

KEITHLEY

Model 6514 System Electrometer

Quick Results Guide

A GREATER MEASURE OF CONFIDENCE

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 6514-903-01) August 2003

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 manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product 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 manual. 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, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley 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 Manual.

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 ca-

bles 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 its 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 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 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  symbol indicates a connection terminal to the equipment frame.

The **WARNING** heading in a 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 in a manual 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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Model 6514 System Electrometer Quick Results Guide

Introduction

This guide is designed to familiarize users with fundamental operation (front panel and remote) of the Keithley Model 6514 System Electrometer. For comprehensive information on all aspects of Electrometer operation, refer to the Model 6514 Instruction Manual.

Operation information in this guide is divided into three parts: (1) basic operation, (2) Settings to optimize performance, and (3) Features to enhance DUT testing. This format allows a new user to easily progress from basic simple operation to more complex procedures.

Remote command programming - For the various Model 6514 operating modes covered in this guide, the related SCPI commands for remote operation are summarized in tables. Most commands have a query form. For example, FUNC 'VOLT' selects the voltage measurement function, while :FUNC? requests the present measurement function. Note that the Model 6514 must be addressed to talk after sending a query command.

For operations where command sequence is important, programming examples are provided. The exact programming syntax will depend on the test program language.

Measurement capabilities

- Voltage from $\pm 10\mu\text{V}$ to $\pm 210\text{V}$.
- Current from $\pm 100\text{aA}$ to $\pm 21\text{mA}$.
- Ohms from $10\text{m}\Omega$ to $210\text{G}\Omega$.
- Coulombs from 10fC to $21\mu\text{C}$.

Front and rear panels

The front and rear panels of the Model 6514 are shown in Figures 1 and 2. The use of the various instrument controls and connectors will be explained throughout this guide.

Figure 1
Front panel

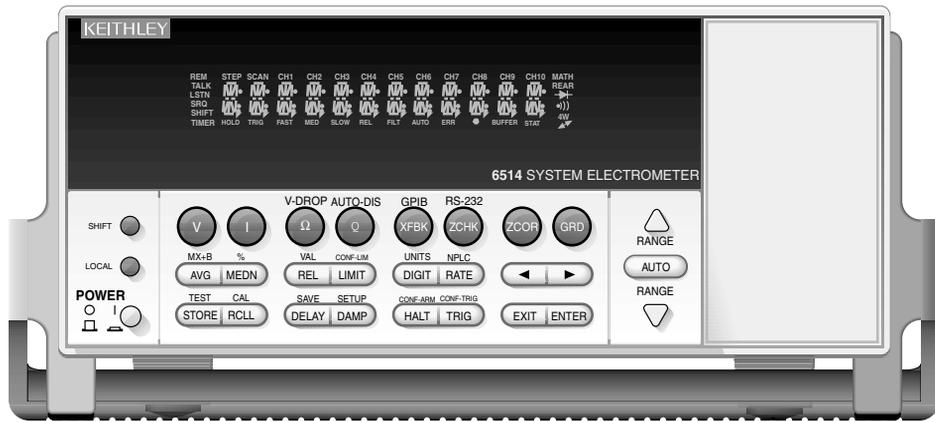
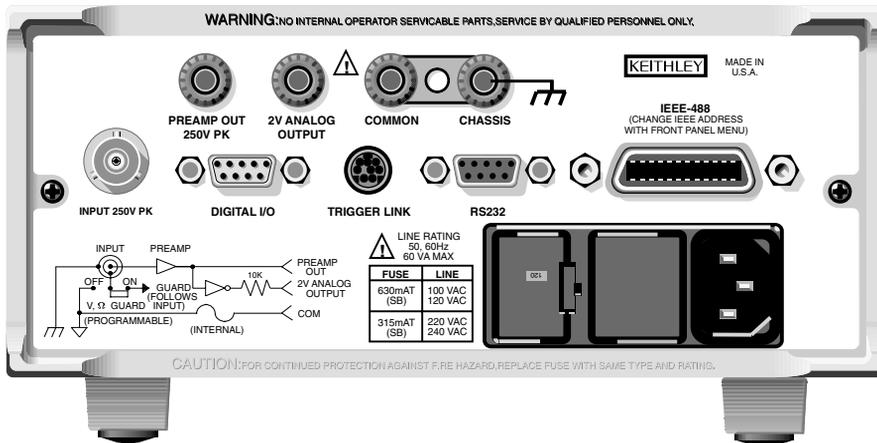


Figure 2
Rear panel



Basic connections

WARNING The maximum common-mode input voltage, which is the voltage between the input (HI or LO) and chassis ground, is 500V peak. Exceeding this value may create a shock hazard.

CAUTION Connecting PREAMP OUT, COMMON, or 2V ANALOG OUTPUT to earth while floating the input may damage the instrument.

Input connector

The rear panel INPUT connector is a 3-lug female triax connector that will mate to a cable terminated with a male triax connector. As shown in Figure 3, the input connector can be configured with guard off or guard on. The guarded configuration is used for guarded Volts and guarded Ohms measurements only. The GRD key toggles guard on and off.

NOTE *The state of guard (on or off) has no affect on the Amps and Coulombs functions. The unguarded configuration is always selected for the Amps and Coulombs functions.*

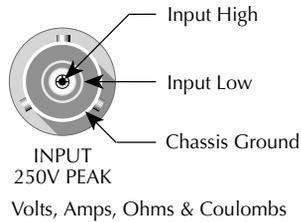
Low noise input cables

When making precision measurements, you should always use low noise cables. The following low noise cables are recommended for use with the Model 6514:

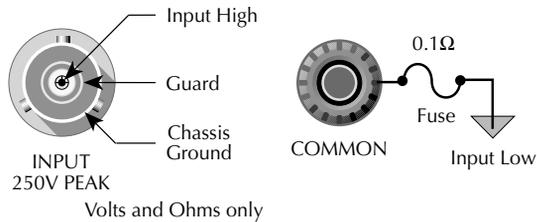
- **Model 237-ALG-2** — This 2-meter low noise triax cable mates directly to the input connector of Model 6514 and is terminated with alligator clips on the other end.
- **Model 7078-TRX-x cables** — These low noise triax cables are terminated with 3-slot triax connectors on both ends.

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

Figure 3
Input connector



A. Unguarded (GRD off)



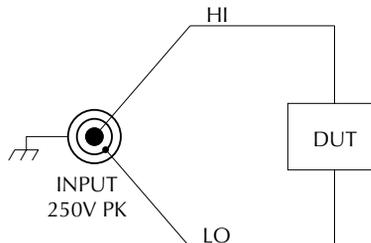
B. Guarded (GRD on)

Basic connections to DUT

Unguarded connections

Basic unguarded connections are shown in Figure 4. The DUT is the voltage, current, resistance, or charge to be measured. For unguarded volts and ohms measurements, the driven guard (GRD) must be off.

Figure 4
Basic connections for unguarded measurements



NOTE: For Volts and Ohms, GRD must be off.

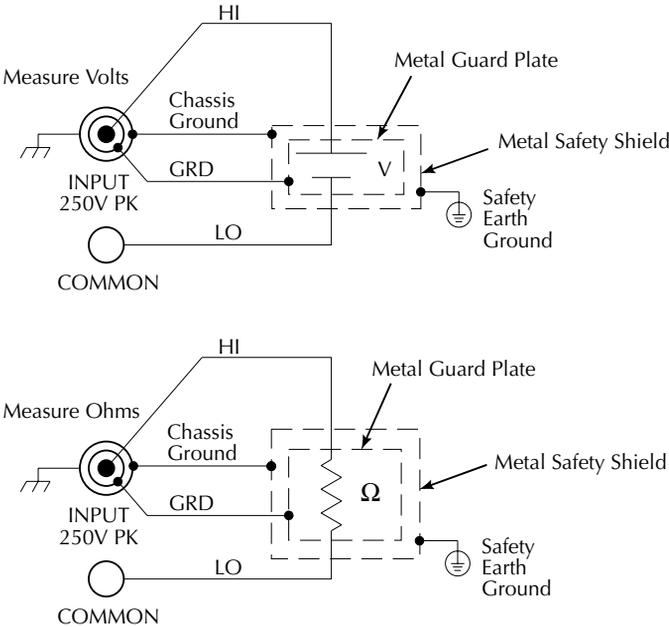
Guarded connections

The basic guarded connections for volts and ohms are shown in Figure 5. With guard (GRD) on, the driven guard is available at the inner shell of the triax connector which is connected to the metal guard plate. The driven guard is used to eliminate leakage current and capacitance in high impedance circuits that could corrupt the volts or ohms measurement.

WARNING The guard voltage is at the same potential as the input. Therefore, hazardous voltage on the input will also be present on the guard plate. To prevent electric shock, always use a metal safety shield (as shown in Figure 5) for guarded voltage measurements above 30Vrms (42V peak). The metal safety shield must be connected to safety earth ground using #18 AWG or larger wire.

WARNING With an open input, up to 250V peak may be present on the guard terminals while in Volts or Ohms. To prevent a safety hazard, enable zero check whenever the input is open.

Figure 5
Basic connections for guarded measurements



NOTE: GRD must be on.

Basic operation

Selecting operating modes

Most front panel keys have a dual operation or function. The nomenclature on a key indicates its primary or unshifted function or operation. The nomenclature above a key indicates its shifted function or operation. To select a primary function press the corresponding key. To select a shifted function, press SHIFT first and then the desired key. For example, press AVG to select the digital filter. Press SHIFT then MX+B to choose the mX + b function.

Making volts and ohms measurements

The basic procedure to make volts and ohms measurements is provided in Table 1.

Table 1

Volts and ohms measurement procedure

Procedure	Details
1. Enable zero check.	Press ZCHK to enable zero check before making connection changes or selecting function.
2. Select function.	Press V to measure voltage. Press Ω to measure ohms.
3. Enable or disable guard.	Use the GRD key to select depending on guarded or unguarded connections.
4. Perform zero correct (volts only).	Press ZCOR to zero correct 6514 for maximum volts accuracy.
5. Select range.	Use RANGE 5 and 6 keys to manually select range. Or press AUTO RANGE (AUTO annunciator on) to enable auto range.
6. Connect DUT to 6514 input.	See Figure 4 (unguarded) or Figure 5 (guarded).
7. Disable zero check.	Press ZCHK to disable zero check in order to make measurements.
8. Take readings from display.	Observe the volts or ohms reading on the front panel display.

Making amps measurements

The basic procedure to make amps measurements is provided in Table 2.

Table 2

Amps measurement procedure

Procedure	Details
1. Enable zero check.	Press ZCHK to enable zero check before making connection changes or selecting function.
2. Select amps function.	Press I to measure current.
3. Perform zero correct.	Press ZCOR to zero correct 6514 for maximum accuracy.
4. Select range.	Use RANGE 5 and 6 keys to manually select range. Or press AUTO RANGE (AUTO annunciator on) to enable auto range.
5. Connect DUT to 6514 input.	See Figure 4.
6. Disable zero check.	Press ZCHK to disable zero check in order to make measurements.
7. Take readings from display.	Observe the amps reading on the front panel display.

Making charge measurements

The basic procedure to make charge measurements is provided in Table 3.

Table 3

Charge measurement procedure

Procedure	Details
1. Enable zero check.	Press ZCHK to enable zero check before making connection changes or selecting function.
2. Select coulombs function.	Press Q to measure charge in coulombs.
3. Select range.	Use RANGE 5 and 6 keys to manually select range. Or press AUTO RANGE (AUTO annunciator on) to enable auto range.
4. Connect input cable to 6514.	Do not connect DUT to cable (open input).
5. Disable zero check, enable relative.	Press ZCHK to disable zero check, then press REL.
6. Connect DUT to 6514 input.	See Figure 4.
7. Take readings from display.	Observe the coulombs reading on the front panel display.

Measurement considerations

For sensitive measurements, keep these points in mind to maximize measurement accuracy:

- Use only low noise triax cable for input connections.
- Use zero correct with zero check enabled to null internal offsets.
- Keep the Model 6514 and test circuit away from electrical noise sources, and shield if necessary.

Remote command programming

Data string

The `:READ?` command is typically used to trigger a reading and request the data string. The data string is sent to the computer when the Model 6514 is addressed to talk. The data string can be made of up to three elements separated by commas. The first element is the voltage, current, resistance, or charge reading, the second is the timestamp, and the third is status. A three-element data string is the default condition. See Section 16, *FORMat subsystem*, of the Model 6514 Instruction Manual for details on all aspects of the data format.

Command characters

Commands characters enclosed in brackets `[]` are optional and are not required. Do not include the brackets when programming the Model 6514. Portions of commands in upper-case indicate the command short form; lower-case command characters are optional and need not be included in the command string. See Section 12 of the Model 6514 Instruction Manual for more information on programming syntax.

SCPI commands

SCPI commands to make basic measurements are provided in Table 4.

Table 4

SCPI commands for basic measurements

Command*	Description
[[:SENSe[1]]:FUNction <name>	Select function: 'VOLTage', 'CURRent', 'RESistance', or 'CHARge'.
[[:SENSe[1]]:XXX:RANGe <n>	Select measure range; <n> = range.
[[:SENSe[1]]:XXX:RANGe:AUTO 	Enable/disable auto range; (ON or OFF).
[[:SENSe[1]]:VOLTage:GUARd 	Enable (ON) or disable (OFF) guard for volts.
[[:SENSe[1]]:RESistance:GUARd 	Enable (ON) or disable (OFF) guard for ohms.
:SYSTem:ZCHeck 	Enable (ON) or disable (OFF) zero check.
:READ?	Trigger and acquire one data string.

* XXX = VOLTage, CURRent, RESistance, or CHARge, depending on function.

Programming examples

Volts measurement example — Table 5 shows a typical command sequence to measure volts on the 20V range with guard enabled.

Amps measurement example — Table 6 shows a typical command sequence to measure amps using auto range.

Table 5

Command sequence for volts measurement example

Command*	Comments
*RST	Restore GPIB defaults.
SENS:FUNC 'VOLT'	Select volts measurement function.
SENS:VOLT:RANG 20	Select 20V range.
SENS:VOLT:GUAR ON	Enable guard mode.
SYST:ZCH OFF	Disable zero check.
READ?	Trigger and acquire one voltage reading.

*Model 6514 must be addressed to talk after sending :READ? to trigger and acquire data.

Table 6
Command sequence for amps measurement example

Command*	Comments
*RST	Restore GPIB defaults.
SENS:FUNC 'CURR'	Select amps measurement function.
SENS:CURR:RANG:AUTO ON	Enable auto range.
SYST:ZCH OFF	Disable zero check.
READ?	Trigger and acquire one current reading.

*Model 6514 must be addressed to talk after sending :READ? to trigger and acquire data.

Settings to optimize performance

Range

To achieve best accuracy, the Model 6514 should be on the lowest possible measurement range. In most situations, auto range can be used to automatically select the best range. Auto range is controlled (enabled/disabled) by the AUTO range key (AUTO annunciator indicates auto range is enabled).

The RANGE 5 and 6 keys are used for manual range selection. Note that pressing either of these keys disables auto range.

The ranges for each measurement function are listed in Table 7. The range setting (fixed or AUTO) is remembered by each function. The full scale readings for every measurement range are 5% over range.

Table 7
Measurement ranges

V	I	Ω	Q
2V	20pA	2k Ω	20nC
20V	200pA	20k Ω	200nC
200V	2nA	200k Ω	2 μ C
	20nA	2M Ω	20 μ C
	200nA	20M Ω	
	2 μ A	200M Ω	
	20 μ A	2G Ω	
	200 μ A	20G Ω	
	2mA	200G Ω	
	20mA		

Rate

The RATE key selects the integration time of the A/D converter. This 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 measurement functions. Therefore, it does not matter what function is presently selected when you set rate. There are two ways to set rate. You can select slow, medium, or fast by using the RATE key, or you can set the number of power cycles from the NPLC menu that is accessed by pressing SHIFT and then NPLC.

To change the rate setting, press (and release) the RATE key until the desired rate annunciator (SLOW, MED, or FAST) is displayed:

- SLOW — Selects the slowest front panel integration time (6 PLC for 60 Hz or 5 PLC for 50 Hz) and sets display resolution to 5½-digit resolution. The SLOW rate provides better noise performance at the expense of speed.
- MED — Selects the medium integration time (1 PLC) and sets display resolution to 5½-digit resolution. Select the MED rate when a compromise between noise performance and speed is acceptable.
- FAST — Selects the fastest front panel integration time (0.1 PLC) and sets display resolution to 4½-digit resolution. Select the FAST rate if speed is of primary importance (at the expense of increased reading noise).

Digits

The DIGIT key sets display resolution for Model 6514. Display resolution can be set from 3½ to 6½ digits. This single global setting affects display resolution for all measurement functions. To set display resolution, press (and release) the DIGIT key until the desired number of digits is displayed.

NOTE Changing the integration rate changes display resolution, but changing display resolution does not change the rate setting (see RATE for details).

Filter

Filtering stabilizes noisy measurements caused by noisy input signals. The Model 6514 uses two types of filters: median and digital. 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. Therefore, the filter configuration applies to all four measurement functions. The MEDN key is used to configure and control the median filter, and the AVG key is used to configure and control the digital filter. When either the median or digital filter is enabled, the FILT annunciator is on.

Median filter

The median filter is used to determine the “middle-most” reading from a group of readings that are arranged according to size. 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)

To configure the median filter, press the MEDN key to display the present filter rank. Then use the RANGE keys to display the desired rank (1 to 5), and press ENTER.

Digital filter

The digital filter type can be either moving or repeating. With the moving filter, each 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. With the repeating filter, the unit takes a selected number of reading conversions, averages them, and yields a reading. It then flushes its stack and starts over.

To configure the digital filter, press the AVG key, (the set the number of readings to average (1-100)). Choose the repeat or moving average type, then press ENTER.

REL key

The REL key nulls an offset or subtracts a baseline value from future readings. Note that the rel value is the same for each measurement range. For example, a rel value of 1V on the 2V range is also 1V on the 20V and 200V ranges.

Perform the following steps to set a rel value:

1. Display the reading you want as the rel value. This could be a zero offset reading that you want to null out, or it could be an applied level that you want to use as a baseline.
2. Press REL. The REL annunciator turns on, and subsequent readings will be the difference between the actual input and the rel value.
3. To disable REL, press the REL key a second time. The REL annunciator turns off.

Remote command programming

The SCPI commands for speed, digits, filter, and rel are listed in Table 8. The commands for ranging are listed in Table 4.

Table 8

SCPI commands: rate, digits, filter, and rel

Command	Description
<p><i>Rate commands:</i></p> <p>[:SENSe[1]]:VOLTage:NPLCycles <n> [:SENSe[1]]:CURRent:NPLCycles <n> [:SENSe[1]]:RESistance:NPLCycles <n> [:SENSe[1]]:CHARge:NPLCycles <n></p>	<p>Set voltage rate in PLCs: 0.01 to 10. Set current rate in PLCs: 0.01 to 10. Set resistance rate in PLCs: 0.01 to 10. Set charge rate in PLCs: 0.01 to 10.</p>
<p><i>Digits command:</i></p> <p>:DISPlay:DIGits <n></p>	<p>Set display resolution: 4 to 7.</p>
<p><i>Median filter commands:</i></p> <p>[:SENSe[1]]:MEDian:RANK <n> [:SENSe[1]]:MEDian[:STATe] </p>	<p>Set median filter rank: 1 to 5. Enable or disable median filter.</p>
<p><i>Digital filter commands:</i></p> <p>[:SENSe[1]]:AVERage:TCONtrol <name> [:SENSe[1]]:AVERage:COUNT <n> [:SENSe[1]]:AVERage[:STATe] </p>	<p>Select filter control: MOVing or REPeat. Set filter count: 1 to 100. Enable or disable digital filter.</p>
<p><i>Rel command:*</i></p> <p>:CALCulate2:NULL:STATe </p>	<p>Enable/disable rel.</p>

* Does not include commands to set and acquire rel values. See Section 7 of Model 6514 Instruction Manual.

Features to enhance DUT testing

Buffer

The Model 6514 has a buffer to store from one to 2500 readings. It also stores overflow readings and includes a timestamp. In addition, recalled data includes statistical information (minimum, maximum, 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 math operations are performed. Math operations include $mX+b$, percent, or limits.

Storing readings

To store readings, press the STORE key, in the number of readings to store, and press ENTER. The star (*) annunciator indicates that the buffer is enabled. If in the immediate trigger mode, the storage process will start immediately. If in the external trigger mode, each input trigger (or press of TRIG key) will store a reading. The star (*) indicator will go off when the buffer is full.

Recalling readings

To recall readings, press the RCLL key. The message "RDG NO 1" is displayed. The arrow annunciator (\leftrightarrow) also turns on to indicate additional data is available for viewing. Use the RANGE and cursor keys to navigate through the reading numbers, reading values, timestamps, and buffer statistics. To return to the normal display, press EXIT.

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) reading is the absolute value of the difference between the MAX and MIN readings. It is calculated as follows:

$$\text{Peak-to-Peak} = |\text{MAX} - \text{MIN}|$$

- **Average** is the mean of the buffer readings. Mean is calculated as follows:

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

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. The equation used to calculate the standard deviation is:

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

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

NOTE The Model 6514 uses IEEE-754 floating point format for math calculations.

Remote buffer programming

SCPI commands

SCPI commands to configure and control the buffer and buffer statistics are listed in Table 9.

Table 9

SCPI commands: buffer

Command	Description
:TRACe:CLear	Clear readings from buffer.
:TRACe FREE?	Query bytes available and bytes in use.
:TRACe:POINts <n>	Specify number of readings to store: 1 to 2500.
:TRACe:FEED <name>	Select source of readings: SENSE[1], CALCulate[1], or CALCulate2.
:TRACe:FEED:CONTRol <name>	Select buffer control mode: NEVER or NEXT.
:TRACe:TSTamp:FORMat <name>	Select timestamp format: ABSolute or DELta.
:TRACe:DATA?	Read all readings in buffer.
:FORMat:ELEMents <list>	Specify buffer data elements: READING, TIME, and STATUS.
:CALCulate3:FORMat <name>	Select buffer statistic: MINimum, MAXimum, MEAN, SDEViation, or PKPK.
:CALCulate3:DATA?	Read selected buffer statistic.

Programming example

Table 10 shows a typical command sequence to store and recall readings and mean buffer statistics.

Table 10

Command sequence for buffer example

Command*	Comments
:TRAC:POIN 20	Set buffer size to 20,
:TRAC:FEED SENS	Set to store raw readings.
:TRAC:FEED:CONT NEXT	Start storing readings.
:TRAC:DATA?	Request all stored readings.*
:CALC3:FORM MEAN	Select mean calculation.
:CALC3:DATA?	Perform calculation and request result.*

*Model 6514 must be addressed to talk after sending :TRAC:DATA? and :CALC3:DATA? to acquire data.

Limit testing

Limit operations set and control the values that determine the pass/fail status of subsequent measurements. The limit test is performed on the result of an enabled Rel, mX+b, or Percent operation.

NOTE This guide contains basic information on limit testing. See Section 10 of the Model 6514 Instruction Manual for complete details on limit testing, including information on binning and using a component handler.

There are two sets of limit tests, Limit 1 and Limit 2. Both limits use high and low values. Factory defaults for both limit tests are +1 (high) and -1 (low). Table 11 lists limit test display messages depending on pass/fail status.

Table 11

Limit test display messages

Display Message	Limit 1 Test Result	Limit 2 Test Result
:OK	Pass	Pass
:L1	Fail	Not Performed
:L2	Pass	Fail

Configuring limit tests

Press SHIFT then CONF-LIM, then select LIMIT 1 or LIMIT 2. Use CONTROL to enable the test, then enter your HILIM and LOLIM values (-9.999999T to +9.999999T). (Place the cursor on the + or - keys to change polarity or the desired range symbol to change range.)

Once limit tests are configured, use the LIMIT key to start and stop the limit test. Results are displayed as summarized in Table 11.

Remote limits programming

SCPI commands

Basic SCPI commands for basic limit testing are listed in Table 12. See Section 10 of the Model 6514 Instruction Manual for additional limit test commands.

Table 12

SCPI commands: basic limit testing

Command	Description
:CALCulate2:LIMit:STATe 	Enable/disable Limit 1 test: = ON or OFF.
:CALCulate2:LIMit:LOWer <n>	Set lower limit for Limit 1: <n> = limit: -9.99999e20 to 9.99999e20.
:CALCulate2:LIMit:UPPer <n>	Set upper limit for Limit 1: <n> = limit: -9.99999e20 to 9.99999e20.
:CALCulate2:LIMit:FAIL?	Query Limit 1 test result (0 = pass, 1 = fail).
:CALCulate2:LIMit2:STATe 	Enable/disable Limit 2 test: = ON or OFF.
:CALCulate2:LIMit2:LOWer <n>	Set lower limit for Limit 2: <n> = limit: -9.99999e20 to 9.99999e20.
:CALCulate2:LIMit2:UPPer <n>	Set upper limit for Limit 2: <n> = limit: -9.99999e20 to 9.99999e20.
:CALCulate2:LIMit2:FAIL?	Query Limit 2 test result (0 = pass, 1 = fail).

Programming example

The programming example in Table 12 tests limits on a voltage. Limit 1 values are ± 1 , and Limit 2 values are ± 0.1 .

Table 13
Command sequence for limit test example

Command*	Comments
*RST	Restore GPIB defaults.
:CALC2:LIM:LOW -1	Set Limit 1 lower limit to -1.
:CALC2:LIM:UPP 1	Set Limit 1 upper limit to 1.
:CALC2:LIM:STAT ON	Enable Limit 1 test.
:CALC2:LIM2:LOW -0.1	Set Limit 2 lower limit to -0.1.
:CALC2:LIM2:UPP 0.1	Set Limit 2 upper limit to 0.1.
:CALC2:LIM2:STAT ON	Enable Limit 2 test.
:READ?	Trigger and request a reading.*
:CALC2:LIM:FAIL?	Request Limit 1 test result.*
:CALC2:LIM2:FAIL?	Request Limit 2 test result.*

*Model 6514 must be addressed to talk after sending :READ?, :CALC2:LIM:FAIL? and :CALC2:LIM2:FAIL? to acquire test result.

Math operations

Model 6514 math operations include $mX + b$ and percent.

$mX+b$

This math operation manipulates normal display readings (X) mathematically according to the following calculation:

$$Y = mX + b$$

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

To configure and enable $mX + b$, press SHIFT and then MX+B to display the present scale factor. Enter the desired M, B, and UNITS values at the prompts, and press ENTER. The MATH annunciator will turn on to indicate that $mX+b$ is enabled. Press SHIFT then MX+B again to disable the function. The MATH annunciator will turn off.

Percent (%)

This math function determines percent deviation from a specified reference value. The percent calculation is performed as follows:

$$\text{Percent} = \frac{\text{Input} - \text{Reference}}{\text{Reference}} \times 100\%$$

where: Input is the normal display reading.
 Reference is the user entered constant.
 Percent is the displayed result.

To configure and enable the percent function, press SHIFT then %. Enter the desired reference value, then press ENTER. The MATH annunciator will turn on to indicate that percent is enabled. Press SHIFT then % again to disable the function. The MATH annunciator will turn off.

Remote $mX+b$ and percent programming

SCPI commands

Table 14 summarizes commands used for $mX+b$ and percent.

Table 14
SCPI commands; $mX+b$ and percent

Command	Description
:CALCulate:FORMat <name>	Select calculation; MXB or PERCent.
:CALCulate:KMATH:MMFactor <n>	Specify scale factor (M) for $mX+b$: -9.99999e20 to 9.99999e20.
:CALCulate:KMATH:MBFactor <n>	Specify offset (B) for $mX+b$: -9.99999e20 to 9.99999e20.
:CALCulate:KMATH:MUNits <name>	Specify units for $mX+b$ (one or two characters enclosed in single or double quotes).
:CALCulate:KMATH:PERcent <n>	Specify reference value for Percent: -9.99999e20 to 9.99999e20.
:CALCulate:KMATH:PERcent:ACQuir	Use input signal as reference value.
:CALCulate:STATe 	Enable or disable the selected calculation.
:CALCulate:DATA?	Query calculation result.

Programming example

The command sequence in Table 15 programs the $mX+b$ function and requests the result.

Table 15
Command sequence for $mX+b$ measurement example

Command*	Comments
:CALC:FORM MXB	Select $mX+b$ function.
:CALC:KMAT:MMF 2	$M = 2$.
:CALC:KMAT:MBF 0.5	$B = 0.5$
:CALC:STAT ON	Enable $mX+b$.
:INIT	Trigger reading and calculation.
:CALC:DATA?	Request $mX+b$ result.

*Model 6514 must be addressed to talk after sending :CALC:DATA? to acquire reading.

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Specifications are subject to change without notice.

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