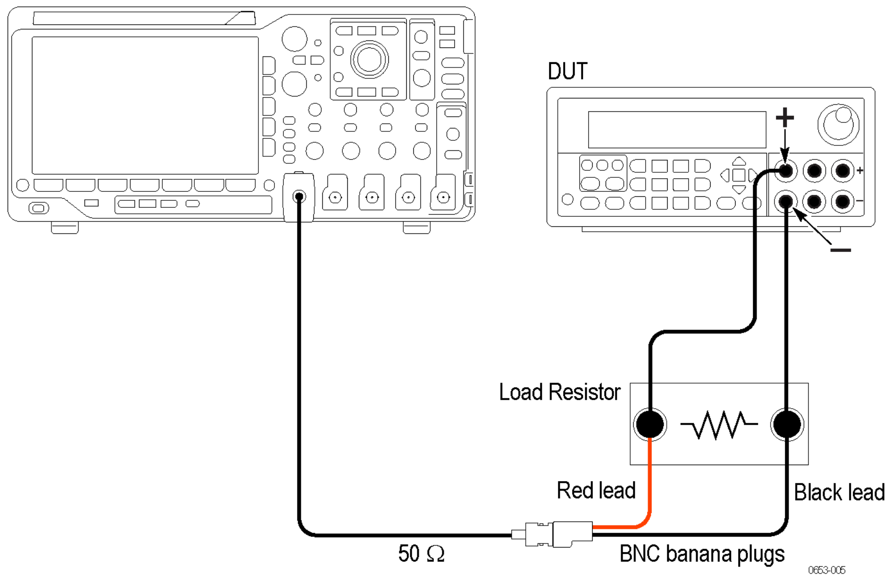


Figure 8: 20 MHz voltage noise test setup. The channel 1 test setup is shown.

5. Set the oscilloscope as follows:
    a. 1 mV/division
    b. 1 MΩ input resistance
    c. 20 MHz bandwidth (BW) limit
    d. AC Coupled
    e. Line trigger
    f. 2 ms/div
    g. Set to measure $V_{p\text{-}p}$ and V_{RMS}
6. Set the channel under test (CUT) to the 100% FS output voltage.
7. Set the channel under test (CUT) to the 100% FS 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 into the table for checking voltage noise at 20 MHz. (See Table 25 on page 22.)

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Check Current Noise

Equipment required	
(Item 5) High current hook up wire (bold line connections)	(Item 12) Oscilloscope
(Item 11) 1 Ω Load Resistor	(Item 14) Oscilloscope 10X probe

For each channel sequentially.

1. Plug the 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.

NOTE. *Ensure the warm-up criteria has been met as described in the Performance Verification Conditions.*

4. Set up the equipment as shown. (See Figure 9.)

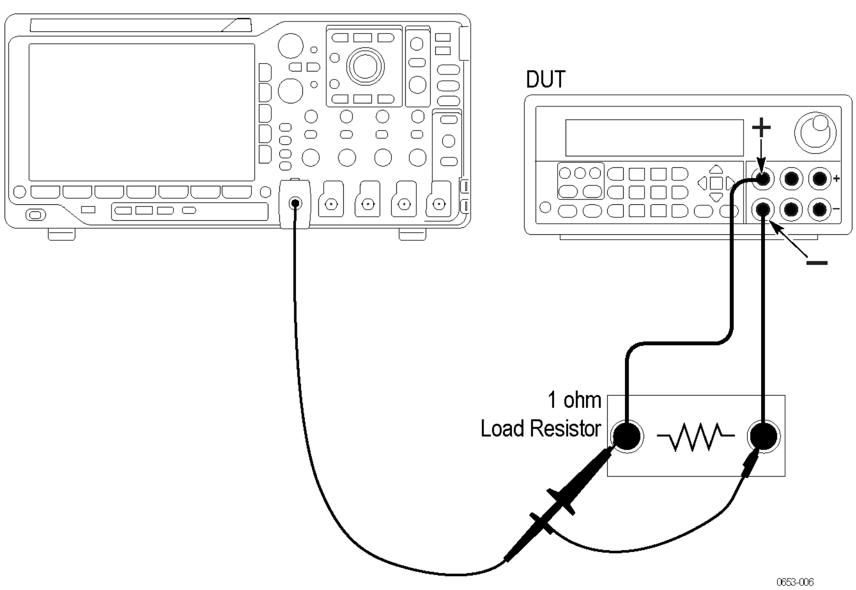


Figure 9: 20 MHz current noise test setup. The channel 1 test setup is shown.

5. Set the oscilloscope as follows:
   a. 1 mV/division
   b. 1 MΩ input resistance
   c. 20 MHz bandwidth (BW) limit
   d. AC Coupled
   e. Line trigger
   f. 2 ms/div
   g. Set to measure $V_{p\text{-}p}$ and V_{RMS}
6. Set the channel under test (CUT) to the 100% FS output voltage.
7. Set the CUT to the 100% FS 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 into the table for checking current noise. (See Table 25 on page 22.)
10. Power off the DUT and test equipment.

This completes the check for one channel. If needed, return to step 1 to run through the check for the next channel.

Keithley Instruments, Inc.
Corporate Headquarters • 28775 Aurora Road • Cleveland, Ohio 44139 • 440-248-0400 • Fax: 440-248-6168 • 1-888-KEITHLEY • www.keithley.com

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