KEITHLEY

Model 6485 Picoammeter
Instruction Manual

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Model 6485 Picoammeter
Instruction Manual

Cleveland, Ohio, U.S.A.
First Printing, November 2001
Document Number: 6485-901-01 Rev. A

1 Getting Started

- **Introduction** — Description of the Model 6485 Picoammeter.
- **Overview of this manual** — Provides content of this manual.
- **General information** — Covers general information that includes warranty information, contact information, safety symbols and terms, inspection, and available options and accessories.
- **Features** — Summarizes the features of Model 6485.
- **Front and rear panel familiarization** — Summarizes the controls and connectors of the instrument as well as providing information on the front panel display.
- **Power-up** — Covers line power connection, line voltage setting, fuse replacement, power 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.
- **SCPI programming** — Explains how SCPI commands are presented in this manual.

Introduction

The Model 6485 is a high resolution bus-programmable (RS-232 and IEEE-488) picoammeter. The Model 6485 has the following current measurement ranges: 8 ranges (from 20mA down to the 2nA range, with the 2nA range having the lowest noise).

Overview of this manual

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

- Section 1: Getting Started
- Section 2: Measurement Concepts and Connections
- Section 3: Measurements
- Section 4: Range, Units, Digits, Rate, and Filters
- Section 5: Relative, mX+b, m/X+b (Reciprocal), and Log
- Section 6: Buffer
- Section 7: Triggering
- Section 8: Limit test
- Section 9: Remote Operation
- Section 10: Status Structure
- Section 11: Common Commands
- Section 12: SCPI Signal Oriented Measurement Commands
- Section 13: DISPlay, FORMat, and SYSTem
- Section 14: SCPI Reference Tables
- Section 15: Performance Verification
- Section 16: Calibration
- Section 17: Routine Maintenance

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: Status and Error Messages
- Appendix C: Measurement Considerations
- Appendix D: DDC Emulation Commands
- Appendix E: Example Programs
- Appendix F: IEEE-488 Bus Overview
- Appendix G: IEEE-488 and SCPI Conformance Information
- Appendix H: Remote Calibration
- Appendix I: Applications Guide

General information

Warranty information

Warranty information is located at the front of this manual. Should your Model 6485 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary 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:

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

The  symbol on the instrument shows that high voltage may be present on the terminal(s). 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 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 6485 Picoammeter from the bag, observe the precautions on handling discussed below.

Handling precautions

- Always grasp the 6485 by the covers.
- After removing the 6485 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 6485 is not installed and connected, keep the unit in its anti-static bag, and store it in the original packing carton.

Package content

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). (Referred to as ground link throughout this manual.)
- Accessories as ordered.
- Certificate of calibration.
- Model 6485 User Manual (P/N LCHR-950-01).
- Manual Addenda (pertains to any improvements or changes concerning the instrument or manual).

Options and accessories

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 is a barrel adapter that allows you to connect two BNC cables together. Both ends of the adapter are terminated with 2-lug female BNC connectors.

GPIB and trigger link cables and adapters

Models 7007-1 and 7007-2 shielded GPIB cables — Connect Model 6485 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.

Models 8501-1 and 8501-2 trigger link cables — Connect Model 6485 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 Model 6485 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 Model 6485 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 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, 6517 A, 7001) side-by-side in a standard 19-inch rack.

Model 4288-4 side-by-side rack mount kit — Mounts Model 6485 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. Includes handles and shoulder strap.

Instruction Manual

If an additional Model 6485 manual is required, order the manual package. The Keithley part number for the Instruction manual is 6485-901-010. The manual package includes an instruction manual and any pertinent addenda.

Additional references

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

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

Features

The Model 6485 is a high-performance picoammeter capable of measuring current. Section 2 contains details on its measurement capabilities ("Measurement overview," page 4-2). Features of Model 6485 Picoammeter include:

Setup storage — Five instrument setups (three user, GPIB defaults, and factory defaults) can be saved and recalled. See "Front panel setup operation," page 1-15.

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 up to 2500 readings in the internal buffer (Section 6).

Limits — Set up to two stages of high and low reading limits to test devices (Section 8).

Remote interface — Model 6485 can be controlled using the IEEE-488 interface (GPIB) or the RS-232 interface (Section 9).

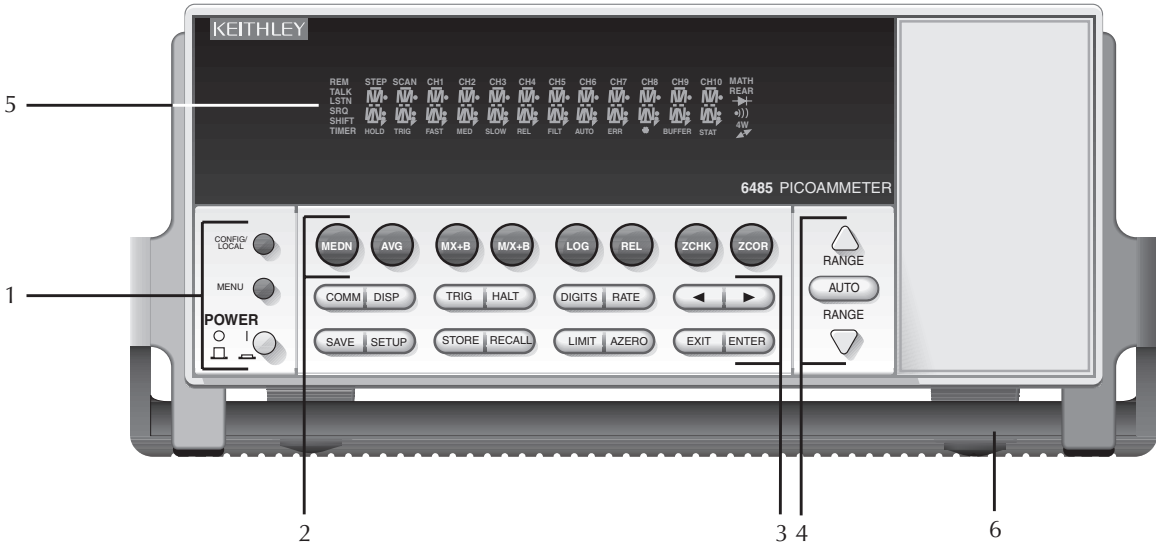
GPIB programming language — When using the GPIB, the instrument can be programmed using the SCPI or DDC programming language (Section 9).

Front and rear panel familiarization

Front panel summary

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

Figure 1-1
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.

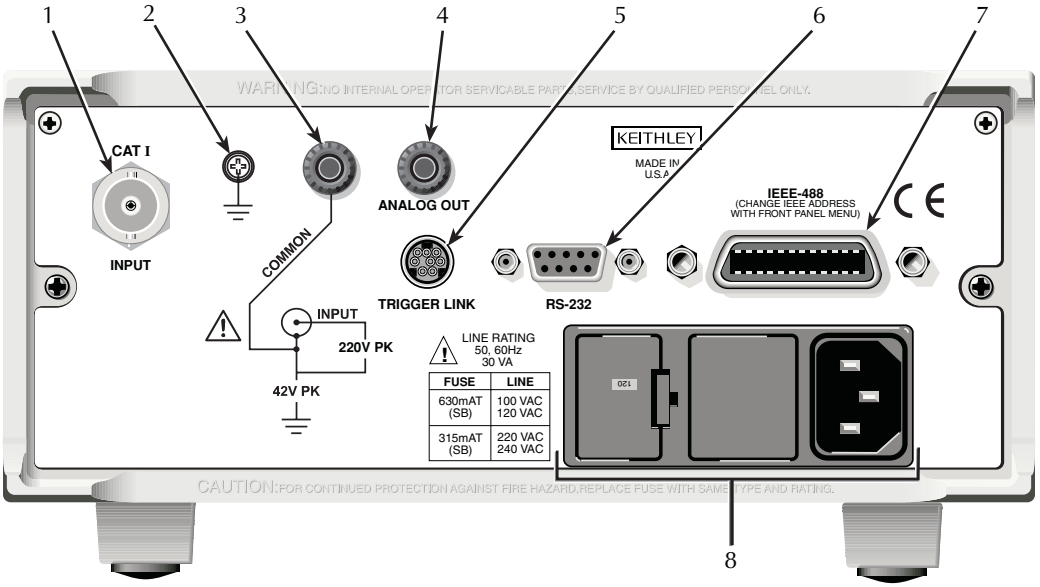
6 Handle

Pull out and rotate to desired position.

Rear panel summary

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

Figure 1-2
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.

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 OUT to earth while floating the input may damage the instrument.

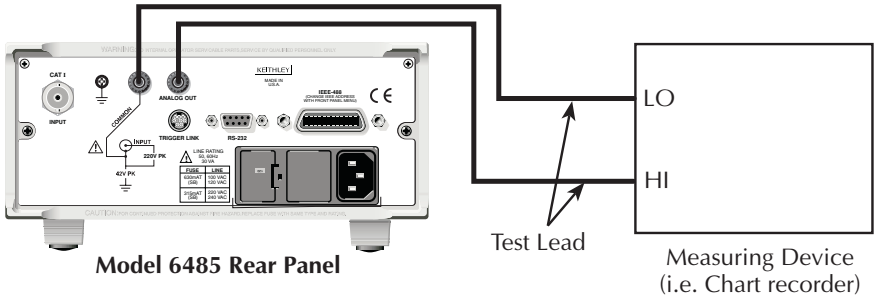
Connections for using this output are shown in Figure 1-3. For a full-scale input (i.e. 2mA on the 2mA range), the output will be -2V. Example analog outputs are listed in Table 1-1.

The 2V analog output signal is not corrected during calibration. Gain errors of up to 3% may appear at this output, depending on range.

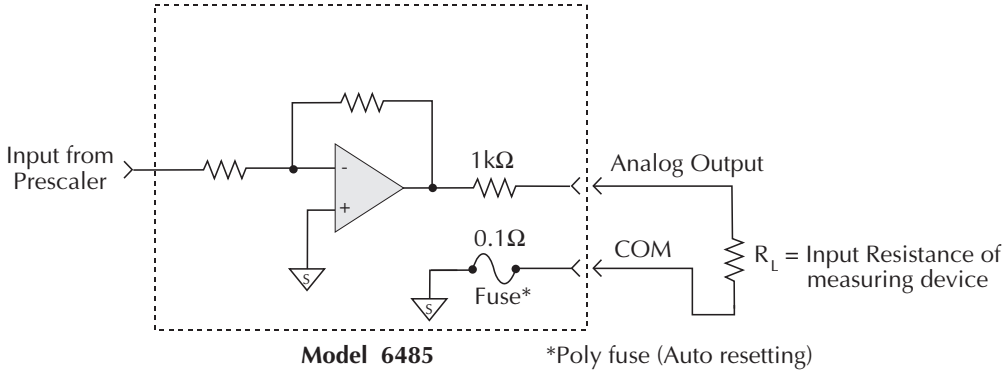
The output impedance is 1kΩ. To minimize the effects of loading, the input impedance of the device connected to the ANALOG OUT should be as high as possible. For example, for a device that has an input impedance of 10MΩ, the error due to loading will be approximately 0.01%. High capacitance connected to the analog output will increase the rise time.

Rel and the result of mX+b, m/X+b, or LOG have no affect on the analog output. The 2V analog output is scaled only to the actual input.

Figure 1-3
Typical analog output connections



A. Connections



B. Equivalent Circuit

Table 1-1
Example 2V analog output values

Range	Applied signal	Analog output value (nominal)*
20nA	10.5nA	-1.05V
2mA	-1.65mA	1.65V

* Output values are within ±3% of nominal value.

Display

Readings can be displayed in engineering units or scientific notation (see "Units," page 4-3 for details). Annunciators indicate various states of operation. See "Front panel summary," page 1-6 for a complete listing of display annunciators.

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. To access these tests:

1. While in reading mode, press MENU. If not in reading mode, press EXIT first then press MENU.
2. Scroll using range keys (▲ or ▼) to the TEST sub-menu (TEST will be flashing).
3. Press ENTER (or ◀ ▶) to select TEST (DISP will be flashing).
4. Scroll using range keys (▲ or ▼) to desired test (DISPlay or KEY).

Refer to Section 13 for additional details.

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.

Messages, both status and error, are held in queues. For information on retrieving messages from queues, see Section 10.

Power-up

Line power connection

Follow the procedure below to connect the Model 6485 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) is correct for the operating voltage in your area. If not, refer to the procedure in Section 17 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 contains a separate ground wire 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 (|) position.

Line frequency

The Model 6485 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 :SYSTem:LFRequency? 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 (see the following procedure) or over the bus. Refer to Table 1-2 for commands.

Front panel procedure

1. Press MENU.
2. Scroll to the LFREQ: menu item using the ▲ and ▼ range keys. The present setting is displayed.
3. Press the ▶ range key. The present setting is now highlighted.
4. Use the ▲ and ▼ range keys to scroll to the desired menu item: AUTO*XX*, 50, or 60
5. Press ENTER.

NOTE *In the setting of AUTOXX, XX is the currently detected frequency.*

SCPI programming — line frequency

Table 1-2
SCPI commands — line frequency

Command	Description
SYSTem	SYSTem Subsystem:
:LFRequency <freq>	Set power line frequency (in Hz) to 50 or 60.
:AUTO <b>	Turn automatic frequency detection ON or OFF.
:AUTO?	Read the present automatic detected line frequency state (1 = on, 0 = off).
:LFRequency?	Read present line frequency setting.

Power-up sequence

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

1. The Model 6485 performs self-tests on its EPROM and RAM with all digits and annunciators turned on. 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.

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 B01`
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.
   Examples:
   `SCPI ADDR: 14`
   `DDC ADDR: 14`
   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`

NOTE *To configure power-on set up:*
-Display PWR-ON: menu (press CONFIG and then SETUP).
-Use ▲ or ▼ range keys to scroll through the menu items.
-Press Enter to select or Exit to quit without changing power-on setup.

If DDC language is selected, user setups cannot be saved as power-on setup.

Default settings

The Model 6485 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 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 1-2.

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.*

Front panel setup operation

To save a user setup

1. Configure Model 6485 for the desired measurement application.
2. Press SAVE to access the save setup menu.
3. Use the ▲ or ▼ key to display the desired memory location (0 = USR0, 1 = USR1, 2 = USR2).
4. Press ENTER.

NOTE *Saved setups should not be used in DDC mode and will not be recalled upon power up (in DDC mode).*

To restore any setup

1. Press SETUP to display the restore menu:
2. Use the ▲ or ▼ key to display the desired setup (FACT, USR0, USR1, USR2, or GPIB).
3. Press ENTER.

To select power-on setup

1. Press CONFIG and then SETUP to display the power-on menu.
2. Use the ▲ or ▼ key to display the desired setup (FACT, USR0, USR1, USR2, or GPIB).
3. Press ENTER.

Remote setup operation

Saving and restoring user setups

The *SAV and *RCL commands are used to save and recall user setups. These commands are documented in Section 9.

Restoring factory or GPIB default setups

The SYSTem:PRESet command returns Model 6485 to the factory defaults and the *RST command returns it to the GPIB defaults. The *RST command is documented in Section 11 and SYSTem:PRESet is covered in Section 12.

Selecting power-on setup

The SYSTem:POSetup command is used to select which setup to return to on power-up. The SYSTem:POSetup command is documented in Section 12.

Table 1-3
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	1
Arm Count	INF	*
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	*
Advanced:	No (disabled)	*
Noise Tolerance	0.0%	*
Display Resolution (DIGITS)	5½-digits	*
Format byte order	Swapped	Normal

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

Table 1-3 (continued)
Default settings

Setting	Factory (:SYStem:PRESet)	GPIB (*RST)
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	*
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	*

*This 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 1-4. Refer to the Section listed in the table 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 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 1-4
MENU structure

Menu item	Description	Reference
CAL	Provides path to the following calibration submenu items: VOFFSET, COUNT, RUN, DATES, UNLOCK, LOCK, and SAVE. See reference section for verification and calibration information.	Section 15, Section 16
TSTAMP	Timestamp format can be ABSolute or DELTa.	Section 6
UNITS	Readings can be displayed in ENGineering units or SCIentific notation.	Section 6
TEST	Run display or key tests.	Section 17
SNUM	Displays the units serial number.	Section 11
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 1-13

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 *Except for Section 14, most SCPI tables in this manual are abridged. That is, they do NOT include most optional command words and query commands. Optional command words and query commands are summarized as follows.*

Optional command words

In order to be in conformance with the IEEE-488.2 standard, Model 6485 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.

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 is addressed to talk, the response message is sent to the computer.

2 Measurement Concepts

- **Measurement overview** — Explains the basic measurement capabilities of Model 6485.
- **Performance considerations** — Covers a couple of considerations that affect overall performance; warm-up and autozero.
- **Connection fundamentals** — Covers fundamental information about connecting test circuits to the picoammeter.
- **Zero check and zero correct** — Provides operation information on these two important aspects of the basic measurement process.
- **Measurement considerations** — Summarizes the various factors that affect low level measurements.

Measurement overview

The basic measurement capabilities of Model 6485 are summarized in Table 2-1. Accuracy for each measurement function and range is listed in specifications (Appendix A).

Table 2-1
Basic measurement capabilities

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

Performance considerations

Warm-up period

Model 6485 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.

Autozero

To help maintain stability and accuracy over time and changes in temperature, the Model 6485 periodically measures internal voltages corresponding to offsets (zero) and amplifier gains. These measurements are used in the algorithm to calculate the reading of the input signal. This process is known as autozeroing.

When autozero is disabled, the offset and gain measurements are not performed. This increases measurement speed up to 3 times. However, the zero and gain reference points can eventually drift resulting in inaccurate readings of the input signal. It is recommended that autozero only be disabled for short periods of time.

To disable autozero from the front panel, press the AZERO button. This button toggles autozero on and off. It can also be enabled by restoring factory or GPIB default conditions. When autozero is enabled, a colon will be displayed after the reading.

For example:

Autozero disabled: `0.00258 nA`
Autozero enabled: `0.00258 nA:`

SCPI programming

Table 2-2
SCPI commands — autozero

Command	Description	Default
SYSTem :AZERo [:STATe] <b>	SYSTem Subsystem: Enable or disable autozero.	 ON

SYSTem:AZERo[:STATe] <b>

Sending this command over the bus does not update the display while in remote. To verify the AZERo state, send the query. The displayed autozero state will be updated when the instrument is placed back in local.

Programming example

The following examples enables or disables the autozero feature:

```
SYST:AZER ON          ' Enable autozero.
SYST:AZER OFF         ' Disable autozero.
SYST:AZER?            ' Query autozero. 1=on, 0=off
```

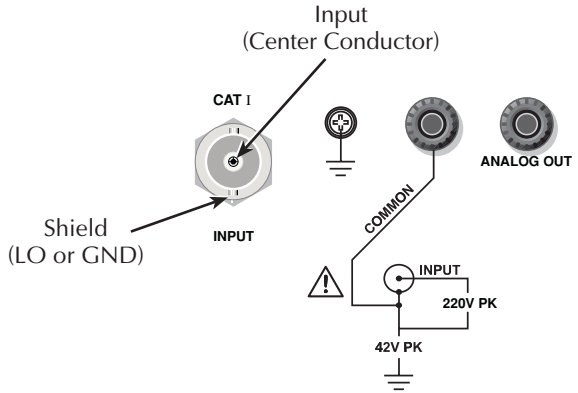
Connection fundamentals

The following provides important fundamental information on input connections to the Model 6485. Typical connection drawings are included with the various measurement procedures provided in subsequent sections of this manual.

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 2-5.)

Figure 2-1
BNC Input connector



Maximum input levels

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

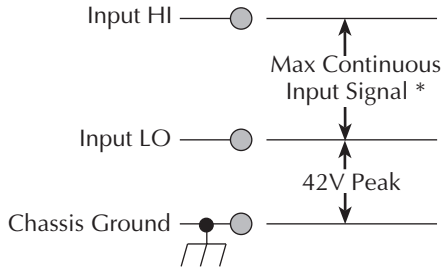
WARNING **The maximum safe voltage between picoammeter LO and chassis ground (common mode voltage) is 42V. The Model 6485 does not internally limit the LO-to-chassis voltage. Exceeding 42V can create a shock hazard.**

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
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. The following low noise cables are recommended for use with Model 6485:

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

Model 4802-10 — This 10 ft (3m) low-noise BNC 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

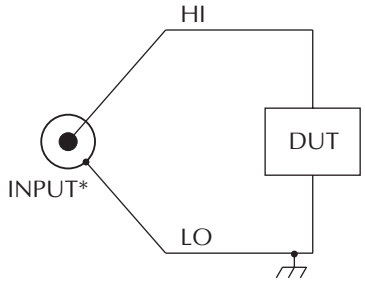
NOTE *As a general rule, always use the shortest possible cable for measurements.*

Basic connections to DUT

Connections

Basic connections are shown in Figure 2-3, 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 2-3
Basic 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.**

Voltages greater than 220V

Often, when making resistance measurements, it is necessary to use an external voltage source with voltages greater than the maximum tolerable input voltage of 220V. In the event that the resistance to be measured becomes shorted, or an incorrect value of resistance is inserted in the test setup, the voltage source can permanently damage the Model 6485. To prevent this damage, the following steps should be taken as a protection precaution. (An alternate protection method is described in "Measuring high resistance with external bias source," page I-19, for cases not requiring the maximum sensitivity of the 6485.)

To prevent accidental damage, a series resistor should be added to the test setup. The minimum value of this series resistor depends on the lowest current range to be used in the measurement. If it will not be necessary to use the lower measurement ranges, a smaller series resistor can be used, reducing the effect it will have on measurement accuracy. The lowest necessary measurement range can be determined from the measurement range accuracy specs, the applied voltage and largest resistance desired to measure. If using auto range, program the Model 6485 to not use its lowest ranges when autoranging.

To set the auto range lower limit from the front panel:

1. Press the CONFIG key.
2. Press the down range key (▼).
3. Use the ▲ and ▼ range keys to scroll through the available lower limit settings.
4. Press ENTER to save the displayed value as the lower limit. Press EXIT to return to the previous setting.

To set the auto range lower limit over the bus, use [CURRent]:RANGe:AUTO:LLIMit (Section 4).

Use the following formula to determine the minimum resistance for proper current limiting resistors:

$$MinR_{series} = \left(\frac{SourceVoltage - 220V}{220V}\right)R_{in}$$

Lowest range to be used	**R_{in}**
2nA or 20nA	11MΩ
200nA or 2µA	3.5MΩ
20µA or 200µA	50kΩ
2mA or 20mA	500Ω

The series limiting resistor should have a minimum power rating of:

$$MinPowerRating = SourceVoltage^2 / R_{series}$$

Example: If measuring 100GΩ resistances using an external voltage source of 500V, and thus, a lowest necessary current range of 20nA, the minimum series resistance that will prevent damage in the case of a shorted resistor would be:

minimum R_{series} = (500V - 220V)/220V×11 MΩ = 14MΩ

minimum power rating = $(500V)^2$/14MΩ =18mW

NOTE *The 14MΩ in series will increase the measured resistance to 100.014GΩ*

The 6485 can be programmed to calculate the resistance and subtract the series resistance. Using the M/X+B function, in the example above, one would set M to 500, B to -14e6, and the units character to “omega”. For more details on the M/X+B function, see Section 5.

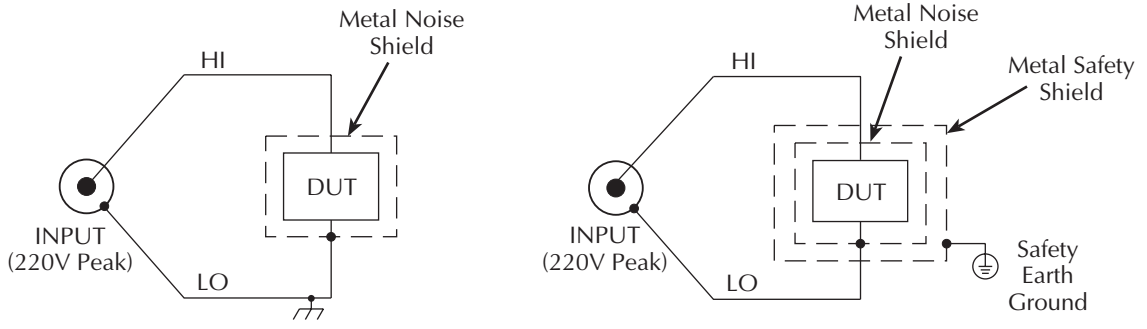
Noise and safety shields — Figure 2-4 shows typical measurement shielding. A noise shield is used to prevent unwanted signals from being induced on the picoammeter input. Amps measurements below 1µA may benefit from effective shielding. Typically, the noise shield is connected to picoammeter input LO. Additionally, Figure 2-4 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 2-4
Shielding for measurements (unguarded)



A. Noise Shield

B. Safety Shield

Input voltage overload (OVRVOLT message)

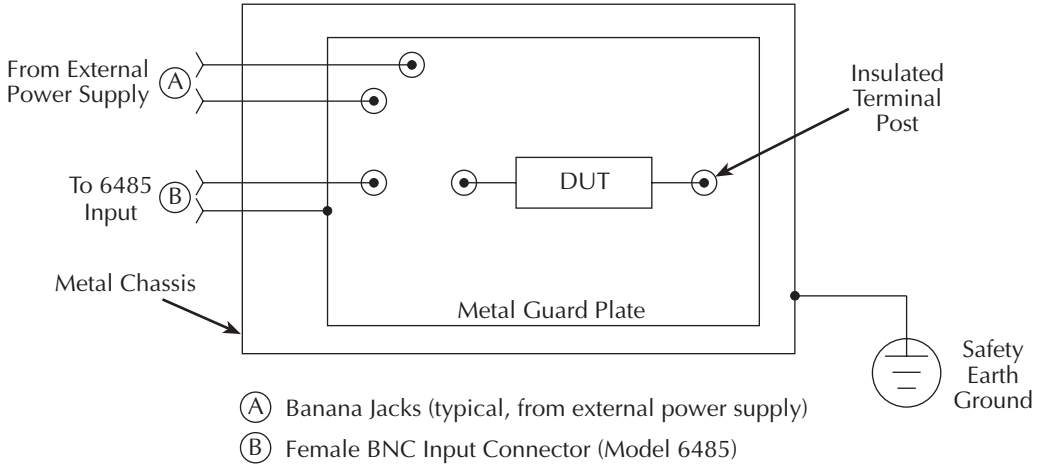
During normal operation, there should not be a significant voltage between the input HI and LO terminals of the Model 6485. However, occasionally, as in the case of a DUT failure, a customer voltage source can become shorted directly to the Model 6485. Under that condition, protection circuits within the 6485 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 auto ranges up to these ranges as a response to the applied voltage, if the input voltage exceeds 60V, the Model 6485 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 (see "Measurement event status," page 10-13.)

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.

Test fixture

Whenever possible, use a shielded low leakage test fixture to make precision measurements. A general purpose test fixture is shown in Figure 2-5. This test fixture will accommodate a variety of connection requirements.

Figure 2-5
General purpose test fixture



Test fixture chassis

- The chassis of the test fixture should be metal so that it can function as a shield for the DUT or test circuit.
- The test box must have a lid that closes to prevent contact with live circuitry.
- The test fixture must have a screw terminal that is used exclusively for connection to safety earth ground.

WARNING **To provide protection from shock hazards, the test fixture chassis must be properly connected to safety earth ground. A grounding wire (#18 AWG or larger) must be attached securely to the test fixture at a screw terminal designed for safety grounding. The other end of the ground wire must be attached to a known safety earth ground.**

Guard plate

A metal guard plate will provide guarding or noise shielding for the DUT or test circuit. It will also serve as a mounting panel for DUT or test circuits. The guard plate must be insulated with appropriate spacing from the chassis of the test fixture commensurate with the external source used.

Connectors, terminals, and internal wiring

Basic connector requirements include a female BNC connector and two banana jacks. The banana jacks provide for connection to an external power supply. The banana jacks must be insulated from the chassis of the test fixture.

DUT and test circuits are to be mounted on the guard plate using insulated terminals. To minimize leakage, select terminals that use virgin Teflon insulators.

Inside the test fixture, use an insulated wire to connect the shell of the BNC connector to the guard plate (the guard plate will serve as a noise shield).

Handling and cleaning test fixtures

Dust, body oil, solder flux, and other contaminants on connector and terminal insulators can significantly decrease the leakage resistance resulting in excessive leakage currents. Contaminants on DUT and test circuit components can create a leakage path. The leakage currents may be large enough to corrupt low-level measurements.

Handling tips:

- Do not touch the bodies of DUT or test circuit components. If you can not handle them by their leads, use clean cotton gloves to install them in the test fixture.
- Do not touch any connector or terminal insulator.
- If installing a test circuit that is on a PC board, handle the board by the edges. Do not touch any board traces or components.

Cleaning tips:

- Use dry nitrogen gas to clean dust off connector and terminal insulators, DUT, and other test circuit components.
- If you have just built the test fixture, remove any solder flux using methanol along with clean foam-tipped swabs or a clean soft brush. Clean the areas as explained in the next tip.
- To clean contaminated areas, use methanol and clean foam-tipped swabs. After cleaning a large area, you may want to flush the area with methanol. Blow dry with dry nitrogen gas.
- After cleaning, the test fixture (and any other cleaned devices or test circuits) should be allowed to dry in a 122° F (50° C) low-humidity environment for several hours.

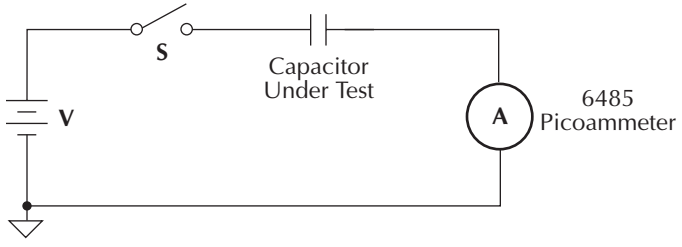
Input protection

Model 6485 incorporates protection circuitry against nominal overload conditions. However, a voltage higher than the maximum voltage value for the selected current range, and the resultant current surge could damage the input circuitry.

NOTE *Maximum peak voltage: 220V Peak*

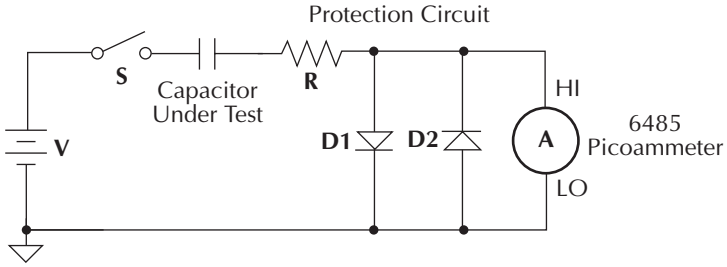
A typical test circuit to measure the leakage current of a capacitor is shown in Figure 2-6. When Switch S is closed, an initial charging current will flow and the high voltage will be seen across the input of Model 6485.

Figure 2-6
Capacitor test circuit without protection



Adding a resistor and two diodes (1N3595) as shown in Figure 2-7 will provide considerable extra protection. The resistor must be large enough to limit the current through the diodes to 20mA or less, and be large enough to withstand the supply voltage. The protection circuit should be enclosed in a light-tight conductive shield.

Figure 2-7
Capacitor test circuit with protection



Floating measurements

Figure 2-8 shows an example where Model 6485 floats.

WARNING **Before attempting floating measurements, make sure to have a thorough understanding of any dangers involved. Take adequate precautions before connecting any instruments or power sources. Also, make sure to read and understand information contained in "Connection fundamentals," page 2-3. Death or injury due to electrical shock can result if adequate safety measures are not taken.**

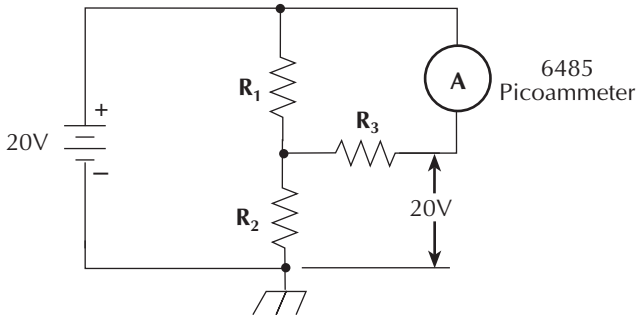
The maximum safe voltage between picoammeter LO and chassis ground (common mode voltage) is 42V. The Model 6485 does not internally limit the LO-to-chassis voltage. Exceeding 42V can create a shock hazard.

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

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

Figure 2-8
Floating measurements



Zero check and zero correct

Table 2-3 lists the display messages associated with zero check and zero correct. The two-character message is displayed along with the reading.

Table 2-3
Display messages for zero check and zero correct

Display Message	Zero Check	Zero Correct
ZC	On	Off
ZZ	On	On
CZ	Off	On

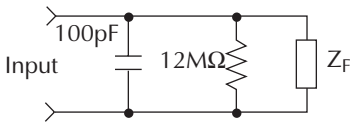
Zero check

When zero check is enabled (on), the input amplifier is reconfigured to shunt the input signal to low as shown in Figure 2-9.

From the front panel, enable / disable zero check by pressing the ZCHK key. Refer to Table 2-4 for bus commands.

Leave zero check enabled when connecting or disconnecting input signals.

Figure 2-9
Equivalent input impedance with zero check enabled



Z_F = 500Ω ||200nF....2 mA, 20 mA
50kΩ || 2nF.....20 µA, 200 µA
5MΩ || 20pF .....200 nA, 2 µA
500MΩ || 5pF ...2 nA, 20 nA

Zero correct

Model 6485 has a zero correct feature to algebraically subtract the voltage offset term from the measurement (to actually reduce the voltage at the input terminals, see the Voltage Offset Correction procedure in Section 16). Perform the following steps to algebraically zero correct the measurement:

NOTE *The ZCOR key toggles zero correct on and off. If zero correct is enabled ("ZZ" or "CZ" message displayed), press ZCOR to disable it.*

1. Enable zero check ("ZC" message displayed).
2. Select the range that will be used for the measurement, or select the lowest range.
3. Press ZCOR to enable zero correct ("ZZ" message displayed).
4. Press ZCHK to disable zero check.
5. Readings can now be taken from the display. The "CZ" message indicates that the displayed reading is zero corrected.

NOTES *With regard to the zero correct feature:*
-Model 6485 will remain zero corrected even if it is upranged. If downranged, re-zero the instrument.
-Model 6485 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 both zero check and zero correct enabled, the instrument may not display a perfectly zeroed reading.
-If Model 6485 is operating at, or near T_{CAL}, zero correction will have very little effect. T_{CAL} is the internal temperature of Model 6485 when it was last calibrated.

SCPI programming — zero check and zero correct

Table 2-4
SCPI commands — zero check and zero correct

Commands	Description	Default	Ref	DDC
SYSTem	SYSTem Subsystem:			
:ZCHeck	Zero check:	ON		
[:STATe] <b>	Enable or disable zero check.	OFF	A	
:ZCORrect	Zero correct:			
[:STATe] <b>	Enable or disable zero correct.	OFF	A	C0 (Off) C1 (On)
:ACQuire	Acquire a new zero correct value.		B	
INITiate	Trigger a reading.		B	

A) SYSTem:ZCORrect:ACQuire

The zero correct value can only be acquired while zero check is enabled and zero correct state is off. The internal offset measured at that moment will become the correction value. Zero correction can then be applied and zero check disabled. This acquire method makes it convenient if you need to re-zero the instrument often.

The following command sequence uses the acquire method to zero correct the 200µA range:

```
*RST                    ' Set instrument to known default
                          conditions in one-shot trigger mode.
SYST:ZCH ON             ' Enable zero check.
CURR:RANG 2E-4          ' Set instrument to 200uA range.
INIT                    ' Trigger one reading.
SYST:ZCOR:ACQ           ' Acquire zero correct value.
SYST:ZCH OFF            ' Disable zero check.
SYST:ZCOR ON            ' Perform zero correction.
```

The INITiate command in the above sequence is used to trigger a reading. This reading is the offset that is acquired as the zero correct value. See Section 7 for more information on INITiate.

NOTE *Sending the :ACQuire command while zero check is disabled will result in an error. The command will not be executed.*

B) SYSTem:ZCORrect[:STATe] <b>

This method to perform zero correction is consistent with the way it is performed from the front panel. That is, zero correction is performed while zero check is enabled. The zero correct state can be turned on and off repeatedly without requiring. If no ACQ has not been performed since the most recent reset, zero is used for the ACQ value.

Measurement considerations

There are a variety of factors to consider when making low level measurements. These considerations are listed and summarized in Table 2-5 and are detailed in Section 3 and Section C. For comprehensive information on all measurement considerations, refer to the Low Level Measurements handbook, which is available from Keithley Instruments.

Table 2-5
Summary of measurement considerations

Considerations	Description
	See Section 3 for details
Input bias current	Offset current of Model 6485 could affect low current measurements.
Voltage burden	Offset voltage of Model 6485 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 Section C 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

- **Measurement overview** — Summarizes the current measurement capabilities of Model 6485 and provides a basic procedure to measure amps.
- **SCPI programming** — Covers the basic SCPI commands.

Measurement overview

Measurements — Model 6485 can make amps measurements from 20fA to 21mA using 8 measurement ranges; 2nA, 20nA, 200nA, 2µA, 20µA, 200µA, 2mA, and 20mA.

NOTE *Accuracy specifications are provided in Appendix A.*

Procedure

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.

To achieve optimum precision for low-level current measurements, input bias current and voltage burden can be minimized by performing the offset correction procedure. Information about these offsets are provided in "Measurement considerations,"on page I-2.

NOTE *After overloading with high voltage, it may take several minutes for the input current to drop to within specified limits. Input current can be verified by placing the protection cap on the input BNC connector and then use the ground link to connect COMMON and CHASSIS ground. With the instrument on the 2nA range and zero check disabled, allow the reading to settle until the input bias current is within specifications. The specifications for input bias current are included in the offset portion of the accuracy specification listed in Appendix A.*

Perform the following steps to measure current:

Step 1. Enable zero check

Zero check should always be enabled before making connection changes. The ZCHK key toggles zero check on and off. When on, the "ZC" or "ZZ" message is displayed. See Section 2 for details on zero check.

Step 2. Perform zero correction

To achieve optimum accuracy for low current measurements, it is recommended that you zero correct the picoammeter. (See Section 2 for details on zero correction:)

-Select the 2nA range (which is the lowest range).
-Press the ZCOR key until the "ZZ" message is displayed.

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

Use the RANGE ▲ and ▼ 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 4. Connect the current to be measured to the picoammeter

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

WARNING **A safety shield is advisable whenever floating measurements are being made (see "Floating measurements," page 2-12). Connections for the safety shield are shown in Figure 3-1. 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. (See "Ground loops," page C-2.)*

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

Step 5. Disable zero check and take a reading from the display

If the readings are noisy, you may want to use filtering to reduce noise. Use filtering if the noise is caused by a noisy input signal. Filtering is covered in Section 4.

Figure 3-1
Connections for amps