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Model 6485 Picoammeter
Model 6487 Picoammeter/Voltage Source

User's Manual

6487-900-01 Rev. C / March 2011

KEITHLEY

A GREATER MEASURE OF CONFIDENCE

Model 6485 Picoammeter
Model 6487 Picoammeter/Voltage Source
User's Manual

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Document number: 6487-900-01 Rev. C / March 2011

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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 non-hazardous 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 rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the user documentation.

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 30V RMS, 42.4V peak, or 60VDC 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 volts, 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, make sure 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.

The instrument and accessories must be used in accordance with specifications and operating instructions, or the safety of 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 safety earth 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 safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument means caution, risk of danger. The user should 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 danger. User standard safety precautions to avoid personal contact with these voltages.

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

The  symbol indicates a connection terminal to the equipment frame.

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

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

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

Instrumentation and accessories shall not be connected to humans.

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

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

To clean an instrument, use a damp cloth or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., 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.

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1 Getting Started

- **Introduction** — Description of the Models 6485 and 6487 Picoammeters.
- **Overview of this manual** — Provides content of this manual.
- **General information** — Covers general information that includes warranty information, contact information, safety symbols and terms, unpacking and inspection, and available options and accessories.
- **Features** — Summarizes the features of Models 6485 and 6487.
- **Model 6485 front and rear panel familiarization** — Summarizes the controls and connectors of the Model 6485 as well as providing information on the front panel display.
- **Model 6487 front and rear panel familiarization** — Summarizes the controls and connectors of the Model 6487 and provides information on the front panel display.
- **Power-up** — Covers line power connection, line frequency, and the power-up sequence.
- **Default settings** — Covers the five instrument setup configurations available to the user; three user-defined, GPIB defaults, or factory defaults.
- **Menu**— Provides menu structures for both the Models 6485 and 6487.
- **SCPI programming** — Explains how SCPI commands are presented in this manual.

Introduction

The Models 6485 and 6487 are high-resolution bus-programmable (RS-232 and IEEE-488) picoammeters. The Models 6485 and 6487 have the following current measurement ranges: eight ranges (from 20mA down to the 2nA range). The Model 6487 also includes a ±500V DC voltage source and an ohms function that includes an alternating voltage mode to improve accuracy and repeatability of very high resistance measurements.

Overview of this manual

This manual describes how to connect, program, and maintain the Models 6485 and 6487 Picoammeters. The sections of the manual are organized as follows:

- Section 1: Getting Started
- Section 2: Connections
- Section 3: Measurements and Sourcing Voltage (Model 6487 only)
- Section 4: Range, Units, Digits, Rate, and Filters
- Section 5: Relative, mX+b, m/X+b (reciprocal), and log
- Section 6: Buffer and Sweeps
- Section 7: Remote Operation and Commands

Appendices to this manual contain specification and also provide additional information on specific topics. The appendices are organized as follows:

- Appendix A: Specifications
- Appendix B: General Measurement Considerations
- Appendix C: Example Programs

General information

Warranty information

Should your Model 6485 or 6487 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information.

Contact information

Worldwide phone numbers are listed at the front of this manual. If you have any questions, please contact your local Keithley representative or call one of our Application Engineers at 1-800-348-3735 (U.S. and Canada only).

Safety symbols and terms

The following symbols and terms may be found on the instrument or used in this manual:

If  or  is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual 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 used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Unpacking and inspection

Inspection for damage

The Model 6485/6487 was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (There may be a protective film over the display lens, which can be removed.) Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. Before removing the Model 6485/6487 from the bag, observe the handling precautions discussed below.

Handling precautions

- Always grasp the Model 6485/6487 by the covers.
- After removing the unit from its anti-static bag, inspect it for any obvious signs of physical damage. Report any such damage to the shipping agent immediately.
- When the instrument is not installed and connected, keep the unit in its anti-static bag and store it in the original packing carton.

Package content

Model 6485

The following items are included with every Model 6485 order:

- Model 6485 Picoammeter with line cord.
- Low Noise Cable with Male BNC on both ends (Model 4801).
- Protective BNC Shield/Cap (CAP-18).
- Banana lead to screw terminal adapter (Model CA-186-1B).
- Accessories as ordered.
- Certificate of calibration.
- Model 6485/6487 User Manual (P/N 6487-900-00).
- Manual Addenda (pertains to any improvements or changes concerning the instrument or manual).
- Product Information CD-ROM that contains PDFs of the User's and Instruction Manuals.

Model 6487

The following items are included with every Model 6487 order:

- Model 6487 Picoammeter with line cord.
- Triax Protective Shield/Cap (CAP-31).
- 7078-TRX-3 Triax cable.
- Model 8607 1kV Source Banana cable set.
- CS-459 4-pin Female Interlock connector.
- Accessories as ordered.
- Certificate of calibration
- Model 6485/6487 User Manual (P/N 6487-900-00).
- Product Information CD-ROM that contains PDFs of the User's and Reference Manuals.

Options and accessories

Model 6485 input cables, connectors, and adapters

Model 4801 Input Cable — This 4 ft (1.2m) low-noise coax cable is terminated with male BNC connectors on each end. (One Model 4801 is included with every order.)

Model 4802-10 — This 10 ft (3m) low-noise coax cable is terminated at one end with a male BNC connector (the other end is unterminated).

Model 4803 Low Noise Cable Kit — This cable kit includes:

- 15m (50 ft) of low noise coax cable
- 10 male BNC connectors
- 5 female BNC chassis-mount connectors

Model 7078-TRX-BNC adapter — 3-slot male triax to female BNC.

Model 8607 — Banana cable set (1m).

CA-186-1B — Banana lead to screw terminal adapter (one model CA-186-1B is included with every order).

CAP-18 — Protective shield/cap for BNC connectors (one model CAP-18 is included with every order).

CS-565 barrel adapter — This barrel adapter allows you to connect two BNC cables together. Both ends of the adapter are terminated with 2-lug female BNC connectors.

Model 6487 input cables, connectors, and adapters

237-TRX-BAR Barrel Adapter — This barrel adapter allows you to connect two triax cables together. Both ends of the adapter are terminated with 3-lug female triax connectors.

Model 237-ALG-2 Triax Cable — This 2m (6.6 ft) low-noise triax cable is terminated with a three slot male triax connector on one end and 3 alligator clips on the other.

Model 237-TRX-T Adapter — This is a 3-slot male to dual 3-lug female triax tee adapter for use with 7078-TRX triax cables. Suitable for use with the Model 6487 V-Source in high voltage applications.

Model 237-TRX-TBC Connector — This is a 3-lug female triax bulkhead connector with cap for assembly of custom panels and interface connections. Suitable for use with the Model 6487 V-Source in high voltage applications.

Models 7078-TRX-3, 7078-TRX-10, and 7078-TRX-20 Triax Cables — These are low noise triax cables terminated at both ends with 3-slot male triax connectors. The -3 model is 3 ft. (0.9m) in length, the -10 model is 10 ft. (3m) in length, and the -20 model is 20 ft. (6m) in length.

Model 7078-TRX-TBC Connector — This is a 3-lug female triax bulkhead connector with cap for assembly of custom panels and interface connections. Suitable for use with the Model 6487 V-Source in high voltage applications.

Model 8009 Resistivity Test Fixture — This is a guarded test fixture for measuring volume and surface resistivities. It can accommodate sheet samples with a diameter between 64 and 102mm (2 to 4 in.) and a thickness of up to 3.175mm (in.).

Model 8606 High Performance Probe Tip Kit — Consists of two spade lugs, two alligator clips, and two spring hook test probes. (The spade lugs and alligator clips are rated at 30V RMS, 42.4V peak; the test probes are rated at 1000V.) These components are designed to

be used with high performance test leads terminated with banana plugs, such as the Model 8607 High Performance Banana Cables.

Model 8607 High Performance Banana Cables — Consists of two high voltage (1000V) banana cables. The cables are terminated with banana plugs that have retractable sheaths.

CAP-31 Protective Shield /Cap — For use with 3-lug triax connectors.

Model 6487 interlock cables and connector

Model 6517-ILC-3 Interlock Cable — Designed to connect the interlock of the Model 6487 to the Model 8009 test fixture.

Model 8002-ILC-3 Interlock Cable — Designed to connect the lid interlock circuit of a test fixture to the interlock circuit of the Model 6487.

CS-459 4-pin Female Interlock Connector — Allows custom wiring of external circuits to the Model 6487 interlock.

GPIB, RS-232, and trigger link cables and adapters

Models 7007-1 and 7007-2 shielded GPIB cables — Connects the Model 6485/6487 to the GPIB bus using shielded cables and connectors to reduce electromagnetic interference (EMI). Model 7007-1 is lm long; Model 7007-2 is 2m long.

Model 7009-5 shielded RS-232 cable — Connects the Model 6485/6487 to the RS-232 interface using shielded cable and connectors to reduce electromagnetic interference (EMI). Model 7009-5 is 5 ft. long.

Models 8501-1 and 8501-2 trigger link cables — Connects the Model 6485/6487 to other instruments with Trigger Link connectors (e.g., Model 7001 Switch System). Model 8501-1 is lm long; Model 8501-2 is 2m long.

Model 8502 trigger link adapter — Lets you connect any of the six trigger link lines of the Model 6485/6487 to instruments that use the standard BNC trigger connectors.

Model 8503 DIN to BNC trigger cable — Lets you connect trigger link lines one (Voltmeter Complete) and two (External Trigger) of the Model 6485/6487 to instruments that use BNC trigger connectors. Model 8503 is lm long.

Rack mount kits

Model 4288-1 single fixed rack mount kit — Mounts a single Model 6485/6487 in a standard 19-inch rack.

Model 4288-2 side-by-side rack mount kit — Mounts two instruments (Models 182, 428, 486, 487, 2000, 2001, 2002, 2010, 2400, 2410, 2420, 2430, 6430, 6485, 6487, 6517A, 7001) side-by-side in a standard 19-inch rack.

Model 4288-4 side-by-side rack mount kit — Mounts Model 6485/6487 and a 5.25-inch instrument (Models 195A, 196, 220, 224, 230, 263, 595, 614, 617, 705, 740, 775A, 6512) side-by-side in a standard 19-inch rack.

Carrying case

Model 1050 padded carrying case — A carrying case for Model 6485/6487. Includes handles and shoulder strap.

Additional references

While reading this document, you may find it helpful to consult the following documentation for reference:

Model 6485 Instruction Manual — Supplied in electronic format on the Product Information CD-ROM included with your shipment, this document provides in-depth information on Model 6485 operation, as well as performance verification, calibration, and routine maintenance procedures. Check www.keithley.com for details.

Model 6487 Reference Manual — Electronic format manual on the Product Information CD-ROM included with your shipment, this document provides in-depth information on Model 6487 operation, as well as performance verification, calibration, and routine maintenance procedures. Check www.keithley.com for details.

Low Level Measurements handbook — Keithley's guide for effective low current, low voltage, and high impedance measurements. Check www.keithley.com for details.

Features

The Model 6485/6487 is a high-performance picoammeter capable of measuring current (the Model 6487 also measures resistance). Section 2 contains details on its measurement capabilities ("Connection fundamentals," page 2-2). Features of Model 6485/6487 Picoammeter include:

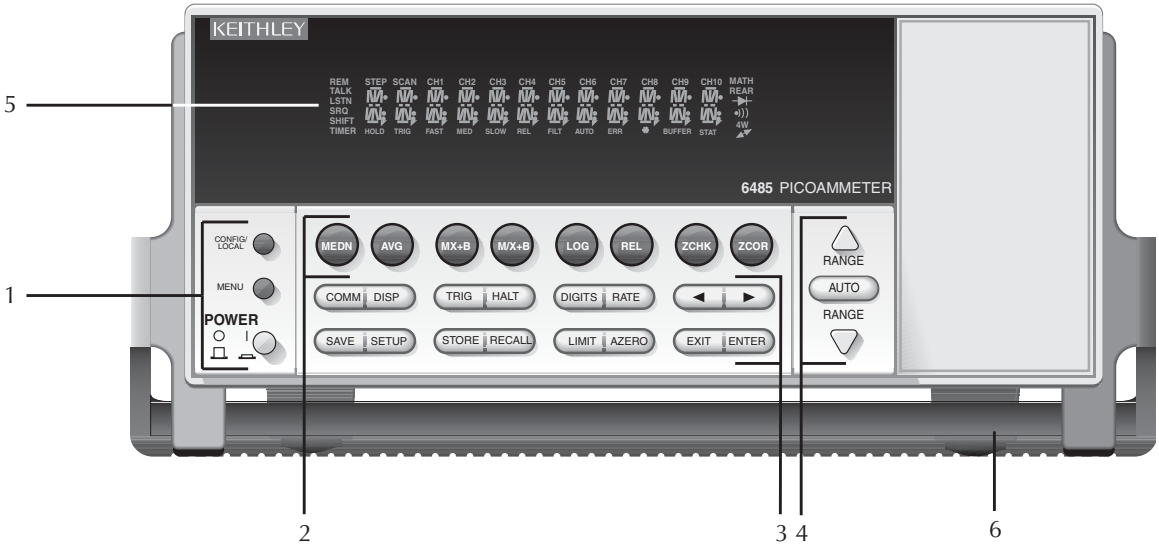
- Setup storage — Five instrument setups (three user, GPIB defaults, and factory defaults) can be saved and recalled.
- mX+b, m/X+b (reciprocal—for resistance calculations), and log10 — These calculations provide mathematical manipulation of readings (Section 5).
- Relative — Null offsets or establish baseline values (Section 5).
- Buffer — Store data in the internal buffer (Section 6).
- **Limits** — Set up to two stages of high and low reading limits to test devices (see Section 8 of the Model 6485 Instruction Manual or Model 6487 Reference Manual).
- Digital I/O port (Model 6487 only) — Four output lines and one input line to control external circuitry as an interface between limit tests and component handler. (See Section 8 of the Model 6487 Reference Manual.)
- Remote interface — Model 6485/6487 can be controlled using the IEEE-488 interface (GPIB) or the RS-232 interface (Section 7).
- Voltage source (Model 6487 only) — Internal ±500V voltage source is also used for ohms function (Section 3).
- GPIB programming language — When using the GPIB, the instrument can be programmed using the SCPI or DDC programming language.

Model 6485 front and rear panel familiarization

Model 6485 front panel summary

The front panel of Model 6485 is shown in Figure 1-1.

Figure 1-1
Model 6485 front panel



NOTE *To modify a key's properties, press the CONFIG / LOCAL key (see Special keys and power switch) and then the key. Not all keys have configurable properties.*

1 Special keys and power switch

CONFIG/ LOCAL	When in Local operation, use to configure properties of the next button pressed. When in Remote operation (REM annunciator lit), cancels GPIB remote mode.
MENU	Provides access to menu.
POWER	Power switch. In position turns 6485 on (I), out position turns it off (O).

2 Function keys

MEDN	Use to control and modify properties of the median filter.
AVG	Use to control and modify properties of the digital filter.
MX+B	Use to perform and configure properties of the mX+b math function.
M/X+B	Use to perform and configure properties of the m/X+b math function.
LOG	Use to convert output / display to log10 (on / off).
REL	Use to control and configure properties of the rel(ative) function.
ZCHK	Use to perform a Zero Check function.
ZCOR	Use to control Zero Correct function (on / off).

3 Operation keys

COMM	Use to control and modify communication properties (GPIB or RS-232).
DISP	Use to turn display on/off.
TRIG	Trigger measurement(s). Takes 6485 out of idle state. Use also to configure trigger properties.

HALT	Stops measurement process. Puts 6485 in idle state.
DIGITS	Use to set display resolution.
RATE	Use to select measurement rate.
◀ and ▶	Use to control cursor position for making selections or editing values.
SAVE	Use to save present setup to a memory location.
SETUP	Use to restore setup to either GPIB or factory defaults, or to a user memory location. Also use to modify properties of power on defaults to either GPIB or factory defaults, or to a user memory location.
STORE	Use to start buffer and modify the number of readings to store.
RECALL	Use to display stored readings (including maximum, minimum, peak-to-peak, average, and standard deviation). The and range keys scroll through the buffer and the or ▶ key toggles between reading number, reading, and timestamp.
LIMIT	Use to perform and create limit tests.
AZERO	Use to control auto zero function (on / off).
EXIT	Use to cancel selection and move back to measurement display.
ENTER	Use to accept selection and move to next choice or back to measurement display.

4 Range keys

	Use to select the next higher measurement range. Also use to modify the upper autorange limit.
	Use to select the next lower measurement range. Also use to modify the lower autorange limit.
AUTO	Enables/disables autorange.

5 Display annunciators

* (asterisk)	Readings being stored in buffer.
(more)	Indicates additional selections are available.
AUTO	Autorange enabled.
BUFFER	Recalling readings stored in buffer.
ERR	Questionable reading or invalid cal step.
FAST	Fast (0.1 PLC) reading rate selected.
FILT	MEDIAN and/or AVERAGE filter enabled.
LSTN	Instrument addressed to listen over GPIB.
MATH	mX+b, m/X+b, or log10 calculation enabled.
MED	Medium (1 PLC) reading rate selected.
REL	Relative enabled for present measurement function.
REM	Instrument in GPIB remote mode.
SLOW	Slow reading rate selected; 6 PLC for 60Hz or 5 PLC for 50Hz.
SRQ	Service request over GPIB.
STAT	Displaying buffer statistics.
TALK	Instrument addressed to talk over GPIB bus.
TIMER	Timer controlled triggering in use.
TRIG	External triggering (GPIB or trigger link) selected.

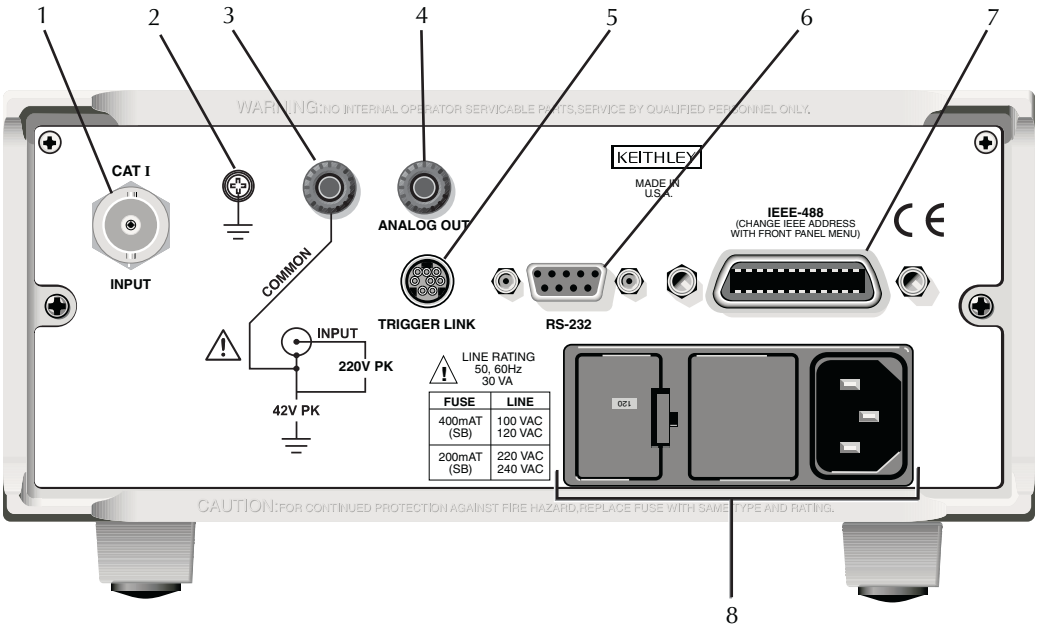
6 Handle

Pull out and rotate to desired position.

Model 6485 rear panel summary

The rear panel of the Model 6485 is shown in Figure 1-2.

Figure 1-2
Model 6485 rear panel



1 INPUT

This standard female BNC connector is used to connect the signal to be measured to the input of the Model 6485. Mates to a BNC cable.

2 CHASSIS

This screw terminal is used to connect COMMON to CHASSIS ground via the ground link connector.

3 COMMON

This standard banana connector can be used as input LO or as the common for the ANALOG OUT. Also can be used as a ground link.

4 ANALOG OUT

This standard banana connector provides a scaled, inverting output (inverting 2V full scale on all ranges).

5 TRIGGER LINK

Eight-pin micro-DIN connector for sending and receiving trigger pulses among connected instruments. Use a trigger link cable or adapter, such as Models 8501-1, 8501-2, 8502, and 8503.

6 RS-232

Female DB-9 connector for RS-232 operation. Use a straight-through (not null modem) DB-9 shielded cable.

7 IEEE-488

Connector for IEEE-488 (GPIB) operation. Use a shielded cable, such as Models 7007-1 and 7007-2.

8 Power module

Contains the AC line receptacle and power line fuse. The instrument can be configured for line voltages of 115V and 230VAC (nominal) at line frequencies of 50 or 60Hz automatically and over the bus. Changing line voltages requires changing fuses.

Analog output

The Model 6485 has an analog output on the rear panel. The ANALOG OUT provides a scaled, inverting ±2V output. A full-scale reading corresponds to ±2V output. See "Analog output," page 2-14 in for full details on analog output operation.

Display

Readings can be displayed in engineering units or scientific notation. Annunciators indicate various states of operation. See "Model 6485 front panel summary," page 1-8 for a complete listing of display annunciators.

NOTE *Changing the display resolution is not allowed if displaying readings in scientific notation.*

The Display and Keys Test allows you to test display digit segments and annunciators, and check the functionality of front panel keys. These tests are accessed through the MENU.

Status and error messages

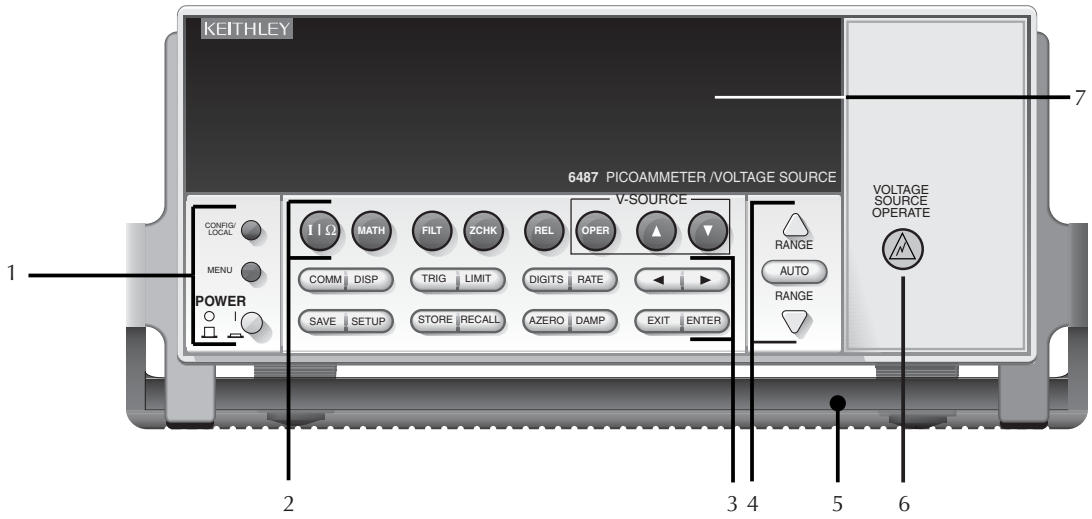
Status and error messages are displayed momentarily. During operation and programming, you will encounter a number of front panel messages. Typical messages are either of status or error variety, as listed in Appendix B of the Model 6485 Instruction Manual.

Model 6487 front and rear panel familiarization

Model 6487 front panel summary

The front panel of the Model 6487 is shown in Figure 1-3.

Figure 1-3
Model 6487 front panel



NOTE *To modify a key's properties, press the CONFIG / LOCAL key (see Special keys and power switch) and then the key. Not all keys have configurable properties.*

1 Special keys and power switch

CONFIG / LOCAL	When in Local operation, use to configure properties of the next button pressed. When in Remote operation (REM annunciator lit), cancels GPIB remote mode.
MENU	Provides access to menu.
POWER	Power switch. In position turns 6487 on (I), out position turns it off (O).

2 Function keys

I|Ω	Use to toggle between regular current measurements and ohms.
MATH	Turns on the selected Math function (selected using the CONFIG >> MATH key sequence).
FILT	Turns on filtering (selected using the CONFIG >> FILT key sequence).
ZCHK	Use to perform a Zero Check function.
REL	Use to control and configure properties of the rel(ative) function.

OPER	Toggles the Vsource state (the Vsource state is displayed by an indicator). (Configured using the CONFIG >> OPER key sequence.)
V-SOURCE	Increments voltage source value
V-SOURCE	Decrements voltage source value

3 Operation keys

COMM	Use to control and modify communication properties (GPIB or RS-232).
DISP	Use to turn display on/off.
TRIG	Trigger measurement(s). Takes 6487 out of idle state. Use also to configure trigger properties.
LIMIT	Use to perform and create limit tests.
DIGITS	Use to set display resolution.
RATE	Use to select measurement rate.
and ▶	Use to control cursor position for making selections or editing values.
SAVE	Use to save present setup to a memory location.
SETUP	Use to restore setup to either GPIB or factory defaults, or to a user memory location. Also use to modify properties of power on defaults to either GPIB or factory defaults, or to a user memory location.
STORE	Use to start buffer and modify the number of readings to store.
RECALL	Use to display stored readings (including maximum, minimum, peak-to-peak, average, and standard deviation). The and RANGE keys scroll through the buffer, and the or ▶ key toggles between reading number, reading, voltage, and timestamp.
AZERO	Use to control auto zero function (on / off).
DAMP	Use to control damping function (on / off).
EXIT	Use to cancel selection and move back to measurement display.
ENTER	Use to accept selection and move to next choice or back to measurement display.

4 Range keys

	Use to select the next higher measurement range. Also use to modify the upper autorange limit.
	Use to select the next lower measurement range. Also use to modify the lower autorange limit.
AUTO	Enables/disables autorange.

5 Handle

Pull out and rotate to desired position.

6 VOLTAGE SOURCE OPERATE indicator

This indicator will turn on when the voltage source is in operate (voltage source output turned on). It will also turn on for about 0.7 sec at power-on to indicate that it is functional.

WARNING Hazardous voltage may be present on the rear panel V-SOURCE OUTPUT terminals when the operate indicator is on.

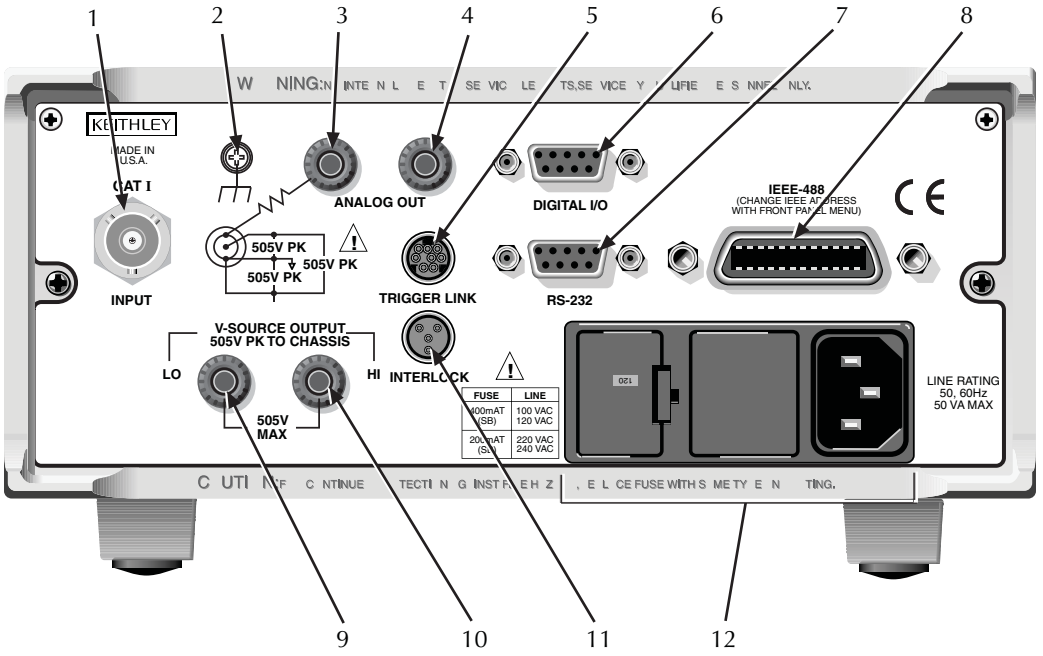
7 Display annunciators

* (asterisk)	Readings being stored in buffer.
(more)	Indicates additional selections are available.
AUTO	Autorange enabled.
BUFFER	Recalling readings stored in buffer.
ERR	Questionable reading or invalid cal step.
FAST	Fast (0.1 PLC) reading rate selected.
FILT	MEDIAN and/or AVERAGE filter enabled (also DAMPING enabled).
LSTN	Instrument addressed to listen over GPIB.
MATH	mX+b, m/X+b, or log10 calculation enabled.
MED	Medium (1 PLC) reading rate selected.
REL	Relative enabled for present measurement function.
REM	Instrument in GPIB remote mode.
SLOW	Slow reading rate selected; 6 PLC for 60Hz or 5 PLC for 50Hz.
SRQ	Service request over GPIB.
STAT	Displaying buffer statistics.
TALK	Instrument addressed to talk over GPIB bus.
TIMER	Timer controlled triggering in use.
TRIG	External triggering (GPIB or trigger link) selected.
MON	Zero correct enabled.
SCAN	Voltage sweep armed and ready to run.
OCOMP	Voltage source in compliance.

Model 6487 rear panel summary

The rear panel of the Model 6487 is shown in Figure 1-4.

Figure 1-4
Model 6487 rear panel



1 INPUT

This standard three-lug female triax connector is used to connect the signal to be measured to the input of the Model 6487. Mates to a three-slot male triax connector cable.

2 CHASSIS

This screw terminal is used to connect COMMON to CHASSIS ground via the ground link connector.

3 COMMON

This standard banana connector can be used as input LO or as the common for the ANALOG OUT. Also can be used as a ground link. Note that there is a 1k(ohm) resistance to input LO from the ANALOG OUT common.

4 ANALOG OUT

This standard banana connector provides a scaled, inverting output (inverting 2V full scale on all ranges).

5 TRIGGER LINK

Eight-pin micro-DIN connector for sending and receiving trigger pulses among connected instruments. Use a trigger link cable or adapter, such as Models 8501-1, 8501-2, 8502, and 8503.

6 DIGITAL I/O

Male DB-9 connector for digital output lines and component handler signals.

7 RS-232

Female DB-9 connector for RS-232 operation. Use a straight-through (not null modem) DB-9 shielded cable.

8 IEEE-488

Connector for IEEE-488 (GPIB) operation. Use a shielded cable, such as Models 7007-1 and 7007-2.

9 V-SOURCE OUTPUT LO

This standard banana connector provides LO connection to the 6487's voltage source.

WARNING Hazardous voltage may be present on the rear panel V-SOURCE OUTPUT terminals when the front panel operate indicator is on.

CAUTION Do not connect external sources to the 6487 voltage source. External sources may damage the 6487 voltage source.

10 V-SOURCE OUTPUT HI

This standard banana connector provides HI connection to the 6487's voltage source.

CAUTION Do not connect external sources to the 6487 voltage source. External sources may damage the 6487 voltage source.

11 INTERLOCK

This interlock connector provides connection of the 6487's voltage source with an interlock connector on a test fixture.

12 Power Module

Contains the AC line receptacle and power line fuse. The instrument can be configured for line voltages of 115V and 230VAC (nominal) at line frequencies of 50 or 60Hz automatically and over the bus. Changing line voltages requires changing fuses.

Voltage source

The Model 6487 voltage source can source up to ±505V DC and is used for the ohms function. See "Basic connections to DUT," page 2-5 in for full details on voltage source operation.

Analog output

The Model 6487 has an analog output on the rear panel. The ANALOG OUT provides a scaled, inverting ±2V output. A full-scale reading corresponds to ±2V output. See "Analog output," page 2-14 in for full details on analog output operation.

Digital I/O

The Model 6487's Digital I/O port is a male DB-9 connector located on the rear panel. The four active-low, digital output lines and one input line are used to control external circuitry. For detailed connection and usage information, refer to Section 8 of the Model 6487 Reference Manual.

Display

Readings can be displayed in engineering units or scientific notation. Annunciators indicate various states of operation. See "Model 6487 front panel summary," page 1-13 for a complete listing of display annunciators. The normal display also includes the voltage source value on the right.

NOTE *Changing the display resolution is not allowed if displaying readings in scientific notation.*

The DISP key can be used to turn the display on or off. The Display and Keys Test allows you to test display digit segments and annunciators, and check the functionality of front panel keys. These tests are accessed through the MENU.

Status and error messages

Status and error messages are displayed momentarily. During operation and programming, you will encounter a number of front panel messages. Typical messages are either of status or error variety, as listed in Appendix B of the Model 6487 Reference Manual.

Power-up

Line power connection

Follow the procedure below to connect the Model 6485/6487 to line power and turn on the instrument.

1. Check to see that the line voltage indicated in the window of the fuse holder assembly (Figure 1-2 or Figure 1-4) is correct for the operating voltage in your area. If not, refer to the procedure in Section 17 of the Model 6485 Instruction Manual or Model 6487 Reference Manual for setting line voltage and fuse replacement.

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

2. Before plugging in the power cord, make sure that the front panel power switch is in the off (O) position.
3. Connect the female end of the supplied power cord to the AC receptacle on the rear panel. Connect the other end of the power cord to a grounded AC outlet.

WARNING The power cord supplied with the Model 6485/6487 contains a separate ground terminal for use with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.

4. Turn on the instrument by pressing the front panel power switch to the on (l) position.

Line frequency

The Model 6485/6487 operates at line frequencies of 50 or 60Hz. When auto detect is enabled (factory default), line frequencies are automatically sensed and set accordingly, therefore there are no switches to set. Use the :SYST:LFR? command (query) to read the line frequency. The factory default setting is auto detect enabled.

If the power line is noisy, auto detect may not be able to lock in on a frequency. If this occurs, set the frequency manually. This may be accomplished using the front panel or over the bus. From the front panel, use the MENU/LFREQ selection to change the frequency. Via remote, send the SYST:LFR <freq> command.

Power-up sequence

The following power-up sequence occurs when the Model 6485/6487 is turned on:

1. The Model 6485/6487 performs self-tests on its EPROM and RAM with all digits and annunciators turned on. (For the Model 6487 at power-up, the VOLTAGE SOURCE OPERATE LED will come on for 0.7 seconds to indicate that it is functional.) If a failure is detected, the instrument momentarily displays an error message and the ERR annunciator turns on. Error messages are listed in Appendix B of the Model 6485 Instruction Manual or Model 6487 Reference Manual.

NOTE *If a problem develops while the instrument is under warranty, return it to Keithley Instruments Inc., for repair.*

2. If the instrument passes the self-tests, the firmware revision levels are displayed. For example:
   `6485 A01` or `6487 A01`
3. After the firmware revision levels are displayed, the detected line frequency is displayed.

   For example:
   `FREQ: 60Hz`
4. After the detected line frequency is displayed, information on the selected remote interface is displayed:
   a. **GPIB —** If the GPIB is the selected interface, the instrument will display the selected language (SCPI or DDC) and primary address.

      Model 6485 Examples:
      ```
      SCPI  ADDR:  14
      DDC  ADDR:  14
      ```

      Model 6487 Examples:
      ```
      SCPI  ADDR:  22
      DDC  ADDR:  22
      ```

   b. **RS-232 —** If RS-232 is the selected interface, the instrument will display the baud rate setting. For example:
      `RS-232:  9600b`
5. If the FACTory setup is selected as the power-on setup, the unit is placed in the default reading mode after the communication information is displayed. If a setup other than FACTory is selected, the configured setup will be displayed. For example, if the USR1 setup (User Setup #1) is selected:

   `USING USR1`

Default settings

The Model 6485/6487 can be restored to one of five setup configurations: factory default (FACT), three user-saved (USR0, USR1, and USR2), and bus default (GPIB). As shipped from the factory, Model 6485/6487 powers up to the factory default settings. Factory default settings provide a general purpose setup for front panel operation, while the bus default (GPIB) settings do the same for remote operation. Factory and GPIB default settings are listed in Table 1-1 and Table 1-2.

The instrument will power up to whichever default setup was saved as the power-on setup.

NOTE *At the factory, the factory default setup is saved into the USR0, USR1, and USR2 setups.*

Saving user setups

To save a user setup, configure Model 6485/6487 for the desired measurement application, then press SAVE and select the desired setup (0 = USR0, 1 = USR1, 2 = USR2). Press ENTER to complete the process. Use the *SAV command to save setups by remote.

To save the power-on setup, press CONFIG and then SETUP, and select FACT, USR0, USR1, USR2, or GPIB, and press ENTER. Use the SYST:POS command to save the power-on setup via remote.

Restoring setups

Press SETUP to display the restore menu, then select the setup (FACT, USR0, USR1, USR2, or GPIB) and press ENTER. Use the *RCL command to recall setups by remote.

Restoring factory default setup

From the front panel, press SETUP, select FACT, and then press ENTER. Use *RST to restore GPIB defaults or SYST:PRES to restore front panel defaults via remote.

Table 1-1
Model 6485 default settings

Setting	Factory (:SYStem:PRESet)	GPIB (*RST)
Trig Layer (CONF-TRIG):		
TRIG:	TRIG-IN	*
Arm-In Source Event	IMM	*
Arm Layer (CONF-ARM):		
Arm-In Source Event	IMM	*
Arm Count	INF	1
Input Trigger Link Line	1	*
Source Bypass	NEVER	*
Output Trigger Link Line	2	*
Output Trigger	Off	*
Buffer (STORE):	Disabled	*
Count	No effect	*
Digital Filter (AVG):	Off	*
Count	10	*
Type	Moving	*
Display Resolution (DIGITS)	5 -digits	*
Format byte order	Swapped	Normal
GPIB:	No effect (On at factory)	*
Address	No effect (14 at factory)	*
Language	No effect (SCPI at factory)	*
Limit Tests:		
Limit 1 and Limit 2:	Disabled	*
HI and LO Values	1, -1	*
Median Filter:	Off	*
Rank	1	*
MX+B:	Disabled	*
"M" Value	1.0	*
"B" Value	0.0	*
Units	X	*
Log	OFF	*
M/X+B (reciprocal)	Disabled	*
"M" Value	1.0	*
"B" Value	0.0	*
Units	X	*
Range	AUTO	*

*The factory (:SYStem:PRESet) and bus (*RST) GPIB defaults are the same. Bus settings that are different from factory reset are as shown.

Table 1-1 (cont.)
Model 6485 default settings

Setting	Factory (:SYStem:PRESet)	GPIB (*RST)
Rate:	Slow	*
NPLC	6.0 (60Hz) or 5.0 (50Hz)	*
Rel:	Off	*
Rel Value (VAL)	0.0	*
RS-232:	No effect (Off at factory)	*
All Settings	No effect	*
Trigger Layer (CONF-TRIG):		
Trig-In Source Event	IMM	*
Trigger Count	1	*
Trigger Delay	0	*
Input Trigger Link Line	1	*
Source Bypass	NEVER	*
Output Trigger Link Line	2	*
Units	No effect	*
Zero Check	Enabled	*
Zero Correct	Disabled	*

*The factory (:SYStem:PRESet) and bus (*RST) GPIB defaults are the same. Bus settings that are different from factory reset are as shown.

Table 1-2
Model 6487 default settings

Setting	Factory (:SYStem:PRESet)	GPIB (*RST)
Arm Layer (CONFIG ARM):		
Arm-In Source Event	IMM	*
Arm Count	INF	1
Input Trigger Link Line	1	*
Source Bypass	NEVER	*
Output Trigger Link Line	2	*
Output Trigger	Off	*
Buffer (STORE):	Disabled	*
Count	No effect	*
Damping (DAMP)	On	*
Digital Filter (FILT):	Off	*
Count	10	*
Type	Moving	*
Display Resolution (DIGITS)	5 -digits	*
Format byte order	Swapped	Normal
Function	Amps	*
GPIB:	No effect (On at factory)	*
Address	No effect (22 at factory)	*
Language	No effect (SCPI at factory)	*
Limit Tests:		
Limit 1 and Limit 2:	Disabled	*
HI and LO Values	1, -1	*
Log (MATH)	OFF	*
Median Filter (FILT):	Off	*
Rank	1	*
M/X+B (MATH)	Disabled	*
"M" Value	1.0	*
"B" Value	0.0	*
Units	X	*
Ohms Mode	Normal	*
Range	AUTO	*
Rate:	Slow	*
NPLC	6.0 (60Hz) or 5.0 (50Hz)	*
Rel:	Off	*
Rel Value (VAL)	0.0	*

*The factory (:SYStem:PRESet) and bus (*RST) GPIB defaults are the same.
Bus settings that are different from factory reset are as shown.

Table 1-2 (cont.)
Model 6487 default settings

Setting	Factory (:SYStem:PRESet)	GPIB (*RST)
RS-232:	No effect (Off at factory)	*
All Settings	No effect	*
Trigger Layer (CONFIG TRIG):		
Trig-In Source Event	IMM	*
Trigger Count	1	*
Trigger Delay	0	*
Input Trigger Link Line	1	*
Source Bypass	NEVER	*
Output Trigger Link Line	2	*
Units	No effect	*
Voltage Source:		
Operate	Off	*
Amplitude	0V	*
Range	10V	*
Current Limit	25mA	*
10V Range Interlock	Off	*
Sweeps:		
Start Voltage	0V	*
Stop Voltage	10V	*
Step Voltage	1V	*
Center Voltage	5V	*
Span Voltage	10V	*
Delay	1s	*
Zero Check	Enabled	*
Zero Correct	Disabled	*

*The factory (:SYStem:PRESet) and bus (*RST) GPIB defaults are the same.
Bus settings that are different from factory reset are as shown.

Menu

Many aspects of operation are configured through the menus summarized in Table 1-3 and Table 1-4. Refer to the section listed in the table for in-depth information. To access the menu, press the MENU key. Use the and RANGE keys to scroll through the menu items and the and ▶ cursor keys to change options. Press ENTER to save any changes made and then leave the menu. Press EXIT to leave the menu without saving changes.

NOTE *The MENU key is used to access the menu structure. However, if in remote for IEEE-488 bus operation (REM annunciator is lit), pressing the menu key has no effect. Press the LOCAL key to place the unit in local operation, then press the MENU key to access the menu items.*

Table 1-3
Model 6485 MENU structure

Menu item	Description	Reference
CAL	Provides path to the following calibration submenu items: VOFFSET, COUNT, RUN, DATES, UNLOCK, LOCK, and SAVE.	Instruction Manual Section 16
TSTAMP	Timestamp format can be ABSolute or DELTa.	Section 6
UNITS	Readings can be displayed in ENGineering units or SCIentific notation.	
TEST	Run display or key tests.	Instruction Manual Section 17
SNUM	Displays the unit's serial number.	
LFREQ	Line frequency can be manually set to 50 or 60 Hz or AUTOmatically set. The number after AUTO indicates present detected frequency value.	"Line frequency," page 1-19

Table 1-4
Model 6487 MENU structure

Menu item	Description	Reference
CAL	Provides path to the following calibration submenu items: VOFFSET, COUNT, RUN, VSRC-RUN, DATES, UNLOCK, LOCK, and SAVE.	Reference Manual Section 16
TSTAMP	Timestamp format can be ABSolute or DELTa.	Section 6
UNITS	Readings can be displayed in ENGineering units or SCIentific notation.	
TEST	Run display or key tests.	Reference Manual Section 17
SNUM	Displays the unit's serial number.	
LFREQ	Line frequency can be manually set to 50 or 60 Hz or AUTOmatically set. The number after AUTO indicates present detected frequency value.	"Line frequency," page 1-19

SCPI programming

SCPI programming information is integrated with front panel operation throughout this manual. SCPI commands are listed in tables and additional information that pertains exclusively to remote operation is provided after each table. The SCPI tables may reference you to other sections of this manual.

NOTE *SCPI tables in this manual are abridged. That is, they do NOT include most optional command words and query commands. See Section 14 of the Model 6485 Instruction Manual or Model 6487 Reference Manual for a complete listing of SCPI commands.*

Optional command words

In order to be in conformance with the IEEE-488.2 standard, the Model 6485/6487 accepts optional command words. Any command word that is enclosed in brackets ([]) is optional and does not have to be included in the program message. Programming examples in this manual use the short form and do not include optional command words for simplicity.

Query commands

Most command words have a query form. A query command is identified by the question mark (?) that follows the command word. A query command requests (queries) the programmed status of that command. When a query command is sent and Model 6485/6487 is addressed to talk, the response message is sent to the computer.

2 Connections

- **Connection fundamentals** — Covers fundamental information about connecting test circuits to the picoammeter.
- **Basic connections to DUT** — Details connecting test circuits to the picoammeter for current measurement and Model 6487 ohms measurements.
- **Using a test fixture** — Discusses using general test fixtures as well as the Model 8009 test fixture.
- **Model 6487 interlock** — Provides information on using the Model 6487 interlock, which must be used to optimize safety.
- **Analog output** — Covers analog output connections and discusses considerations when using the analog output.
- **Measurement considerations** — Summarizes considerations that could affect overall measurement accuracy.

Connection fundamentals

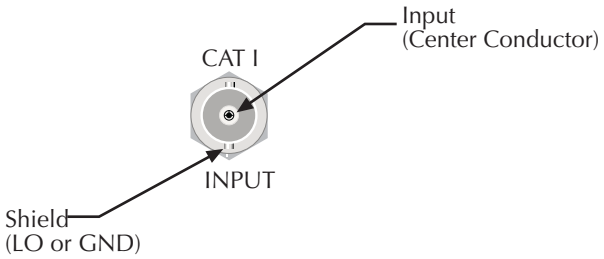
The following provides important fundamental information on input connections to the Models 6485 and 6487. Typical connection drawings are provided in "Basic connections to DUT," page 2-5. More detailed connections for specific measurements are in Section 3.

Model 6485 connections

Input connector

The rear panel INPUT connector is a 2-lug female BNC connector (Figure 2-1). Make connections using a male terminated BNC cable ("Low noise input cables," page 2-3).

Figure 2-1
Model 6485 BNC Input connector



Maximum input levels

The maximum input levels to the Model 6485 are summarized in Figure 2-2.

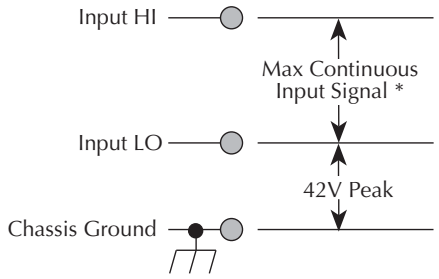
WARNING The maximum safe voltage between picoammeter LO and chassis ground (common mode voltage) is 42V. The Model 6485 does not internally limit the LO-to-chassis voltage. Exceeding 42V can create a shock hazard.

CAUTION The LO-to-chassis breakdown voltage is 500V. Exceeding this voltage may cause damage to the instrument.

Connecting COMMON or ANALOG OUTPUT to earth while floating the input may damage the instrument.

NOTE *Analog outputs will be at same voltages as applied to the BNC shell.*

Figure 2-2
Model 6485 maximum input levels



* Maximum Continuous Input Signals
220V Peak, DC to 60Hz sine wave

Low noise input cables

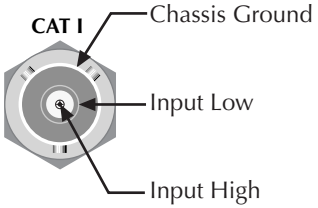
When making precision measurements, you should always use low noise cables. As a general rule, always use the shortest possible cable for measurements. See "Model 6485 input cables, connectors, and adapters," page 1-4 for recommended cables.

Model 6487 connections

Input connector

The rear panel INPUT connector is a 3-lug female triax connector (Figure 2-3). Make connections using a male terminated triax cable.

Figure 2-3
Model 6487 triax Input connector



Voltage source output connectors

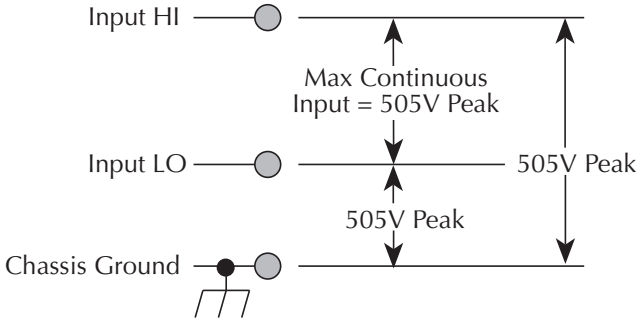
The rear panel V-SOURCE OUTPUT HI and LO connectors (see Figure 1-4 in Section 1) are used to connect the voltage source to the DUT. The voltage source is primarily used for ohms measurements. See "Ohms measurement connections," page 2-7 for details.

Maximum input levels

The maximum input levels to the Model 6487 are summarized in Figure 2-4.

WARNING The maximum safe voltage between the voltage source or ammeter common and chassis ground (common mode voltage) is 505V peak. Exceeding this voltage can create a shock hazard.

Figure 2-4
Model 6487 maximum input levels



Connecting cables and test leads

When making precision measurements, you should always use low-noise triax cables for INPUT connections. As a general rule, always use the shortest possible cable for measurements. When using the voltage source, the test leads must be rated for 505V minimum and should include safety sheaths. See "Model 6487 input cables, connectors, and adapters," page 1-5 in for recommended cables and test leads.

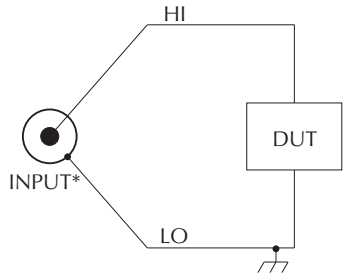
Basic connections to DUT

Model 6485 DUT connections

Connections

Basic connections are shown in Figure 2-5, the DUT is the current to be measured. Circuit high is connected to the center conductor of the input connector and circuit low is connected to the connector's shell.

Figure 2-5
Basic Model 6485 connections



* Maximum Continuous Input Signals
220V Peak, DC to 60Hz sine wave

WARNING If it is possible for the DUT or external supply to present more than 42V to the input HI, it is imperative that the connection between input LO and the external voltage source be sufficiently low impedance and capable of carrying the short-circuit current of the source, in order that the LO not exceed 42V.

CAUTION Current limiting resistors are required for DUTs capable of forcing voltages 220V or greater. Damage to the instrument may result if voltages greater than 220V are forced on the Model 6485 Input HI.

Noise and safety shields

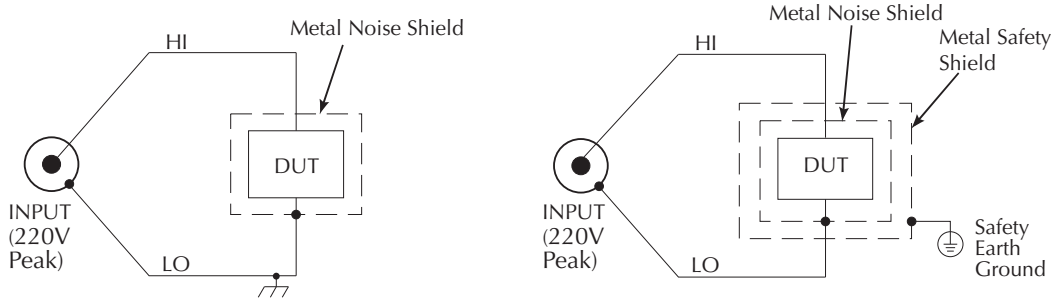
Figure 2-6 shows typical measurement shielding. A noise shield is used to prevent unwanted signals from being induced on the picoammeter input. Amps measurements below 1µA may benefit from effective shielding. Typically, the noise shield is connected to picoammeter input LO. Additionally, Figure 2-6 shows LO connected to earth ground via the ground link.

WARNING The maximum safe voltage between picoammeter LO and chassis ground (common mode voltage) is 42V. The Model 6485 does not internally limit the LO-to-chassis voltage. Exceeding 42V can create a shock hazard.

If it is possible for the DUT or external supply to present more than 42V to the input HI, it is imperative that the connection between input LO and the external voltage source be sufficiently low impedance and capable of carrying the short-circuit current of the source, in order that the LO not exceed 42V.

CAUTION The LO to chassis breakdown voltage is 500V. Exceeding this voltage may cause damage to the instrument.

Figure 2-6
Shielding for Model 6485 measurements (unguarded)



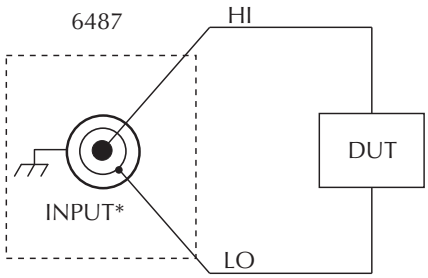
A. Noise Shield **B. Safety Shield**

Model 6487 DUT connections

Current measurement connections

Basic connections for current measurements are shown in Figure 2-7; the DUT is the current to be measured. Circuit high is connected to the center conductor of the input connector and circuit low is connected to the connector's input LO (inner shield).

Figure 2-7
Basic Model 6487 current measurement connections



* Maximum Continuous Input: 505V Peak

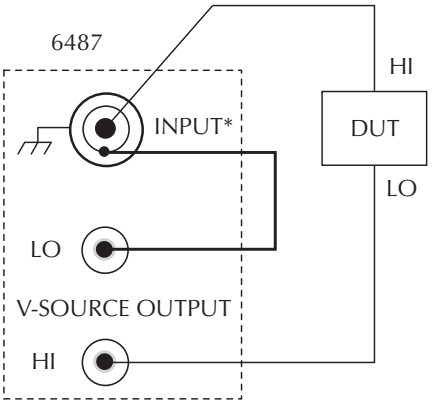
WARNING If it is possible for the DUT or external supply to present more than 505V to the input HI, it is imperative that the connection between input LO and the external voltage source be sufficiently low impedance and capable of carrying the short-circuit current of the source, in order that the LO not exceed 505V.

CAUTION Current limiting resistors are required for DUTs capable of forcing voltages 505V or greater. Damage to the instrument may result if voltages greater than 505V are forced on the Model 6487 INPUT HI.

Ohms measurement connections

Basic connections for ohms measurements are shown in Figure 2-8; the DUT is the resistance to be measured. Circuit high is connected to the center conductor of the INPUT connector and circuit low is connected to the V-SOURCE OUTPUT HI terminal. Note that INPUT LO and V-SOURCE OUTPUT LO are connected together externally.

Figure 2-8
Basic Model 6487 ohms connections



* Maximum Continuous Input: 505V Peak

Noise and safety shields

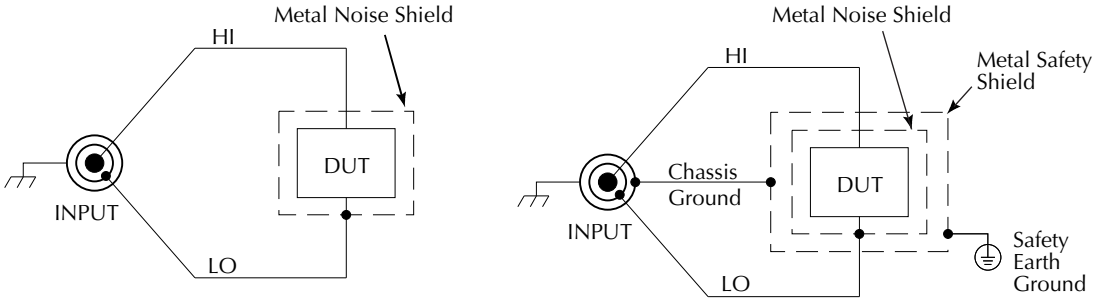
Figure 2-9 shows typical measurement shielding. In (A), a noise shield is used to prevent unwanted signals from being induced on the picoammeter input. Amps measurements below 1µA may benefit from effective shielding. Typically, the noise shield is connected to picoammeter input LO. Additionally, Figure 2-9(B) shows an added safety shield connected to earth ground and Model 6487 chassis. This type of shielding should be used whenever hazardous voltages will be present in the test circuit.

WARNING **The maximum safe voltage between picoammeter LO and chassis ground (common mode voltage) is 505V peak. The Model 6487 does not internally limit the LO-to-chassis voltage. Exceeding 505V can create a shock hazard.**

If it is possible for the DUT or external supply to present more than 505V to the input HI, it is imperative that the connection between input LO and the external voltage source be sufficiently low impedance and capable of carrying the short-circuit current of the source, in order that the LO not exceed 505V.

CAUTION The LO to chassis breakdown voltage is 505V. Exceeding this voltage may cause damage to the instrument.

Figure 2-9
Shielding for Model 6487 measurements (unguarded)



A. Noise Shield

B. Safety Shield

Input voltage overload (OVRVOLT message)

During normal operation, there should not be a significant voltage between the input HI and LO terminals of the Model 6485/6487. However, occasionally, as in the case of a DUT failure, a customer voltage source can become shorted directly to the Model 6485/6487. Under that condition, protection circuits within the 6485/6487 will limit the current flow for higher current ranges (20µA to 20mA). Additionally, when operating on the 2mA and 20mA ranges or when the 6485/6487 auto ranges up to these ranges as a response to the applied voltage, if the input voltage exceeds 60V, the Model 6485/6487 will change from a current limit to a 1MΩ– 3MΩ input impedance to prevent excess power dissipation. The OVRVOLT message will be displayed to indicate the change in the protection circuit. The same information is available with remote operation.

To return the instrument to normal operation, the over-voltage condition must be removed. Once the input voltage is reduced to under 60V, the protection circuit will return to its current limit operation until the current is reduced to a valid (on-scale) level. Extended operation near, but under 60V, will produce heat inside the instrument and may require time to cool before returning to accurate readings.

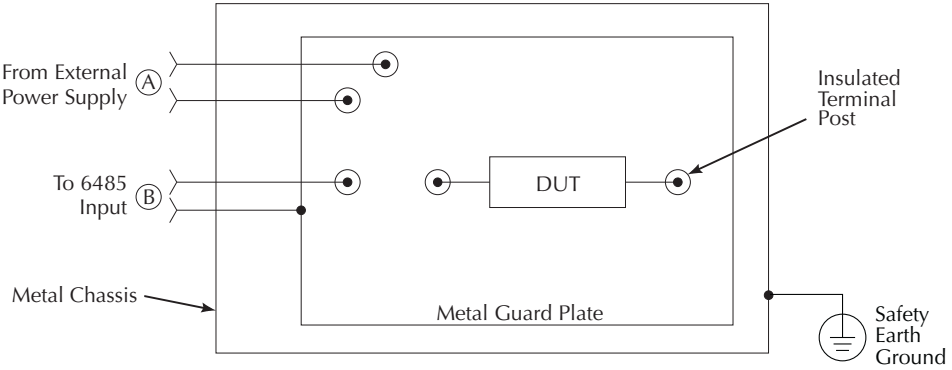
Using a test fixture

Whenever possible, use a shielded low-leakage test fixture to make precision measurements and for safety when high voltages (>30V) are used.

General purpose test fixture

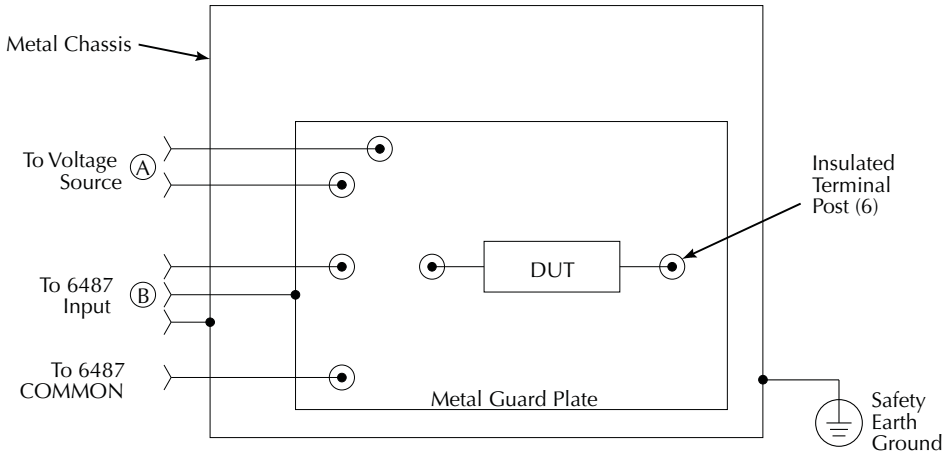
Connections to a general purpose test fixture are shown in Figure 2-10 and Figure 2-11. This test fixture will accommodate a variety of connection requirements.

Figure 2-10
General purpose test fixture connections to Model 6485



Ⓐ Banana Jacks (typical, from external power supply)
Ⓑ Female BNC Input Connector (Model 6485)

Figure 2-11
General purpose test fixture connections to Model 6487



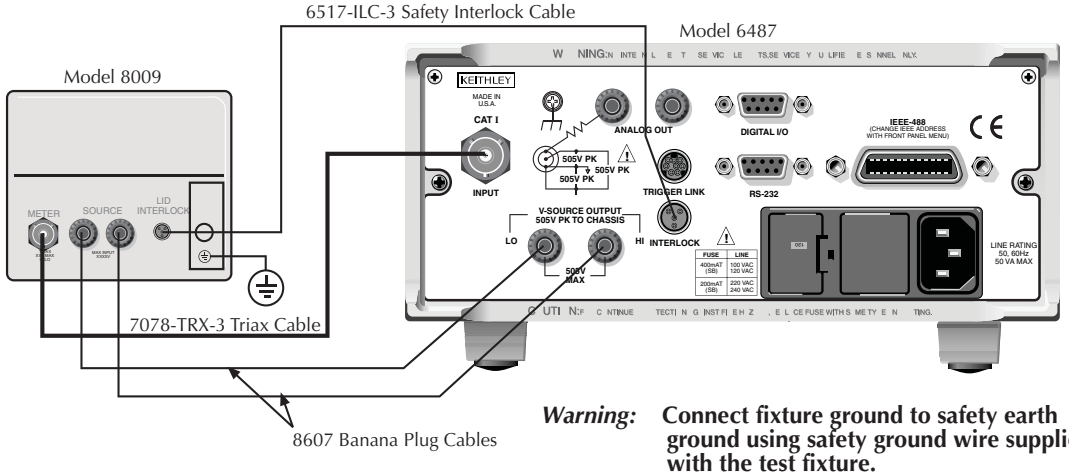
Ⓐ Banana Jacks

Ⓑ 3-Lug Female Triax Connector on 6487.

Model 8009 resistivity test fixture

This test fixture allows volume resistivity in the range from 10^3 to $10^{18}\Omega$-cm and surface resistivity in the range from 10^3 to $10^{17}\Omega$/sq. For typical connections to the Model 6487, refer to Figure 2-12.

Figure 2-12
Typical connections for Model 6487 measurements using the Model 8009 test fixture



Warning: **Connect fixture ground to safety earth ground using safety ground wire supplied with the test fixture.**

Model 6487 interlock

The Model 6487 has a built-in interlock that works in conjunction with the voltage source. The interlock prevents the voltage source from being placed in operate on the 50V and 500V ranges, and optionally on the 10V range, to assure safe operation.

Interlock connections

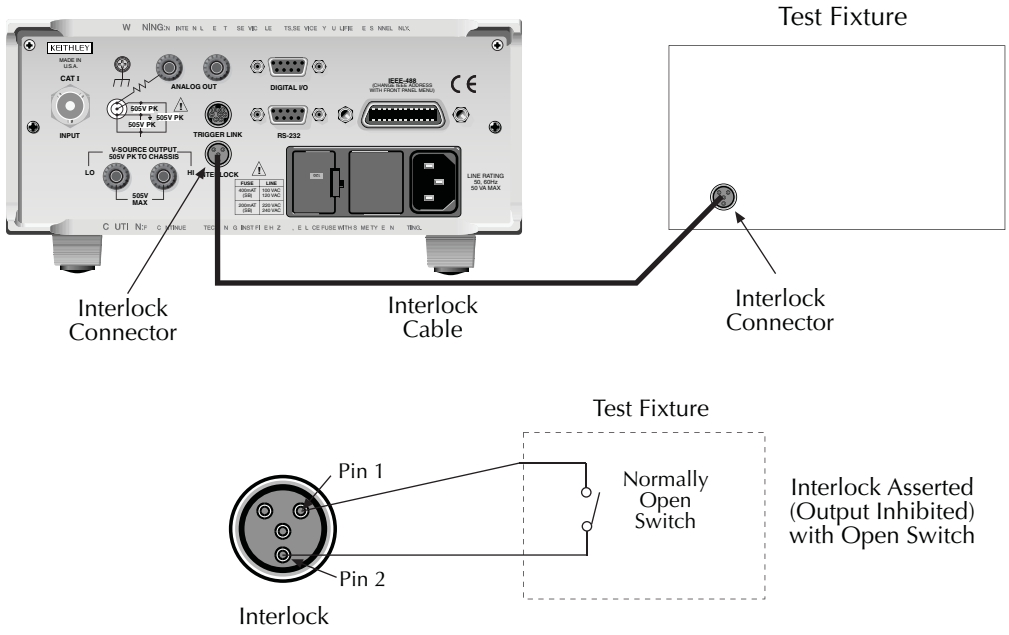
Figure 2-13 shows interlock connections and the pin diagram of the INTERLOCK connector. Typically, the INTERLOCK connector is connected to the same type of connector on the test fixture. A normally open switch is connected to pins 1 and 2 of the INTERLOCK connector as shown. When the switch is open, the interlock is asserted and the voltage source cannot be placed in operate on the 50V or 500V voltage source ranges and optionally for the 10V range.

WARNING If the voltage source was operating when the interlock is asserted, the voltage source will change to a high impedance state, possibly leaving charged DUT capacitance.

Interlock operation

The interlock is always operational for the 50V and 500V voltage source ranges. To enable the voltage source output, pins 1 and 2 of the INTERLOCK connector must be shorted together. For the 10V range, the interlock is optional and can be controlled with instrument programming. To enable the 10V range interlock, send :SOUR:VOLT:INT ON. To disable the 10V range interlock, send :SOUR:VOLT:INT OFF.

Figure 2-13
Model 6487 interlock connections



How is the interlock different between a Model 487 and Model 6487?

The Model 487 uses a 3-pin DIN interlock connector, while the Model 6487 uses a 4-pin DIN for the interlock
connection.

The Model 487 interlock prevents voltage source output only with the Model 236-ILC-3 cable connected. Without the cable connected, the Model 487 allows voltage source output on the 50V or 500V ranges. The Model 6487 will prevent voltage source output for the 50V or 500V ranges unless pins 1 and 2 are connected through an external switch by the customer. The Model 6487 will allow 10V range output by factory default without the external interlock connection but can be configured to require the external interlock connection.

With Model 6487 front panel operation, an open interlock will display "CLOSE INTLCK" as an error message when attempting to operate the voltage source on the 50V and 500V ranges. The Model 6487 in the Model 487 DDC emulation mode displays "IDDCO ERROR" on the front panel when an "O1" command is sent. The Model 487 displays "INTERLOCK" for the same condition. The "U9" voltage source error status word functions the same for either the Model 487 or Model 6487 in DDC emulation mode.

Analog output

The Model 6485/6487 has an analog output on the rear panel. The ANALOG OUT provides a scaled, inverting ±2V output. A full-scale reading corresponds to ±2V output.

CAUTION Connecting COMMON or ANALOG OUT to earth while floating the input may damage the instrument.

Connections for using this output are shown in Figure 2-14 (Model 6485) and Figure 2-15 (Model 6487). For a full-scale input (i.e. 2mA on the 2mA range), the output will be -2V. The 2V analog output signal is not corrected during calibration. The Model 6485 output impedance is 1kΩ, while the Model 6487 output impedance is <100Ω. To minimize the effects of loading, the input impedance of the device connected to the ANALOG OUT should be as high as possible.

Figure 2-14
Typical Model 6485 analog output connections

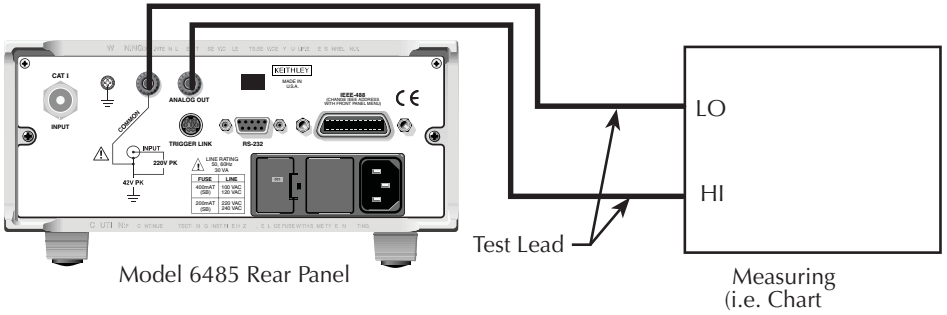
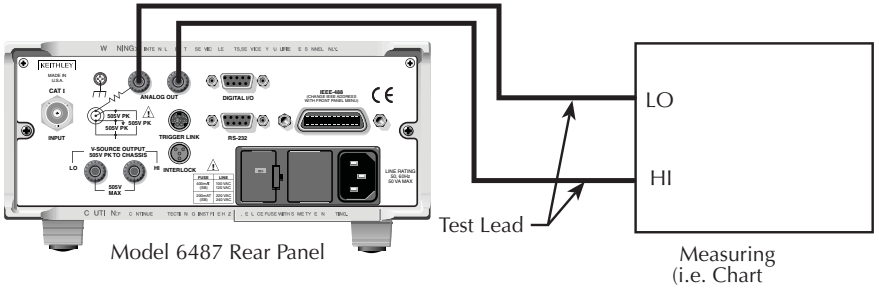


Figure 2-15
Typical Model 6487 analog output connections



Measurement considerations

There are a variety of factors to consider when making low-level measurements. These considerations are summarized in Table 2-1 and are detailed in Appendix C of the Model 6485 Instruction Manual and Appendix G of the Model 6487 Reference Manual, as well as in Appendix B of this manual. For comprehensive information on all measurement considerations, refer to the Low Level Measurements handbook, which is available from Keithley Instruments.

Table 2-1
Summary of measurement considerations

Considerations	Description
	See Model 6485 Instruction Manual, Appendix C or Model 6487 Reference Manual, Appendix G for details.
Input bias current	Offset current of Model 6485/6487 could affect low current measurements.
Voltage burden	Offset voltage of Model 6485/6487 could cause errors if it is high in relation to the voltage of the measured circuit.
Noise	Noise generated by source resistance and source capacitance.
	See Appendix B for details.
Ground loops	Multiple ground points can create error signals.
Triboelectric effects	Charge currents generated in a cable by friction between a conductor and the surrounding insulator (i.e., bending a triax cable).
Piezoelectric and stored charge effects	Currents generated by mechanical stress on certain insulating materials.
Electrochemical effects	Currents generated by the formation of chemical batteries on a circuit board caused by ionic contamination.
Humidity	Reduces insulation resistance on PC boards and test connection insulators.
Light	Light sensitive components must be tested in a light-free environment.
Electrostatic interference	Charge induced by bringing a charged object near your test circuit.
Magnetic fields	The presence of magnetic fields can generate EMF (voltage).
Electromagnetic Interference (EMI)	EMI from external sources (i.e., radio and TV transmitters) can affect sensitive measurements.

3 Measurements and Sourcing Voltage

- **Measurement overview** — Explains the basic measurement and voltage source capabilities of Model 6485/6487.
- **Performance considerations** — Covers warm-up period, voltage offset correction, auto zero, zero check, and zero correct.
- **Current measurements** — Provides a basic procedure to measure current.
- **Model 6487 ohms measurements** — Covers methods to set up and use the ohms measurement function.
- **Model 6487 voltage source operation** — Discusses configuring and using the voltage source.

Measurement overview

Current measurements

The basic current measurement capabilities of the Models 6485 and 6487 are summarized in Table 3-1. Accuracy for each measurement function and range is listed in the specifications (Appendix A).

Table 3-1
Basic Model 6485 and 6487 current measurement capabilities

Function	Reading Range	Available Ranges
Amps	±10fA to ±21mA	2nA, 20nA, 200nA, 2µA, 20µA, 200µA, 2mA, and 20mA

Model 6487 voltage source

The basic voltage source output capabilities of the Model 6487 are summarized in Table 3-2. Accuracy specifications are shown in Appendix A.

Table 3-2
Basic Model 6487 voltage source output capabilities

Function	Output Range	Available Ranges
Source voltage	±200µV to ±505V	10V, 50V, 500V

Performance considerations

Warm-up period

The Model 6485/6487 can be used within one minute after it is turned on. However, the instrument should be turned on and allowed to warm up for at least one hour before use to achieve rated accuracy. If the instrument has been exposed to extreme temperatures, allow extra time for the internal temperature to stabilize.

Voltage offset correction

Voltage offset correction should be performed periodically to null input amplifier offsets. Install the shielding cap on the INPUT jack, then use the CAL:VOFFSET selection in the main MENU. To perform correction via remote, send CAL:UNPR:VOFF.

Autozero

To help maintain stability and accuracy over time and changes in temperature, the Model 6485/6487 periodically measures internal voltages corresponding to offsets (zero) and amplifier gains; a process known as autozeroing. With autozero disabled, measurement speed increases up to three times, but measurement accuracy will be reduced. It is recommended that autozero only be disabled for short periods of time.

To toggle autozero on or off, press the AZERO button. When autozero is enabled, a colon will be displayed after the reading. Via remote, send SYST:AZER ON or SYST:AZER OFF.

Zero check and zero correct

Zero check

When zero check is enabled (on), the input amplifier is reconfigured to shunt the input signal to low. From the front panel, enable/disable zero check by pressing the ZCHK key. Refer to Table 3-3 for bus commands. Leave zero check enabled when connecting or disconnecting input signals.

Zero correct

NOTE *The Model 6485/6487 saves a single zero correct value (not one for each range).*
For best results, acquire a new zero correct value after changing to the desired range.

The Model 6485/6487 has a zero correct feature to algebraically subtract the voltage offset term from the measurement. Perform the following steps to algebraically zero correct the measurement:

1. Enable zero check by pressing ZCHK. (For the Model 6485 "ZC" will be displayed; for the Model 6487, the "*ZEROCHK*" message will be displayed.)
2. Select the range that will be used for the measurement or select the lowest range.
3. Press ZCOR (Model 6485) or REL (Model 6487) to enable zero correct. (For the Model 6485, "ZZ" message is displayed; for the Model 6487, the MON annunciator turns on.)
4. Press ZCHK to disable zero check.
5. Readings can now be taken from the display. (For the Model 6485, the "CZ" messages indicates a zero corrected reading. For the Model 6487, the MON annunciator indicates that the displayed reading is zero corrected.)
6. To turn off zero correct, press ZCOR (Model 6485) or REL (Model 6487) again with zero check enabled.

NOTES *With regard to the zero correct feature:*

- *The Model 6485/6487 will remain zero corrected even if it is upranged. If downranged, re-zero the instrument.*
- *The Model 6485/6487 does not have to be re-zero corrected as long as the ambient temperature remains stable.*
- *Zero correction cancels the voltage offset term of the amplifier. With zero correct enabled, the instrument may not display a perfectly zeroed reading.*
- *If the Model 6485/6487 is operating at or near T_{CAL}, zero correction will have very little effect. T_{CAL} is the internal temperature of Model 6485/6487 when it was last calibrated.*

SCPI programming — zero check and zero correct

Table 3-3
SCPI commands — zero check and zero correct

Commands	Description
SYST:ZCH <b>	Enable (ON) or disable (OFF) zero check.
SYST:ZCOR <b>	Enable (ON) or disable (OFF) zero correct.
SYST:ZCOR:ACQ	Acquire zero correct value.
INIT	Trigger a reading.

Current measurements

Precautions

Model 6485 precautions

WARNING The maximum safe voltage between picoammeter LO and chassis ground (common mode voltage) is 42V. The Model 6485 does not internally limit the LO to chassis voltage. Exceeding 42V can create a shock hazard.

If it is possible for the DUT or external supply to present more than 42V to the input HI, it is imperative that the connection between input LO and the external voltage source be sufficiently low impedance and capable of carrying the short-circuit current of the source, in order that the LO not exceed 42V.

CAUTION The LO to chassis breakdown voltage is 500V. Exceeding this voltage may cause damage to the instrument.

The maximum input voltage and current to Model 6485 is 220V peak and 21mA. Exceeding either of these values may cause damage to the instrument that is not covered by the warranty.

Model 6487 precautions

WARNING The maximum safe voltage between picoammeter LO and chassis ground (common mode voltage) is 505V. The Model 6487 does not internally limit the LO to chassis voltage. Exceeding 505V can create a shock hazard.

If it is possible for the DUT or external supply to present more than 505V to the input HI, it is imperative that the connection between input LO and the external voltage source be sufficiently low impedance and capable of carrying the short-circuit current of the source, in order that the LO not exceed 505V.

CAUTION The maximum input voltage and current to Model 6487 is 505V peak and 21mA. Exceeding either of these values may cause damage to the instrument that is not covered by the warranty.

Procedure

Perform the following steps to measure current:

Step 1. Select current function

For the Model 6487, press the I|Ω key to make sure the current function is selected.

Step 2. Enable zero check

Zero check should always be enabled before making connection changes. The ZCHK key toggles zero check on and off.

Step 3. Perform zero correction

To achieve optimum accuracy for low current measurements, it is recommended that you zero correct the picoammeter. To do so, make sure the 2nA range is selected, then press the ZCOR key (Model 6485) or REL key (Model 6487) to perform zero correction ("ZZ" indicated for Model 6485; MON indicator on for Model 6487).

Step 4. Select a manual measurement range or enable auto range

Use the manual RANGE keys to select a manual measurement range or press AUTO to enable auto range. With auto range enabled, the instrument will automatically go to the most sensitive range to make the measurement. See Section 4 for details on range.

Step 5. Connect the current to be measured to the picoammeter

Basic connections for measurements are shown in Figure 3-1 and Figure 3-2.

WARNING A safety shield is advisable whenever floating measurements are being made. Connections for the safety shield are shown in **Figure 3-1** and **Figure 3-2**. The metal safety shield must completely surround the noise shield or floating test circuit, and it must be connected to safety earth ground using #18 AWG or larger wire.

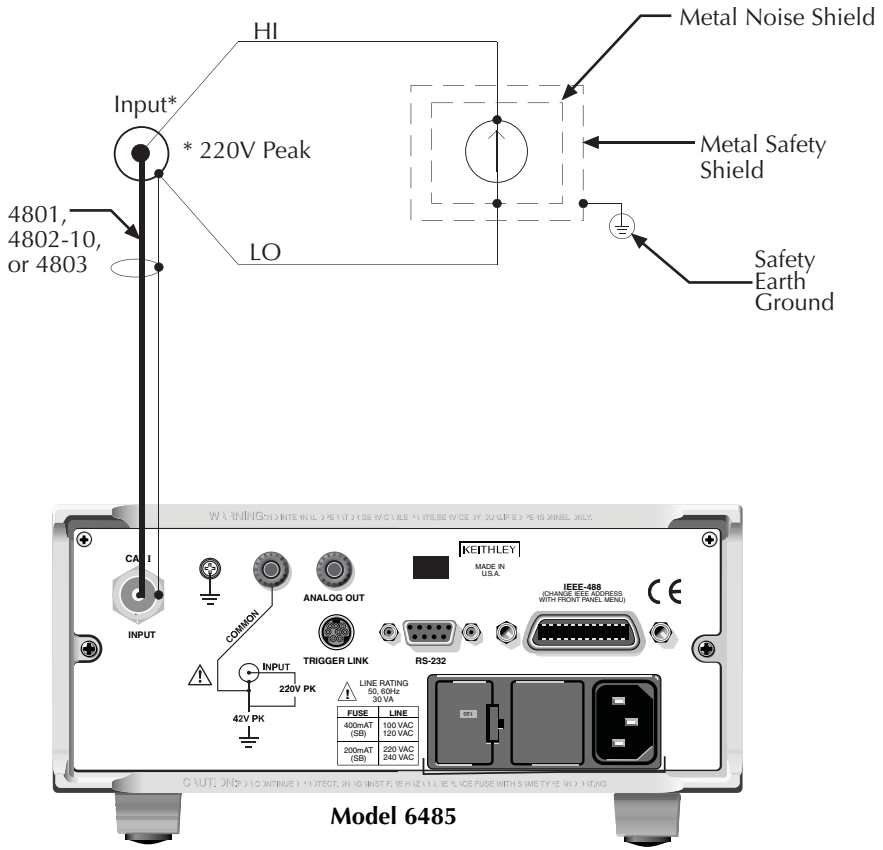
NOTE *When not making floating measurements, it is recommended that you ground measurement LO at only one place in the circuit, such as with the ground link connection on the rear panel of the 6485/6487. (See "Ground loops," page B-2.)*

Fundamental information on making connections to the picoammeter input is provided in Section 2.

Step 6. Disable zero check and take a reading from the display

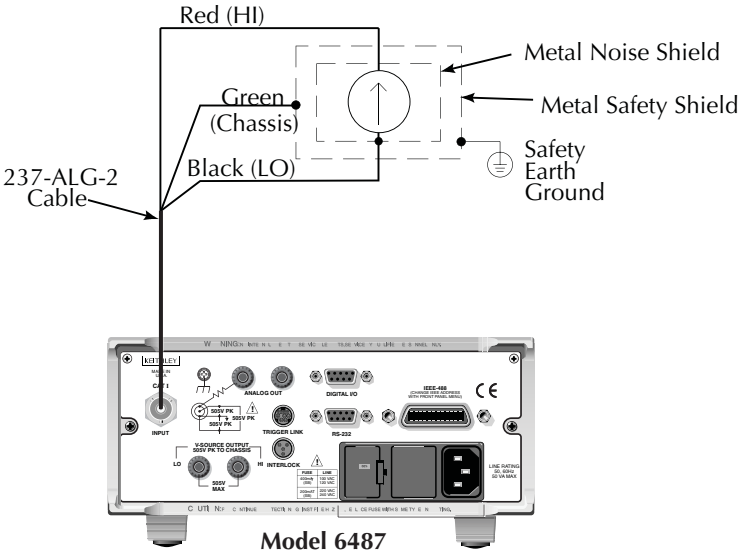
If the readings are noisy, you may want to use filtering to reduce noise. Filtering is covered in Section 4.

Figure 3-1
Connections for Model 6485 current measurements



Model 6485

Figure 3-2
Connections for Model 6487 current measurements



SCPI programming — current measurements

Table 3-4
SCPI commands — basic current measurements

Commands*	Description
FUNC 'CURR'	Select current function (Model 6487 only).
RANG <Range>	Select manual range (-0.021 to 0.021A).
RANG:AUTO <b>	Enable (ON) or disable (OFF) auto range.
INIT	Trigger reading.
READ?	Trigger and return reading(s).

* Zero correct and zero check commands not included. See Table 3-3.

Programming example — current measurements

The following command sequence will perform one zero-corrected current measurement:

```
*RST                        ' Return 6485/6487 to GPIB defaults.
SYST:ZCH ON                 ' Enable zero check.
RANG 2e-9                   ' Select the 2nA range.
INIT                        ' Trigger reading to be used as zero
                            ' correction.
SYST:ZCOR:ACQ               ' Use last reading taken as zero
                            ' correct value.
SYST:ZCOR ON                ' Perform zero correction.
RANG:AUTO ON                ' Enable auto range.
SYST:ZCH OFF                ' Disable zero check.
READ?                       ' Trigger and return one reading.
```

Model 6487 ohms measurements

Overview

To measure ohms with the Model 6487, you must set up the voltage source to the desired range, value, and current limit (see "Model 6487 voltage source operation," page 3-12), choose an appropriate current measurement range (or use auto range), and enable the ohms function. With the ohms function enabled, the Model 6487 calculates the measured resistance from the voltage source value and the measured current (R = V/I). When setting up the voltage source, choose as high a voltage value as possible for maximum current, keeping in mind such factors as the power dissipation and voltage coefficient of the resistance being tested.

DC and alternating voltage ohms

Model 6487 ohms measurements can be made using either the DC or alternating voltage modes, which can be used to enhance accuracy of very high resistance measurements. Only the DC mode is covered in this manual. See Section 3 of the Model 6487 Reference Manual for information on the alternating voltage mode.

Procedure

WARNING Always turn off the Model 6487's voltage source before changing voltage source connections to avoid a possible shock hazard.

Perform the following steps to measure resistance:

Step 1. Set up voltage source

Press either of the V-SOURCE adjustment keys, then use a manual RANGE key to set the voltage source range. Set the voltage and current limit to the desired values. You can skip the current limit prompt by pressing EXIT after adjusting the voltage.

Step 2. Perform zero correction

To achieve optimum accuracy for high resistance measurements, it is recommended that you zero correct the picoammeter before enabling the ohms function. To do so, make sure that zero check and the 2nA range are selected, then press the REL key to perform zero correction (MON indicator on).

Step 3. Select a manual current range or enable auto range

Use the manual RANGE keys to select a manual current measurement range or press AUTO to enable auto range. When using manual ranging, choose an appropriate value based on the voltage source setting and the expected measured resistance (I = V/R).

Step 4. Connect the resistance to be measured to the picoammeter

Basic connections for ohms measurements are shown in Figure 3-3. Note that both the picoammeter INPUT and the V-SOURCE OUTPUT jacks are connected to the resistance under test.

WARNING A safety shield is advisable whenever measurements are being made with voltages over 30V DC. Connections for the safety shield are shown in **Figure 3-3**. The metal safety shield must completely surround the noise shield or floating test circuit, and it must be connected to safety earth ground using #18 AWG or larger wire.

Step 5. Select ohms function

Press the I|Ω key to make sure the ohms function is selected.

Step 6. Turn on voltage source

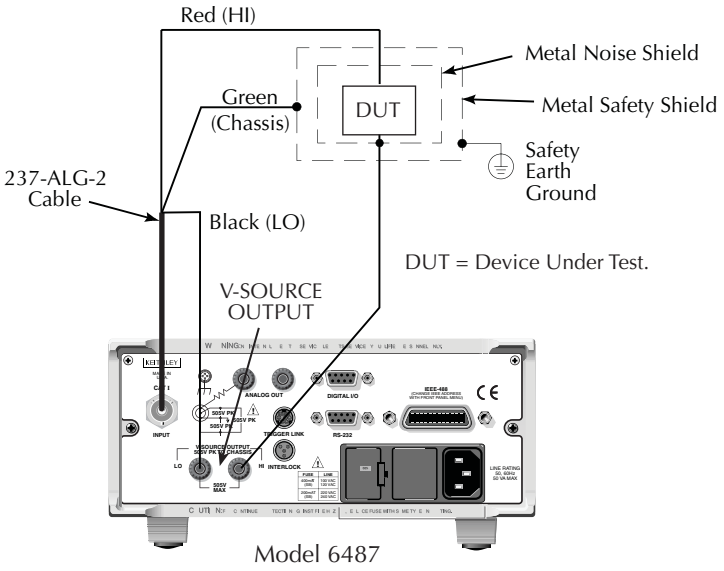
Press the OPER key to turn on the voltage source output. The VOLTAGE SOURCE OPERATE indicator will turn on.

Step 7. Disable zero check and take a reading from the display

If the readings are noisy, use filtering to reduce noise. It may be advisable to use the alternating voltage ohms or add shielding.

NOTE *For any ohms measurements, the ohms reading is invalid and unknown if the voltage source is in compliance. Therefore, a value of -9.9e+36 will be returned over the GPIB and the message I-LIMIT will be displayed on the front panel for both normal readings and buffer recall readings for any ohms readings where the voltage source went into compliance.*

Figure 3-3
Connections for Model 6487 ohms measurements



SCPI programming — ohms measurements

Table 3-5
SCPI commands — basic Model 6487 ohms measurements

Commands*	Description
SENS:OHMS ON	Select ohms function.
RANG <Range>	Select manual current range (-0.021 to 0.021A).
RANG:AUTO <b>	Enable (ON) or disable (OFF) auto current range.
SOUR:VOLT:RANG <Range>	Set voltage source range (10, 50, or 500).
SOUR:VOLT <Volts>	Set output voltage (-505V to +505V).
SOUR:VOLT:ILIM <Current>	Set current limit (25µA, 250µA, 2.5mA, or 25mA).
SOUR:VOLT:STAT <b>	Turn voltage source output ON or OFF.
READ?	Trigger and return reading(s).

* Zero correct and zero check commands not included. See Table 3-3.

Programming example — ohms measurements

The following command sequence will perform one zero-corrected resistance measurement:

```
*RST                        ' Return 6487 to GPIB defaults.
FORM:ELEM READ,UNIT         ' Measurement, units elements only.
SYST:ZCH ON                 ' Enable zero check.
RANG 2e-9                   ' Select the 2nA range.
INIT                        ' Trigger reading to be used as zero
                            ' correction.
SYST:ZCOR:ACQ               ' Use last reading taken as zero
                            ' correct value.
SYST:ZCOR ON                ' Perform zero correction.
RANG:AUTO ON                ' Enable auto current range.
SOUR:VOLT:RANG 10           ' Select 10V source range.
SOUR:VOLT 10                ' Set voltage source output to 10V.
SOUR:VOLT:ILIM 2.5e-3       ' Set current limit to 2.5mA.
SENS:OHMS ON                ' Enable ohms function.
SOUR:VOLT:STAT ON           ' Put voltage source in operate.
SYST:ZCH OFF                ' Disable zero check.
READ?                       ' Trigger and return one reading.
```

Model 6487 voltage source operation

Configuring the voltage source

Press CONFIG then OPER to set the voltage source mode. You will first be prompted to choose DC or SWEEP mode. (Select DC for normal operation. See Section 6 for details on sweeps.) After the mode is selected, the display shows a full-resolution value of the voltage source with the left-most position highlighted for editing. (If you do not wish to change the mode, you can jump right to this voltage edit display by pressing either V-SOURCE adjustment key). The and ▶ keys are used to select the digit being edited, and the V-SOURCE and keys change the value. The RANGE and keys change the voltage source range and indicate the range selected. Note that the V-SOURCE and keys will operate in the same manner as the RANGE and keys if they are not being used to change the voltage source value.

Voltage values are changed immediately from this configuration by pressing the arrow key. The digits will not increment beyond the maximum voltage for the selected range.

After the voltage value and range are selected press EXIT to return to normal readings display or press ENTER to advance to the current limit display. The current limit display offers different choices depending on the source range (refer to Table 3-6). Pressing ENTER or EXIT from this display returns you to the normal readings display.

Table 3-6
Voltage source current limits

Source Range:	Selectable Current Limit			
10.0000V Range	25µA	250µA	2.5mA	25mA
50.000V Range	25µA	250µA	2.5mA	
500.00V Range	25µA	250µA	2.5mA	

Sourcing voltage

CAUTION Do not connect external sources to the Model 6487 voltage source. External sources may damage the Model 6487 voltage source.

Turning source on and off

The OPER key will toggle the voltage source state (on/off). The Model 6487 will output the configured voltage and the VOLTAGE SOURCE OPERATE indicator will turn on.

OPER (operate) key

The OPER (operate) key will function to turn the voltage source off, even if the instrument is operating under remote control (REM annunciator on), assuming that the LLO (Local Lockout) function has not been employed. While in remote, the OPER key will only turn the source off. To turn it on, the Model 6487 must be in local (see Section 7).

Voltage source off state

The voltage source is not in a high-impedance state when it is turned off. Rather, it is in a state that acts just like the voltage source was programmed to 0V on the selected range. It will enter this state on power-up after the VOLTAGE SOURCE OPERATE light blinks. In contrast, the safety interlock *will* cause the voltage source to go into a high-impedance state instead of 0V output and the source will stay in the high-impedance state until the operate state is changed to on. The exception is the 10V range where the interlock is optional. The OPERATE light and front panel display do not indicate the difference between 0V output and high-impedance output caused by an open interlock. The interlock status is available by query via remote (see Table 3-7).

Compliance indication

At any time, it is possible that the voltage source will go into compliance (current limit reached). Should this situation occur, the OCOMP annunciator (Output Compliance) will flash and the displayed voltage value (visible when current readings are configured for readings of less than 6 digits) will alternate between showing the value and displaying "CMPL". If you are in a menu where the voltage source value is not shown on the right-most four characters of the display, only the flashing OCOMP annunciator will be shown.

Open interlock indication

If the interlock is asserted (opened) while the unit is on the 50V or 500V range, the voltage source will also technically be in compliance. However, there will be no indication of that status over the front panel or in the status registers. The open interlock takes precedence.

SCPI commands — voltage source

Table 3-7
SCPI commands — voltage source

Command	Description
SOUR:VOLT <Voltage>	Set the source output level (-500 to +500V).
SOUR:VOLT:RANG <Range>	Set source range to one of three ranges: 10, 50, and 500V.
SOUR:VOLT:ILIM <Limit>	Set the source current limit: 2.5e-5, 2.5e-4, 2.5e-3, or 2.5e-2.[1]
SOUR:VOLT:STAT <b>	Enable (ON) or disable (OFF) source output.
SOUR:VOLT:INT <b>	Enable (ON) or disable (OFF) interlock for 10V range.[2]
SOUR:VOLT:INT:FAIL?	Query interlock state (1 = asserted); source output cannot be turned on.

[1] 2.5e-2 not available for 50V and 500V ranges.
[2] See Section 2 for interlock operation.

Programming example — voltage

The following command sequence will output 5V on the 10V range with a 2.5mA limit:

```
*RST                        ' Return 6487 to GPIB defaults.
SOUR:VOLT:RANG 10           ' Select 10V source range.
SOUR:VOLT 5                 ' Set voltage source output to 5.
SOUR:VOLT:ILIM 2.5e-3       ' Set current limit to 2.5mA.
SOUR:VOLT:STAT ON           ' Put voltage source in operate.
```

4 Range, Units, Digits, Rate, and Filters

- **Range, units, and digits** — Provides details on measurement range, reading units, and display resolution selection. Includes the SCPI commands for remote operation.
- **Rate** — Provides details on reading rate selection. Includes the SCPI commands for remote operation.
- **Model 6487 damping** — Provides details on damping rate selection. Includes the SCPI command for remote operation.
- **Filters** — Explains how to configure and control the digital and median filters. Includes the SCPI commands for remote operation.

Range, units, and digits

Range

The ranges for current measurements are listed in Table 4-1.

Table 4-1
Measurement ranges

nA	µA	mA
2nA	2µA	2mA
20nA	20µA	20mA
200nA	200µA	

The full scale readings for every measurement range are 5% over range. For example, on the 20µA range, the maximum input current is ± 21µA. Input values that exceed the maximum readings cause the overflow message (OVRFLOW) to be displayed.

Manual ranging

To select a range, press the desired manual RANGE key. The instrument changes one range per key-press. If the instrument displays the OVRFLOW message on a particular range, select a higher range until an on-range reading is displayed. Use the lowest range possible without causing an overflow to ensure best accuracy and resolution.

Autoranging

When using autorange, the instrument automatically goes to the most sensitive available range to measure the applied signal. Up-ranging occurs at 105% of range, while down-ranging occurs at the range value. The AUTO key toggles the instrument between manual ranging and autoranging. The AUTO annunciator turns on when autoranging is selected. To disable autoranging, press AUTO or a manual RANGE key. Pressing AUTO to disable autoranging leaves the instrument on the present range.

Every time an autorange occurs, a search for every available range of the selected function is performed. The time it takes to perform the search could slow down range change speed significantly. Setting upper and/or lower autorange limits can reduce search time.

Autorange limits

Search time for finding the correct amps range can be reduced by setting upper and/or lower autorange limits. To set upper and/or lower autorange limits, press CONFIG then either manual RANGE key (for UPPER or LOWER), then scroll through the available range limits using the RANGE keys. Press ENTER when the desired range is flashing.

Units

Readings can be displayed using engineering (ENG) units (i.e., 1.236 mA) or scientific (SCI) notation (i.e., 1.236E-03A). To change units, press the MENU key, select UNITS, then press ENTER. Select ENG or SCI, then press ENTER.

NOTE *The units setting can only be changed from the front panel (no remote operation). Scientific notation provides more resolution on small values than engineering units.*

Digits

The DIGITS key sets display resolution for Model 6485/6487. Display resolution can be set from 3 to 6 digits. This single global setting affects display resolution for all measurement ranges. To set display resolution, press (and release) the DIGITS key until the desired number of digits is displayed.

NOTE *For the Model 6487, the voltage source value will not be displayed in the 6 digit display mode.*

SCPI programming — range and digits

Table 4-2
SCPI commands — range and digits

Commands	Description
RANG <n>	Select range: -0.021 to 0.021 (A).
RANG:AUTO <b>	Enable (ON) or disable (OFF) autorange.
RANG:AUTO:ULIM <n>	Specify upper range limit for autorange: -0.021 to 0.021 (A).
RANG:AUTO:LLIM <n>	Specify lower range limit for autorange: -0.021 to 0.021 (A).
DISP:DIG <n>	Set display resolution: 4 (3 digits) to 7 (6 digits).

Programming example — range and digits

The following command sequence selects the 20mA range and sets display resolution to 3 digits.

```
*RST                        ' Restore RST defaults.
RANG 0.02                   ' Set to 20mA range.
DISP:DIG 4                  ' Set display resolution to 3-1/2 digits.
```

Rate

The RATE key selects the integration time of the A/D converter, which is the period of time the input signal is measured. The integration time affects the amount of reading noise, as well as the ultimate reading rate of the instrument. The integration time is specified in parameters based on a number of power line cycles (NPLC), where 1 PLC for 60Hz is 16.67msec (1/60) and 1 PLC for 50Hz (and 400Hz) is 20msec (1/50). The rate setting is global for all ranges. Therefore, it does not matter what range is presently selected when you set rate.

To select the rate, either press the RATE key to select SLOW (6 PLC, 60Hz; 5 PLC, 50Hz), MED (1 PLC), or FAST (0.1 PLC), or press CONFIG and then RATE, and then enter the desired number of PLCs (0.01 to 60, 60Hz; 0.01 to 50, 50Hz).

To set the rate by remote, send :NPLC <plc> with an allowable range, or 0.01 to 60 (60Hz), or 0.01 to 50 (50Hz).

Model 6487 damping

High capacitance seen at the input will increase reading noise. This capacitance can be attributed to a long input cable or to the capacitance of the source, or a combination of both. Enabling damping (analog filtering) will reduce noise caused by high capacitance for current measurements. However, damping will also slow down the response of the measurement.

To enable or disable damping from the front panel, simply press the Model 6487 DAMP key. Note that the FILT annunciator will be on when damping is enabled. Via remote, send DAMP ON or DAMP OFF. Note that the FILT annunciator is used for both the analog damping filter and the two types of digital filters.

Filters

Filtering stabilizes noisy measurements caused by noisy input signals. The Model 6485/6487 uses two types of filters: median and digital. The displayed, stored, or transmitted reading is simply the result of the filtering processes. Note that both the median and digital filters can be in effect at the same time.

With both filters enabled, the median filter operation is performed first. After the median filter yields a reading, it is sent to the stack of the digital filter. Therefore, a filtered reading will not be displayed until both filter operations are completed.

The settings for the filter are global. For the Model 6485, the MEDN key controls the median filter and the AVG key controls the average filter. For the Model 6487 both filters are controlled with the FILT key. When either the median or digital filter is enabled, the FILT annunciator is on. Note that the FILT annunciator is used for both the digital filters and the Model 6487 analog damping filter.

Median filter

The median filter is used to determine the "middle-most" reading from a group of readings that are arranged according to size. For example, assume the following readings:

20mA, 1mA, 3mA

The readings are rearranged in an ascending order as follows:

1mA, 3mA, 20mA

From the above readings, it is apparent that 3mA is the median (middle-most) reading. The number of sample readings used for the median calculation is determined by the selected rank (1 to 5) as follows:

Sample readings = $(2 \times R) + 1$

where; R is the selected rank (1 to 5)

Note that the median filter throws out the oldest of the ranked values. It is especially useful for noise characterized by unwanted spikes.

Digital filter

Digital filter types

An additional filter parameter is type (type is either moving or repeating).

Moving Filter — Every time a reading conversion occurs, the readings in the stack are averaged to yield a single filtered reading. The stack type is first-in, first-out. After the stack fills, the newest reading conversion replaces the oldest. Note that the instrument does not wait for the stack to fill before releasing readings.

Repeating Filter — Takes a selected number of reading conversions, averages them, and yields a reading. It then flushes its stack and starts over.

Filter control

Model 6485 front panel control

The median filter is turned on or off with the MEDN key. To configure the median filter, press CONFIG then MEDN, then select the desired rank (1-5) with the RANGE keys.

The average filter is enabled or disabled with the AVG key. To control average filter parameters, press CONFIG then AVG, then select COUNT (2-100), and MOVING or REPEAT.

Model 6487 front panel control

Both the median and average filters are controlled by pressing CONFIG then FILT. Select MEDIAN or AVERAGE, then set appropriate parameters. For the MEDIAN selection, you can choose ON or OFF and set the RANK (1-5). For the AVERAGE filter, you can choose ON or OFF, COUNT (2-100), MOVING or REPEAT.

Once the filter is configured, you can toggle the filter state on or off by pressing FILT. The FILT annunciator will show when the filter is on.

SCPI commands — filters

Table 4-3
SCPI commands — filters

Commands	Description
MED <b>	Enable (ON) or disable (OFF) median filter.
MED:RANK <n>	Specify median filter rank: 1 to 5.
AVER <b>	Enable (ON) or disable (OFF) digital filter.
AVER:TCON <name>	Select filter control: MOVing or REPeat.
AVER:COUNt <n>	Specify filter count: 2 to 100.

Programming example

The following command sequence configures and enables both filters:

```
' Median Filter:
MED:RANK 5                ' Set rank to 5.
MED ON                    ' Enable median filter.

' Digital Filter:
AVER:COUN 20              ' Set filter count to 20.
AVER:TCON MOV             ' Select moving filter.
AVER ON                   ' Enable digital filter.
```

5 Relative, mX+b, m/X+b (reciprocal), and log

- **Relative** — Explains how to null an offset or establish a baseline value. Includes the SCPI commands for remote operation.
- **mX+b, m/X+b (reciprocal), and Logarithmic** — Covers these three basic math operations and includes the SCPI commands for remote operation.

Relative

Relative (Rel) nulls an offset or subtracts a baseline reading from present and future readings. When a Rel value is established, subsequent readings will be the difference between the actual input and the Rel value.

Displayed (Rel'ed) Reading = Actual Input - Rel Value

A Rel value is the same for all measurement ranges. For example, a Rel value of 1E-6 is 1µA on the 2µA range. It is also 1µA on the 20µA range and the 200µA range. Note changing ranges does not disable Rel.

Front panel relative

From the front panel, there are two ways to set the Rel value. You can either use the input reading as the Rel value or you can manually key in the Rel value.

To use the present reading, disable zero check, display the reading, then press REL. The REL annunciator will turn on and subsequent readings will be the difference between the actual input and the Rel value. To disable relative, press REL again (for the Model 6487, while zero check is disabled). To enter a reading, press CONFIG then REL, enter the desired value, then press ENTER. Relative will be enabled after you enter the value.

NOTE *For the Model 6487, separate Rel values are stored for the amps and ohms functions.*

SCPI programming — relative

Table 5-1
SCPI commands — relative (null)

Commands	Description
CALC2:FEED <name>	Specify reading to Rel: SENS or CALC1.
CALC2:NULL:ACQ	Use input signal as Rel value.
CALC2:NULL:OFFS <Rel>	Specify Rel value: -9.999999e20 to 9.999999e20.
CALC2:NULL:STAT <b>	Enable (ON) or disable (OFF) Rel.
CALC2:DATA?	Return Rel'ed readings triggered by INIT.
CALC2:DATA:LAT?	Return only the latest Rel'ed reading.
INIT	Trigger one or more readings.

Programming example — relative

This program fragment establishes a 1µA baseline for measurements:

```
CALC2:NULL:OFFS 1e-6      ' Set Rel value of 1µA.
CALC2:NULL:STAT ON        ' Enable Rel.
SYST:ZCH OFF              ' Turn off zero check.
INIT                      ' Trigger reading.
CALC2:DATA?               ' Request Rel'ed reading.
```

mX+b, m/X+b (reciprocal), and Logarithmic

mX+b and m/X+b

The following math operations manipulate normal display readings (X) mathematically according to the following calculations:

$Y = mX+b$

$Y = m/X+b$

where: X is the normal display reading.
m and b are user-entered constants for scale factor and offset.
Y is the displayed result.

NOTE *Changing the "m" or "b" for mX+b also changes it for m/X+b.*

Logarithmic

This calculation converts input readings to logarithm base 10 values. The calculation is performed as follows:

$$\log_{10} X = Y$$

where: X is the input reading.
Y is the logarithmic result.

For example: Assume that exactly 1mA is being measured by the Model 6485/6487.

$$\log_{10} 1.000000\,\text{mA} = -3$$

NOTE *This calculation uses the absolute value of the normal input reading as the log of a negative number cannot be computed.*

Configuring math functions

Model 6485

To select and configure math functions from the Model 6485 front panel, press either the MX+B or M/X+B key, then enter the required m, b, and units parameters. Use MX+B or M/X+B to toggle math on or off. The MATH annunciator will turn on to indicate that the math function is enabled.

Model 6487

To select and configure math functions from the Model 6487 front panel, press CONFIG then MATH. Select the math function to configure, then enter the required parameters for mX + b and m/X + b (m, b, and units). Once a math function is selected, simply press the MATH key to toggle math on or off. The MATH annunciator will turn on to indicate that the math function is enabled.

SCPI programming — mX+b, m/X+b, and log

Table 5-2
SCPI commands — mX+b, m/X+b, and log

Commands	Description
CALC:FORM <name>	Select math function: MXB, REC, or LOG10.
CALC:KMAT:MMF <n>	Set M for mX+b and m/X+b: -9.99999e20 to 9.99999e20.
CALC:KMAT:MBF <n>	Set B for mX+b and m/X+b: -9.99999e20 to 9.99999e20.
CALC:KMAT:MUN <name>	Set units for mX+b or m/x+b: 1 character: A–Z, '['=Ω, '\'=°, ']'=%.
CALC:STAT <b>	Enable or disable the selected math function.
CALC:DATA?	Returns all CALC results triggered by the INIT.
CALC:DATA:LAT?	Returns only the latest CALC reading.

Programming example — mX+b

This command sequence performs a single mX+b calculation and returns the result:

```
*RST                    'Restore RST defaults.
CALC:FORM MXB           'Select mX+b calculation.
CALC:KMAT:MMF 2e-3      'Set scale factor (M) to 2e-3.
CALC:KMAT:MBF 5e-4      'Set offset (B) to 5e-4.
CALC:STAT ON            'Enable calculation.
SYST:ZCH OFF            'Disable zero check.
INIT                    'Perform one measurement and
                        'calculate mX+b.
CALC:DATA?              'Request mX+b result.
```

6 Buffer and Sweeps

- **Buffer operations** — Explains how to store and recall readings including buffer statistics.
- **Model 6487 voltage sweeps** — Discusses how to generate sweeps using the voltage source.

Buffer operations

The Model 6485 has a buffer to store from one to 2,500 readings. The Model 6487 buffer can store from one to 3,000 readings. Both instruments also store overflow readings and a timestamp, and each Model 6487 reading includes the voltage source value. The timestamp for each reading is referenced to the time the measure/store process is started. In addition, recalled data includes statistical information (maximum, minimum, peak-to-peak, average and standard deviation).

The buffer fills with the specified number of readings and stops. Readings are placed in the buffer after any filters and/or math operations have been performed. Math operations include relative, mX+b, m/X+b, LOG, or limits (see Section 5).

Buffered data is overwritten each time the storage operation is selected. The data is volatile — it is not saved through a power cycle.

Measurement function changes are permissible during the storage process. Note however, that the statistics will be based on the readings of the different measurement functions.

Store

To store readings, set up the instrument for the desired configuration, then press CONFIG followed by STORE. Set the number of readings to store (1-2500, Model 6485; 1-3000, Model 6487), and press ENTER. Press the STORE key to start data storage. The asterisk (*) annunciator turns on to indicate that the data storage operation is active. To abort storage while active, press EXIT.

Recall

To view stored readings and buffer statistics, press RECALL, then use the RANGE and cursor keys to navigate through the reading numbers and buffer statistics, reading values, voltage source values (Model 6487 only), and timestamps. (Use the RANGE keys to scroll through statistics and reading values; use the cursor keys to select among readings, Model 6487 voltage source values, and timestamps.) The BUFFER annunciator will be on while readings are being recalled. Press EXIT to return to normal display.

NOTE *For the Model 6487, if the voltage source was in compliance when the reading was acquired, the recalled front panel SRC: display will show the voltage value dimmed. Over the GPIB, a value of -999 returned for the voltage source element indicates that the source was in compliance.*

Buffer timestamp

To change the buffer timestamp format, press MENU, select TSTAMP, then press ENTER. Select the desired option: ABS (absolute) or DELT (delta). For ABS, each timestamp is referenced to the first reading stored in the buffer. The first reading always has a timestamp of 0000000.0000. With DELT, each timestamp provides the time between the readings.

Clear

To clear the Model 6487 buffer, press CONFIG followed by STORE, then set the reading count to 0 (pressing AUTO will clear the display quickly). Press ENTER with a reading count of 0 displayed to finish clearing the buffer.

Buffer statistics

- MIN and MAX provides the minimum and maximum readings stored in the buffer. It also indicates the buffer location of these readings.
- The **PK-PK (peak-to-peak)** value is the difference between the maximum and minimum readings stored in the buffer:

  PK-PK = MAX - MIN
- Average is the mean of the buffer readings. Mean is calculated as follows:

$$y = \sum_{i=1}^{n} \frac{X_i}{n}$$

Where: X_i is a stored reading.
n is the number of stored readings.

- The STD DEV value is the standard deviation of the buffered readings. Standard deviation is calculated as follows:

$$y = \sqrt{\frac{\sum_{i=1}^{n} (Avg - X_i)^2}{n - 1}}$$

Where: X_i is a stored reading.
n is the number of stored readings.
Avg is the mean of the buffer readings.

NOTE *If any readings stored in the buffer are the result of an overflow or Model 6487 overvoltage condition, the buffer statistics calculation will not be performed. Buffer recall via front panel operation will show a series of dashes in place of the requested buffer statistics value. In remote operation, the corresponding buffer statistics will be represented by the value +9.91e37.*

SCPI programming — buffer

Table 6-1
SCPI commands — buffer

Commands	Description
TRAC:CLE	Clear readings from buffer.
TRAC:FREE?	Query bytes available and bytes in use.
TRAC:POIN <n>	Specify number of readings to store: 1 to 2500, Model 6485; 1 to 3000, Model 6487.
TRAC:POIN:ACT?	Returns number of readings actually stored in buffer.
TRAC:FEED <name>	Select source of readings for buffer: SENS, CALC1, or CALC2.
TRAC:FEED:CONT <name>	Select buffer control mode: NEV or NEXT.
TRAC:TST:FORM <name>	Select timestamp format: ABS or DELT.
TRAC:DATA?	Read all readings in buffer.
FORM:ELEM <list>	Specify data elements for TRAC:DATA? response message: READ, UNIT, VSO, TIME, and STAT (VSO, 6487 only).
CALC3:FORM <name>	Select buffer statistic: MIN, MAX, MEAN, SDEV, or PKPK.
CALC3:DATA?	Read the selected buffer statistic.

Programming example

The following command sequence stores 20 readings into the buffer and then calculates the mean average on the buffer readings:

```
' Select data elements:
*RST                          ' Return 6485/6487 to RST defaults.
FORM:ELEM READ,TIME           ' Select reading and timestamp.

' Store and Recall Readings:
TRIG:COUN 20                  ' Set trigger model to take to 20
                                readings.
TRAC:POIN 20                  ' Set buffer size to 20.
TRAC:FEED SENS                ' Store raw input readings.
TRAC:FEED:CONT NEXT           ' Start storing readings.
SYST:ZCH OFF                  ' Turn off zero check.
INIT                          ' Trigger readings.
TRAC:DATA?                    ' Request all stored readings.

' Acquire Mean Statistic for Buffer Readings:
CALC3:FORM MEAN               ' Select mean statistic.
CALC3:DATA?                   ' Request mean statistic.
```

Model 6487 voltage sweeps

The Model 6487 voltage source can be used to generate voltage sweeps from a start voltage to a stop voltage at discrete step voltages. The Model 6487 stores readings in the buffer for later recall, one set of readings per voltage step.

Front panel sweeps

To generate sweeps from the front panel, press CONFIG then OPER, select SWEEP, then press ENTER. At the prompts, enter the start, stop, and step voltages, and the delay time (time between each voltage step and measurement). Note that sweeps can be positive-going or negative-going by programming the start and stop voltages accordingly, but the programmed step voltage is always positive. The SCAN annunciator will turn on to indicate that the sweep is armed.

To start a sweep, press the TRIG key. The sweep will be performed and readings will be stored in the buffer for later recall (see "Recall," page 6-2). To abort a sweep in progress, press the EXIT key.

SCPI programming — sweeps

NOTE *When programming sweeps via remote, the arm count may have to be reset to initiate after *RST. See Section 7 of the Model 6487 Reference Manual for details on triggering.*

Table 6-2
SCPI commands — sweeps

Commands	Description
SOUR:VOLT:SWE:STAR <Volts>	Program start voltage: -505V to 505V.
SOUR:VOLT:SWE:STOP <Volts>	Program stop voltage: -505V to 505V.
SOUR:VOLT:SWE:STEP <Volts>	Program step voltage: -505V to 505V.
SOUR:VOLT:SWE:CENT <Volts>	Program center voltage: -505V to 505V.*
SOUR:VOLT:SWE:SPAN <Volts>	Program span voltage: 0V to 1010V.*
SOUR:VOLT:SWE:DEL <Delay>	Set delay between voltage step and measurement: 0 to 999.9999s.
SOUR:VOLT:SWE:INIT	Arm sweep, put source in operate.
SOUR:VOLT:SWE:ABOR	Abort sweep, put source in standby.
SOUR:VOLT:SWE:STAT?	Query if sweep still running: 1 = sweep in progress.
INIT	Trigger sweep.

* CENTer and SPAN are alternate methods of setting sweep parameters. They are coupled with STARt and STOP commands.

Programming example

The following command sequence performs a sweep from 1V to 10V in 1V increments:

```
*RST                        ' Return 6487 to RST defaults.
SOUR:VOLT:SWE:STAR 1        ' Start voltage = 1V.
SOUR:VOLT:SWE:STOP 10       ' Stop voltage = 10V.
SOUR:VOLT:SWE:STEP 1        ' Step voltage = 1V.
SOUR:VOLT:SWE:DEL 0.1       ' 0.1s delay.
ARM:COUN 10                 ' Reset arm count.
FORM:ELEM READ,VSO          ' Select reading, voltage source data.
SOUR:VOLT:SWE:INIT          ' Arm sweep, put source in operate.
SYST:ZCH OFF                ' Turn off zero check.
INIT                        ' Trigger sweep.
TRAC:DATA?                  ' Request all stored readings.
```

7 Remote Operation and Commands

- **Selecting and configuring an interface** — Explains how to select and configure an interface: GPIB or RS-232.
- **Remote commands** — Lists the following types of bus commands: general bus commands, common commands, signal oriented commands, and SCPI command subsystems.

Selecting and configuring an interface

Interfaces

The Model 6485/6487 supports two built-in remote interfaces: GPIB interface and RS-232 interface. You can use only one interface at a time. At the factory, the GPIB is selected. To select the interface, press COMM, select RS 232 or GPIB, then press ENTER. The Model 6485/6487 will reset with the new interface selected.

GPIB interface

To configure the GPIB (IEEE-488) interface, press CONFIG then COMM when the GPIB interface is selected, then select the primary address (0-30; Model 6485 default 14; Model 6487 default 22) and language (SCPI, DDC, or 488.1). The primary address must be the same as that specified in the computer program, but be sure to avoid address conflicts. Use the SCPI language setting for most applications. See the Model 6485 Instruction Manual or Model 6487 Reference Manual for information on the DCC and 488.1 programming languages.

NOTE *DDC timing is not guranteed to match the timing of the original instrument (487) being emulated. Additionally, SLOW is not available in DDC mode. If you experince a lockout on the front panel it is intentional to prevent you from entering a NPLC rate that is not supported in DDC mode.*

RS-232 interface

To configure the RS-232 interface, press CONFIG then COMM when the RS-232 interface is selected, then set baud rate, data bits, parity, terminator, and flow control. To assure proper operation, be sure that interface parameters are the same as those used by the controlling computer.

Connections

GPIB connections

With the power off, connect a shielded GPIB cable (Keithley Model 7007) between the rear panel IEEE-488 connection (Figure 7-1 or Figure 7-2) and the computer bus connector.

RS-232 connections

With the power off, connect the Model 6485/6487 RS-232 connector (Figure 7-1 or Figure 7-2) to the computer serial port using a straight through shielded RS-232 cable terminated with DB-9 connectors (Keithley Model 7009). Do not use a null modem cable.

Figure 7-1
Model 6485 IEEE-488 and RS-232 connector locations

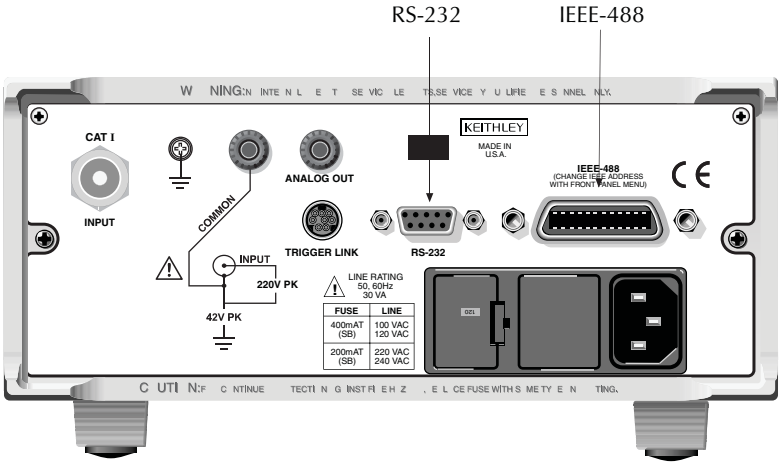
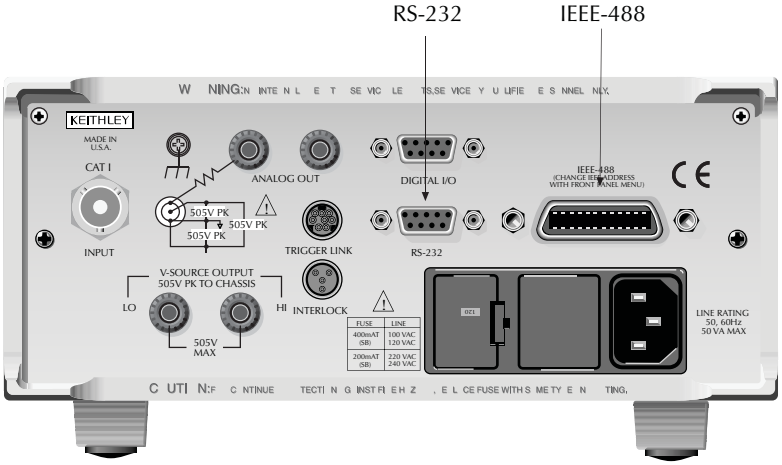


Figure 7-2
Model 6487 IEEE-488 and RS-232 connector locations



Front panel GPIB operation

Error and status messages

See Appendix B in the Model 6485 Instruction Manual or Model 6487 Reference Manual for a list of error and status messages associated with IEEE-488 programming.

GPIB status indicators

REM shows when the instrument is in the remote state, TALK is on when the instrument is in the talker active state, and LSTN is on when the Model 6485/6487 is in the listener active state. SRQ shows when the instrument has generated a service request.

LOCAL key

The LOCAL key cancels the remote state and restores local operation of the instrument. Pressing the LOCAL key also turns off the REM indicator and returns the display to normal if a user-defined message was displayed. If the unit is in LOCAL (not in remote), the LOCAL key acts as a configure key (see "Model 6485 front panel summary," page 1-8 or "Model 6487 front panel summary," page 1-13.)

If the LLO (Local Lockout) command is in effect, the LOCAL key is also inoperative.

Remote commands

General bus commands

General bus commands are listed in Table 7-1. These commands are not available for the RS-232 interface.

Table 7-1
General bus commands

Command	Effect on Model 6485/6487
REN	Goes into remote when next addressed to listen.
IFC	Reset interface; all devices go into talker and listener idle states.
LLO	LOCAL key locked out.
GTL	Cancel remote; restore front panel operation for Model 6485/6487.
DCL	Returns all devices to known conditions.
SDC	Returns Model 6485/6487 to known conditions.
GET	Initiates a trigger.
SPE, SPD	Serial polls Model 6485/6487.

Common commands

Common commands are summarized in Table 7-2.

Table 7-2
IEEE-488.2 common commands and queries

Mnemonic	Name	Description
*CLS	Clear status	Clears all event registers and error queues.
*ESE <NRf>	Event enable command	Program the standard event enable register.
*ESE?	Event enable query	Read the standard event enable register.
*ESR?	Event status register query	Read the standard event enable register and clear it.
*IDN?	Identification query	Returns the manufacturer, model number, serial number, and firmware revision levels of the unit.
*OPC	Operation complete command	Set the operation complete bit in the standard event register after all pending commands have been executed.
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.
*OPT?	Option query	Returns model number of any installed options.
*RCL <NRf>	Recall command	Returns Model 6485/6487 to the user-saved setup.
*RST	Reset command	Returns Model 6485/6487 to the *RST default conditions.
*SAV <NRf>	Save command	Saves the present setup as the user-saved setup.
*SRE <NRf>	Service request enable command	Programs the service request enable register.
*SRE?	Service request enable query	Reads the service request enable register.
*STB?	Status byte query	Reads the status byte register.
*TRG	Trigger command	Sends a bus trigger to Model 6485/6487.
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.
*WAI	Wait-to-continue command	Wait until all previous commands are executed.

Signal oriented commands.

Signal oriented commands used to make basic measurements are shown in Table 7-3.

Table 7-3
Signal oriented commands

Command	Description
CONFigure[:<function>]	Places Model 6485/6487 in a "one-shot" measurement mode. <function> = CURR[:DC]
CONFigure?	Queries the selected function. Returns 'CURR'.
FETCh?	Requests the latest reading(s).
READ?	Performs an INITiate and a :FETCh?.
MEASure[:<function>]?	Performs a CONFigure:<function> and a :READ?.

SCPI command subsystems

Table 7-4 summarizes the various SCPI subsystems used to program most Model 6485/ 6487 operations. Detailed lists of commands associated with these subsystems are located in Section 14 of the Model 6485 Instruction Manual or Model 6487 Reference Manual.

Table 7-4
SCPI command subsystems

Subsystem	Function(s)
CALCulate[1]	Math functions.
CALCulate2	Limit tests, relative.
CALCulate3	Buffer statistics.
CALibration	Instrument calibration.
DISPlay	Display digits and text messages.
FORMat	Format of returned remote data.
SENSe[1]	Current measurements and associated modes.
SOURce[1]	Model 6487 voltage source operation.
SOURce2	Model 6487 Digital I/O port.
STATus	Instrument status.
SYSTem	Zero check, correct, line frequency, error messages.
TRACe	Buffer operation and data.
TRIGger	Instrument triggering.

Programming syntax

The following paragraphs cover syntax for both common commands and SCPI commands. For more information, see the IEEE-488.2 and SCPI standards.

Command words

Program messages are made up of one or more command words. Common commands and SCPI commands may or may not use a parameter. There must be at least one space between the command word and its parameter. Some command words are enclosed in brackets ([ ]). These brackets are used to denote an optional command word that does not need to be included in the program message.

Common commands and SCPI commands are not case sensitive. You can use upper or lower case and any case combination. A SCPI command word can be sent in its long-form or short-form version. The command tables in this manual use the short-form version. You can send multiple command messages in the same program message as long as they are separated by semicolons (;).

The query command requests the presently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form.

Each program message must be terminated with an LF (line feed), EOI (end or identify), or an LF+EOI. Each response is terminated with an LF (line feed) and EOI (end or identify).

Parameter types

The following are some of the common parameter types:

<b>	Boolean — Used to enable or disable an instrument operation. 0 or OFF disables the operation and 1 or ON enables the operation.
<name>	Name parameter — Select a parameter name from a listed group.
<NRf>	Numeric representation format — A number that can be expressed as an integer (e.g., 8), a real number (e.g., 23.6), or an exponent (2.3E6).
<NDN>	Non-decimal numeric — A non-decimal value that can be used to program status enable registers. A unique header identifies the format: #B (binary), #H (hexadecimal), and #Q (octal).
<n>	Numeric value — Can consist of an NRf number or one of the following name parameters: DEFault, MINimum, or MAXimum. When the DEFault parameter is used, the instrument is programmed to the *RST default value. When the MINimum parameter is used, the instrument is programmed to the lowest allowable value. When the MAXimum parameter is used, the instrument is programmed to the largest allowable value.

Angle brackets < > — Used to denote a parameter type. Do not include the brackets in the program message.

A Specifications

6485 Picoammeter Specifications

RANGE	5½ DIGIT DEFAULT RESOLUTION	ACCURACY (1YR) [1] ±(% RDG. + OFFSET) 18°–28°C, 0–70% RH	TYPICAL RMS NOISE [2]	ANALOG RISE TIME [3] (10% to 90%)
2 nA	10 fA	0.4 % + 400 fA	20 fA	8 ms
20 nA	100 fA	0.4 % + 1 pA	100 fA	8 ms
200 nA	1 pA	0.2 % + 10 pA	1 pA	500 µs
2 µA	10 pA	0.15% + 100 pA	10 pA	500 µs
20 µA	100 pA	0.1 % + 1 nA	100 pA	500 µs
200 µA	1 nA	0.1 % + 10 nA	1 nA	500 µs
2 mA	10 nA	0.1 % + 100 nA	10 nA	500 µs
20 mA	100 nA	0.1 % + 1 µA	100 nA	500 µs

TEMPERATURE COEFFICIENT: 0°–18°C & 28°–50°C. For each °C, add 0.1 × (% rdg + offset) to accuracy spec.

INPUT VOLTAGE BURDEN: <200µV on all ranges except <1mV on 20mA range.

MAXIMUM INPUT CAPACITANCE: Stable to 10nF on all nA ranges and 2µA range; 1µF on 20µA and 200µA ranges, and on mA ranges.

MAXIMUM CONTINUOUS INPUT VOLTAGE: 220VDC

NMRR[1]: (50 or 60Hz) :60dB

MAXIMUM COMMON MODE VOLTAGE: 42V.

ISOLATION (Meter COMMON to chassis): Typically $>5\times10^{11}\Omega$ in parallel with <1nF.

ANALOG OUTPUT: Scaled voltage output (inverting 2V full scale on all ranges) 3% ±2mV, 1kΩ impedance.

[1] At 1 PLC – limited to 60 rdgs/sec under this condition.

[2] At 6 PLC, 1 standard deviation, 100 readings, filter off, capped input – limited to 10 rdgs/sec under this condition.

[3] Measured at analog output with resistive load >100kΩ.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

IMPLEMENTATION: SCPI (IEEE-488.2, SCPI-1996.0); DDC (IEEE-488.1).

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Zero Check, Zero Correct, EOI (DDC mode only), Trigger, Terminator (DDC mode only), Calibration (SCPI mode only), Display Format, SRQ, REL, Output Format, V-offset Cal.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

LANGUAGE EMULATION: Keithley Model 485 emulation via DDC mode.

RS-232 IMPLEMENTATION:
Supports: SCPI 1996.0.
Baud Rates: 300, 600, 1200, 2400, 4800, 9600, 19.2k, 38.4k, 57.6k.
Protocols: Xon/Xoff, 7 or 8 bit ASCII, parity-odd/even/none.
Connector: DB-9 TXD/RXD/GND.

GENERAL

INPUT CONNECTOR: BNC on rear panel.

DISPLAY: 12 character vacuum fluorescent.

RANGING: Automatic or manual.

OVERRANGE INDICATION: Display reads "OVRFLOW".

CONVERSION TIME: Selectable 0.01 PLC to 60 PLC (50PLC under 50Hz operation). (Adjustable from 200µs to 1s)

READING RATE:
To internal buffer 1000 readings/second[1]
To IEEE-488 bus 900 readings/second[1, 2]

Notes:
[1] 0.01 PLC, digital filters off, front panel off, auto zero off.
[2] Binary transfer mode. IEEE-488.1.

BUFFER: Stores up to 2500 readings.

PROGRAMS: Provide front panel access to IEEE address, choice of engineering units or scientific notation, and digital calibration.

EMC: Conforms with European Union Directive 89/336/EEC, EN61326-1.

SAFETY: Conforms with European Union Directive 73/23/EEC, EN61010-1.

TRIGGER LINE: Available, see manual for usage.

DIGITAL FILTER: Median and averaging (selectable from 2 to 100 readings).

ENVIRONMENT:
Operating: 0°–50°C; relative humidity 70% non-condensing, up to 35°C. Above 35°C, derate humidity by 3% for each °C.
Storage: –25° to +65°C.

WARM-UP: 1 hour to rated accuracy (see manual for recommended procedure).

POWER: 100–120V or 220–240V, 50–60Hz, 30VA.

PHYSICAL:
Case Dimensions: 90mm high × 214mm wide × 369mm deep (3½ in. × 8⅜ in. × 14⁹⁄₁₆ in.).
Working Dimensions: From front of case to rear including power cord and IEEE-488 connector: 394mm (15.5 inches).
Net Weight: <2.8 kg (<6.1 lbs).
Shipping Weight: <5 kg (<11 lbs).

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6487 Picoammeter Specifications

RANGE	5½ DIGIT DEFAULT RESOLUTION	ACCURACY (1YR) [1] ±(% RDG. + OFFSET) 18°–28°C, 0–70% RH	TYPICAL RMS NOISE [2]	TYPICAL ANALOG RISE TIME (10% TO 90%)[3] DAMPING[4] OFF	ON
2 nA	10 fA	0.3 % + 400 fA	20 fA	4 ms	80 ms
20 nA	100 fA	0.2 % + 1 pA	20 fA	4 ms	80 ms
200 nA	1 pA	0.15 % + 10 pA	1 pA	300 µs	1 ms
2 µA	10 pA	0.15% + 100 pA	1 pA	300 µs	1 ms
20 µA	100 pA	0.1 % + 1 nA	100 pA	110 µs	110 µs
200 µA	1 nA	0.1 % + 10 nA	100 pA	110 µs	110 µs
2 mA	10 nA	0.1 % + 100 nA	10 nA	110 µs	110 µs
20 mA	100 nA	0.1 % + 1 µA	10 nA	110 µs	110 µs

TEMPERATURE COEFFICIENT: 0°–18°C & 28°–50°C. For each °C, add 0.1 × (% rdg + offset) to accuracy spec.

INPUT VOLTAGE BURDEN: <200µV on all ranges except <1mV on 20mA range.

MAXIMUM INPUT CAPACITANCE: Stable to 10nF on all nA ranges and 2µA range; 1µF on 20µA and 200µA ranges, and on mA ranges.

MAXIMUM CONTINUOUS INPUT VOLTAGE: 505 VDC

NMRR[1]: (50 or 60Hz) :60dB

ISOLATION (Ammeter Common or Voltage Source to chassis): Typically >1×10^{11}Ω in parallel with <1nF.

MAXIMUM COMMON MODE VOLTAGE (Between Chassis and Voltage Source or Ammeter): 505 VDC.

MAXIMUM VOLTAGE BETWEEN VOLTAGE SOURCE AND AMMETER: 505 VDC

ANALOG OUTPUT: Scaled voltage output (inverting 2V full scale on all ranges) 2.5% ±2mV

ANALOG OUTPUT IMPEDANCE[3]: <100Ω, DC-2kHz.

VOLTAGE SOURCE

Range (Max)	Step Size (typical)	Accuracy[5] ±(% PROG. + OFFSET) 18°C - 28°C, 0 - 70% R.H.	Noise (p-p) 0.1 - 10 Hz	Temperature Coefficient	Typical Rise Time [6,8] (10%-90%)	Typical Fall Time [7,8] (90%-10%)
±10.100	200µV	0.1% + 1mV	<50µV	(0.005% + 20µV) / °C	250 µs	150 µs
±50.500	1mV	0.1% + 4mV	<150µV	(0.005% + 200µV) / °C	250 µs	300 µs
±505.00	10mV	0.15% + 40mV	<1.5mV	(0.008% + 2mV) / °C	4.5 ms	1 ms

SELECTABLE CURRENT LIMIT: 2.5mA, 250µA, 25µA for 50V and 500V ranges, 25mA additional limit for 10V range. All current limits are -20%/+35% of nominal.

WIDEBAND NOISE[9]: <30mVp-p 0.1Hz - 20MHz.

TYPICAL TIME STABILITY: ±(0.003% + 1mV) over 24 hours at constant temperature (within 1°C, between 18°C - 28°C, after 5 minute settling).

OUTPUT RESISTANCE: <2.5Ω.

VOLTAGE SWEEPS: Supports linear voltage sweeps on fixed source range, one current or resistance measurement per step. Maximum sweep rate: 200 steps per second. Maximum step count 3000. Optional delay between step and measure.

RESISTANCE MEASUREMENT (V/I): Used with voltage source; resistance calculated from voltage setting and measured current. Accuracy is based on voltage source accuracy plus ammeter accuracy. Typical accuracy better than 0.6% for readings between 1kΩ and 1TΩ.

ALTERNATING VOLTAGE RESISTANCE MEASUREMENT: Offers alternating voltage resistance measurements for resistances from 10^{9}Ω to 10^{15}Ω. Alternates between 0V and user-selectable voltage up to ±505V.

[1] At 1 PLC – limited to 60 rdgs/sec under this condition.

[2] At 6 PLC, 1 standard deviation, 100 readings, filter off, capped input – limited to 10 rdgs/sec under this condition.

[3] Measured at analog output with resistive load >2kΩ.

[4] Maximum rise time can be up to 25% greater.

[5] Accuracy does not include output resistance/load regulation.

[6] Rise Time is from 0V to ± full-scale voltage (increasing magnitude).

[7] Fall Time is from ± full-scale voltage to 0V (decreasing magnitude).

[8] For capacitive loads, add C*ΔV/I_{Limit} to Rise Time, and C*ΔV/1mA to Fall Time.

[9] Measured with LO connected to chassis ground.

REMOTE OPERATION

IEEE-488 BUS IMPLEMENTATION: SCPI (IEEE-488.2, SCPI-1996.0); DDC (IEEE-488.1).

LANGUAGE EMULATION: Keithley Model 486/487 emulation via DDC mode.

RS-232 IMPLEMENTATION:
Supports: SCPI 1996.0.
Baud Rates: 300, 600, 1200, 2400, 4800, 9600, 19.2k, 38.4k, 57.6k.
Protocols: Xon/Xoff, 7 or 8 bit ASCII, parity-odd/even/none.
Connector: DB-9 TXD/RXD/GND.

GENERAL

AMMETER INPUT CONNECTOR: Three lug triaxial on rear panel.

ANALOG OUTPUT CONNECTOR: Two banana jacks on rear panel.

VOLTAGE SOURCE OUTPUT CONNECTOR: Two banana jacks on rear panel.

INTERLOCK CONNECTOR: 4 pin DIN.

TRIGGER LINE: Available, see manual for usage.

DISPLAY: 12 character vacuum fluorescent.

DIGITAL FILTER: Median and averaging (selectable from 2 to 100 readings).

RANGING: Automatic or manual.

AUTORANGING TIME[3]: <250ms (analog filter off, 1PLC)

OVERRANGE INDICATION: Display reads "OVRFLOW".

CONVERSION TIME: Selectable 0.01 PLC to 60 PLC (50PLC under 50Hz operation). (Adjustable from 200µs to 1s)

READING RATE:
To internal buffer 1000 readings/second[1]
To IEEE-488 bus 900 readings/second[1, 2]

BUFFER: Stores up to 3000 readings.

PROGRAMS: Provide front panel access to IEEE address, choice of engineering units or scientific notation, and digital calibration.

EMC: Conforms with European Union Directive 89/336/EEC, EN61326-1.

SAFETY: Conforms with European Union Directive 73/23/EEC, EN61010-1, CAT I.

ENVIRONMENT:
Operating: 0°–50°C; relative humidity 70% non-condensing, up to 35°C. Above 35°C, derate humidity by 3% for each °C.
Storage: –10°C to +65°C.

WARM-UP: 1 hour to rated accuracy (see manual for recommended procedure).

POWER: 100–120V or 220–240V, 50–60Hz, (50VA).

PHYSICAL:

Case Dimensions: 90mm high × 214mm wide × 369mm deep (3½ in. × 8⅜ in. × 14^{9}⁄$_{16}$ in.).

Working Dimensions: From front of case to rear including power cord and IEEE-488 connector: 394mm (15.5 inches).

NET WEIGHT: <4.7 kg (<10.3 lbs).

Notes:
[1] 0.01 PLC, digital filters off, front panel off, auto zero off.
[2] Binary transfer mode. IEEE-488.1.
[3] Measured from trigger in to meter complete.

Specifications are subject to change without notice.

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B General Measurement Considerations

- **Measurement considerations —** lists and defines nine types of measurement considerations.

Measurement considerations

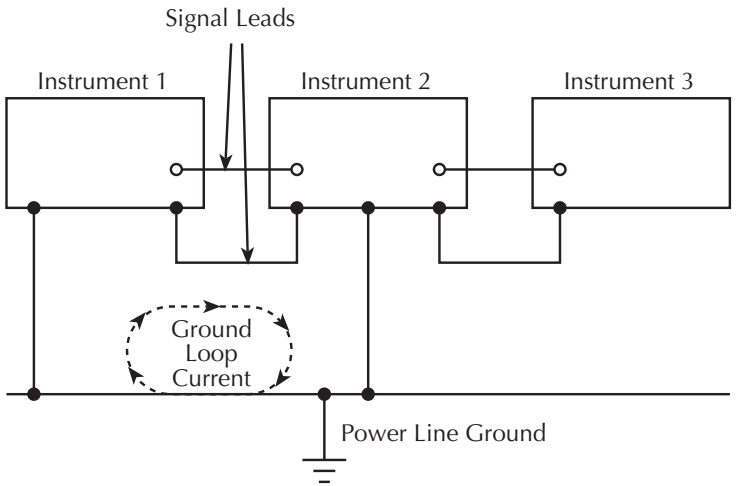
The following measurement considerations apply to all precision measurements. Table 2-1 lists all measurement considerations and indicates where to find detailed information on them.

For additional measurement considerations, see Appendix C of the Model 6485 Instruction Manual or Appendix G of the Model 6487 Reference Manual. For comprehensive information on all measurement considerations, refer to the Low Level Measurements handbook, which is available from Keithley.

Ground loops

Ground loops that occur in multiple-instrument test setups can create error signals that cause erratic or erroneous measurements. The configuration shown in Figure B-1 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances, either in the wires or at the connecting points. This small resistance results in voltage drops that can affect the measurement. Even if the ground loop currents are small, magnetic flux cutting across the large loops formed by the ground leads can induce sufficient voltages to disturb sensitive measurements.

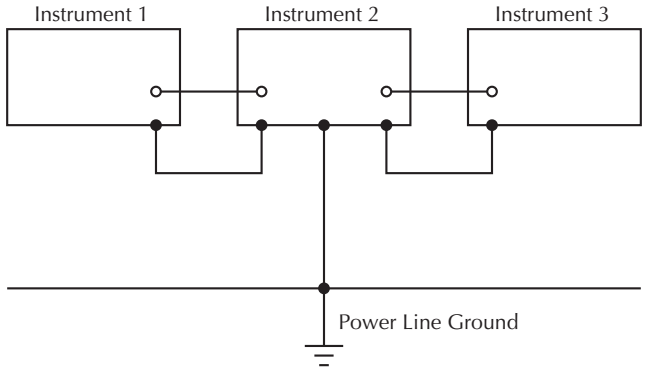
Figure B-1
Power line ground loops



To prevent ground loops, instruments should be connected to ground at only a single point as shown in Figure B-2. Note that only a single instrument is connected directly to power line ground. Experimentation is the best way to determine an acceptable arrangement. For

this purpose, measuring instruments should be placed on their lowest ranges. The configuration that results in the lowest noise signal is the one that should be used. A convenient way to make this connection uses the ground link at the rear of the Model 6485/6487.

Figure B-2
Eliminating ground loops



Triboelectric effects

Triboelectric currents are generated by charges created between a conductor and an insulator due to friction. Here, free electrons rub off the conductor and create a charge imbalance that causes the current flow. For example, bending a triaxial cable causes friction between the center conductor (HI) and its surrounding insulator resulting in triboelectric currents. Triboelectric currents can be minimized as follows:

- Use "low noise" cables. These cables are specially designed to minimize charge generation and use graphite to reduce friction. Use Keithley Models 4801, 4802, and 4803 coax cables for the Model 6485; and Models 237 and 7078 triax cables for the Model 6487 are low noise.
- Use the shortest cables possible and secure them (i.e., taping or tying) to a non-vibrating surface to keep them from moving.

Piezoelectric and stored charge effects

Piezoelectric currents are generated when mechanical stress is applied to certain insulating materials (i.e., crystalline). In some plastics, pockets of stored charge cause the material to behave in a similar manner.

When building test fixtures, choose good insulating materials and make connecting structures as rigid as possible. Make sure there are no mechanical stresses on the insulators.

Electrochemical effects

Error currents also arise from electrochemical effects when ionic chemicals create weak batteries on a circuit board. These batteries could generate a few nanoamps of current between conductors. Ionic contamination may be the result of body oils, salts, or solder flux. The problem is further enhanced by high humidity (moisture) that decreases insulation resistance.

When building test fixtures, select insulators that resist water absorption and use the fixture in a moderate humidity environment. Also, be sure that all insulators are kept clean and free of contamination.

Humidity

Excess humidity can reduce insulation resistance on PC boards and in test connection insulators. Reduction in insulation resistance can, of course, seriously affect high-impedance measurements. Also, humidity (moisture) can combine with contaminants to produce offset currents caused by electrochemical effects. To minimize the effects of moisture, keep humidity to a minimum (ideally <50%) and keep components and connectors in the test system clean.

Light

Some components, such as semiconductor junctions and MOS capacitors on semiconductor wafers, are excellent light detectors. Consequently, these components must be tested in a light-free environment. While many test fixtures provide adequate light protection, others may allow sufficient light penetration to affect the test results. Areas to check for light leaks include doors and door hinges, tubing entry points, and connectors or connector panels. With this in mind, the Model 6485/6487 display may be turned off by sending the :DISP:ENAB OFF command.

Electrostatic interference

Electrostatic interference occurs when an electrically charged object is brought near an uncharged object, thus inducing a charge on the previously uncharged object. Usually, effects of such electrostatic action are not noticeable because low impedance levels allow the induced charge to dissipate quickly. However, the high impedance levels of many measurements do not allow these charges to decay rapidly and erroneous or unstable readings may result. These erroneous or unstable readings may be caused in the following ways:

1. DC electrostatic field can cause undetected errors or noise in the reading.
2. AC electrostatic fields can cause errors by driving the input preamplifier into saturation or through rectification that produces DC errors.

Electrostatic interference is first recognizable when hand or body movements near the experiment cause fluctuations in the reading. Pick-up from AC fields can also be detected by observing the picoammeter analog output on an oscilloscope. Line frequency signals on the output are an indication that electrostatic interference is present. Means of minimizing electrostatic interference include:

1. Shielding. Possibilities include: a shielded room, a shielded booth, shielding the sensitive circuit, and using shielded cable. The shield should always be connected to a solid connector that is connected to signal low. If circuit low is floated above ground, observe safety precautions and avoid touching the shield. Meshed screen or loosely braided cable could be inadequate for high impedances or in string fields. Note, however, that shielding can increase capacitance in the measuring circuit, possibly slowing down response time.
2. Reduction of electrostatic fields. Moving power lines or other sources away from the experiment reduces the amount of electrostatic interference seen in the measurement.

Magnetic fields

A magnetic field passing through a loop in a test circuit will generate a magnetic EMF (voltage) that is proportional to the strength of the field, the loop area, and the rate at which these factors are changing. Magnetic fields can be minimized by following these guidelines:

- Locate the test circuit as far away as possible from such magnetic field sources as motors, transformers, and magnets.
- Avoid moving any part of the test circuit within the magnetic field.
- Minimize the loop area by keeping leads as short as possible and twisting them together.

Electromagnetic Interference (EMI)

The electromagnetic interference characteristics of the Model 6485/6487 comply with the electromagnetic compatibility (EMC) requirements of the European Union as denoted by the CE mark. However, it is still possible for sensitive measurements to be affected by external sources. In these instances, special precautions may be required in the measurement setup.

Sources of EMI include:

- Radio and TV broadcast transmitters.
- Communications transmitters, including cellular phones and handheld radios.
- Devices incorporating microprocessors and high-speed digital circuits.
- Impulse sources as in the case of arcing in high-voltage environments.

The effect on instrument performance can be considerable if enough of the unwanted signal is present. The effects of EMI can be seen as an unusually large offset or, in the case of impulse sources, erratic variations in the displayed reading.

The instrument and experiment should be kept as far away as possible from any EMI sources. Additional shielding of the instrument, experiment and test leads will often reduce EMI to an acceptable level. In extreme cases, a specially constructed screen room may be required to sufficiently attenuate the troublesome signal.

External filtering of the input signal path may be required. In some cases, a simple one-pole filter may be sufficient. In more difficult situations, multiple notch or band-stop filters, tuned to the offending frequency range, may be required. Connecting multiple capacitors of widely different values in parallel will maintain a low impedance across a wide frequency range. Keep in mind, however, that such filtering may have detrimental effects (such as increased response time) on the measurement.

C
Example Programs

- **Programming examples** — lists and defines three types of programming examples.

Programming examples

This section contains example programs (pseudo-code) to achieve speed and buffer size specifications.

1000 readings/second into internal buffer

NOTE *This program configures the Model 6485/6487 to 0.01 PLC, digital filters off, front panel off, auto-zero off, as well as takes and stores 2000 readings.*

```
*RST                        ' Return 6485/6487 to RST defaults.
TRIG:DEL 0                  ' Set trigger delay to zero seconds.
TRIG:COUN 2000              ' Set trigger count to 2000.
NPLC .01                    ' Set integration rate to .01 PLC.
RANG .002                   ' Use 2mA range.
SYST:ZCH OFF                ' Turn zero check off.
SYST:AZER:STAT OFF          ' Turn auto-zero off.

DISP:ENAB OFF               ' Turn display off.
*CLS                        ' Clear status model.

TRAC:POIN 2000              ' Set buffer size to 2000.
TRAC:CLE                    ' Clear buffer.
TRAC:FEED:CONT NEXT         ' Set storage control to start on next
                            ' reading.
STAT:MEAS:ENAB 512          ' Enable buffer full measurement event.
*SRE 1                      ' Enable SRQ on buffer full measurement
                            ' event.

*OPC?                       ' Operation complete query
                            ' (synchronize completion of commands).
read back result of *opc?

INIT                        ' Start taking and storing readings.
                            ' Wait for GPIB SRQ line to go true.

DISP:ENAB ON                ' Turn display back on.

TRAC:DATA?                  ' Request data from buffer.
read back result
```

900 readings/second to IEEE-488 bus

This program uses multiple reading queries to get high speed measurements over the bus in real time. To improve continuity of readings, reduce the trigger count. To improve throughput, increase the trigger count.

NOTE *This program configures the Model 6485/6487 to 0.01 PLC, digital filters off, front panel off, auto-zero off, binary transfer, and IEEE-488.1 (language).*

Model 6485/6487 must be set to IEEE-488.1 operation from the front panel. Press CONFIG then COMM, select LANG: 488.1, then press ENTER. See instruction or reference manual for details.

```
*RST                        ' Return 6485/6487 to RST defaults.
FORM:ELEM READ              ' Return readings only.
FORM:BORD SWAP              ' Set for swapped byte order.
FORM:DATA SRE               ' Return single precision floating.
                            ' point binary.
TRIG:DEL 0                  ' Set trigger delay to zero seconds.
TRIG:COUN 8                 ' Set trigger count to 8.

NPLC .01                    ' Set integration rate to .01 PLC.
RANG .002                   ' Use 2mA range.

SYST:ZCH OFF                ' Turn zero check off.
SYST:AZER:STAT OFF          ' Turn auto-zero off.

DISP:ENAB OFF               ' Turn display off.

*OPC?                       ' Operation complete query
                            ' (synchronize completion of commands).
read back result of *opc?

for i = 1 to 1000
"talk" Model 6485/6487.     ' In 488.1 mode this will
                            ' automatically do a READ?
                            ' (see Reference manual).
read back the binary data
next i

DISP:ENAB ON                ' Turn display back on.
```

3000 readings into internal buffer

NOTE *This program is for the Model 6487 only. Due to memory limitations, the maximum product of the trigger count times the arm count is 2,048. Consequently, two triggers are required to completely fill the buffer to its 3,000 reading maximum. See Section 7 of the Model 6487 Reference Manual for triggering details.*

```
*RST                        ' Return 6487 to RST defaults.
TRIG:DEL 0                  ' Set trigger delay to zero seconds.
TRIG:COUN 1500              ' Set trigger count to 1500.
NPLC .01                    ' Set integration rate to .01 PLC.
RANG .002                   ' Use 2mA range.
SYST:ZCH OFF                ' Turn zero check off.

*CLS                        ' Clear status model.

TRAC:POIN 3000              ' Set buffer size to 3000.
TRAC:CLE                    ' Clear buffer.
TRAC:FEED:CONT NEXT         ' Set storage control to start on next
                            ' reading.
STAT:MEAS:ENAB 512          ' Enable buffer full measurement event.
*SRE 1                      ' Enable SRQ on buffer full measurement
                            ' event.

*OPC?                       ' Operation complete query
                            ' (synchronize completion of commands).
read back result of *opc?

INIT                        ' First trigger to store 1500 readings
                            ' wait for reading storage complete.

INIT                        ' Take and store last 1500 readings
                            ' wait for GPIB SRQ line to go true.

TRAC:DATA?                  ' Request data from buffer.

read back result
```

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