M1412A 7.5 Digit PXIe Digital Multimeter

KEYSIGHT

USER'S GUIDE

Notices

Copyright Notice

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This product has been designed and tested in accordance with accepted industry standards, and has been supplied in a safe condition. To review the Declaration of Conformity, go to www.keysight.com/go/conformity.

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Contact Keysight to obtain the source code. Keysight may charge for shipping.

Latest Information

To get the latest firmware/software/electronic manuals/specifications/support information, go to www.keysight.com and type in the product number in the Search field at the top of the page.

Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual may impair the protections provided by the product. In addition, it violates safety standards of design, manufacture, and intended use of the product. Keysight Technologies assumes no liability for customer's failure to comply with these requirements.

- Do not use this product in any manner not specified by the manufacturer. The protective features of this product may be impaired if it is used in a manner not specified in the operation instructions.

- This product is INDOOR USE product.

- This product complies with POLLUTION DEGREE 2 defined in IEC 61010-1.

- If an instrument is marked CAT I (IEC Measurement Category I), or it is not marked with a measurement category, its measurement terminals must not be connected to line-voltage mains.

WARNING

The persons who plan, supervise, consign, and implement the installation, start-up, maintenance, and delivery of this product are required to carefully read documents related to the equipment and take and implement safety measures to prevent accidents. Also, safety and performance of the system in which the equipment is installed are the responsibility of the assembler responsible for the system construction.

WARNING

Equipment built in the system may be heavy. So there is the possibility of physical disability in the person by moving the equipment to a high place or moving it from a high place. To prevent accidents, take appropriate safety work means.

DANGEROUS PROCEDURE WARNINGS

Warnings, such as above WARNING, shall be complied. Procedures throughout in this manual prevent you from potentially hazard. Their instructions contained in the warnings must be followed.

BEFORE APPLYING POWER

Verify that all safety precautions are taken. Make all connections to the instrument before applying power. Note the instrument's external markings described under "Safety Symbols".

GROUND THE INSTRUMENT

This is Safety Class I instrument. To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The power terminal and the power cable must meet International Electrotechnical Commission (IEC) safety standards.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

DO NOT REMOVE COVERS

No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock do not remove covers.

IN CASE OF DAMAGE

Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel. Return the instrument to a Keysight Technologies sales or service office for services and repair to ensure that safety features are maintained.

USE ONLY THE SPECIFIC ACCESSORIES

Specific accessories satisfy the requirements for specific characteristics for using the instrument. Use the specific accessories, cables, adapters, and so on for safety reasons.

CLEANING

To prevent electrical shock, disconnect the instrument from AC mains power and disconnect all test leads before cleaning. Clean the outside of the instrument using a soft, lint-free, cloth slightly dampened with water. Do not use detergent or solvents. Do not attempt to clean internally. If needed, contact a Keysight Technologies Sales and Service office to arrange for proper cleaning to ensure that safety features and performance are maintained.

CURRENT MEASUREMENT PROTECTION FUSE

For continued protection against fire, replace current-protection fuses only with fuses of the specified type and rating. The instrument must be disconnected from AC mains power, and all measurement terminals must be disconnected before changing the fuse.

MEASURING AC POWER MAINS

The Hi, Lo, and I input terminals may be connected to AC mains power in IEC Category II installations for line voltages up to 300 VAC. To avoid the danger of electric shock, do not connect the inputs to AC mains power for line voltages above 300 VAC. See IEC MEASUREMENT CATEGORY II (next page) for further information.

MEASURING CURRENT WITH A CURRENT TRANSFORMER

If a current transformer is used for measuring current, you must use a current transformer with internal secondary protection. Using a current transformer without protection may result in a hazardous voltage resulting in a severe shock or death. In addition, this may cause damage to the instrument.

CREST FACTOR

Exceeding the crest factor limit may result in an inaccurate or lower reading display. Do not exceed the crest factor limit to avoid instrument damage and risk of electric shock. The crest factor limit is listed in the product data sheet.

MEASUREMENT LIMITS

To avoid instrument damage and the risk of electric shock, do not exceed any of the Measurement Limits.

IEC MEASUREMENT CATEGORY II

To protect against the danger of electric shock, Keysight M1412A protects the user from AC mains power overvoltage events. When measuring AC mains, the Hi and Lo input terminals may be connected to AC mains power up to 300 VAC under Measurement Category II conditions as defined below.

IEC Measurement Category II includes electrical devices connected to AC mains power at an outlet on a branch circuit. Such devices include most small appliances, test equipment, and other devices that plug into a branch outlet or socket. The instrument may be used to make measurements with the Hi and Lo inputs connected to AC mains power in such devices, or to the branch outlet itself (up to 300 VAC).

However, the instrument may not be used with its Hi and Lo inputs connected to AC mains power in permanently installed electrical devices such as the main circuit-breaker panel, sub-panel disconnect boxes, or permanently wired motors. Such devices and circuits are subject to overvoltages that may exceed the instrument's protection capabilities.

Voltages above 300 VAC may be measured only in circuits that are isolated from AC mains power. However, transient overvoltages are also present on circuits that are isolated from AC mains power. The instrument is designed to safely withstand occasional transient overvoltages up to 2500 Vpk when measuring voltages up to 300 VAC. Do not use this equipment to measure circuits where transient overvoltages could exceed this level.

EMC

This product is a sensitive test and measurement equipment.

When subjected to transient radiated and/or conducted electromagnetic phenomena, the product may have temporary loss of function or performance which is self-recovering. Recovery may take longer than 10 seconds.

When subjected to continuously present electromagnetic phenomena, some degradation of performance may occur.

South Korean EMC Declaration

Information to the user:

This equipment has been conformity assessed for use in business environments. In a residential environment this equipment may cause radio interference.

(*) This EMC statement applies to the equipment only for use in business environment.

사용자안내문
이 기기는 업무용 환경에서 사용할 목적으로 적합성평가를 받은 기기로서 가정용 환경에서 사용하는 경우 전파간섭의 우려가 있습니다.

(*) 사용자 안내문은 "업무용 방송통신기자재"에만 적용한다.

Safety Symbols

The general definitions of safety symbols used on equipment or in manuals are listed below.

Direct current.

Alternating current.

Earth ground terminal.

Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Grounded terminal which indicates the earth potential.

On supply.

Off supply.

Standby supply. The equipment will be marked with this symbol is not completely disconnected from AC mains when power switch is in the standby position.

In position of a bi-stable push switch.

Out position of a bi-stable push switch.

Hazardous voltage and potential for electrical shock. Do not touch terminals that have this symbol when the equipment is on.

Hot surface. Avoid contact. Surfaces are hot and may cause personal injury if touched.

Low temperature or freezing conditions. Avoid contact. Surfaces are cold and may cause personal injury if touched.

Heavy object. Lifting can cause back injury. Use mechanical lifting device to move.

Caution, refer to accompanying documentation. The equipment will be marked with this symbol when it is necessary for the user to refer to the instruction manual.

Read operator's manual. To indicate that the operator's manual or card should be read before continuing the operation.

Affixed to product containing static sensitive devices--use anti-static handling procedures to prevent electrostatic discharge damage to component.The CE mark shows that the product complies with all applicable European Directives.

The CSA mark is a registered trademark of the Canadian Standards Association.

The RCM mark is a registered trademark of the Australian Communications Authority. This signifies compliance with the Australian EMC Framework Regulations under the terms of the Radio communications Act.

The UKCA mark shows that the product complies with all applicable UK regulations.

This is the symbol for an Industrial, Scientific and Medical, Group 1 Class A product. (CISPR 11)

CAN ICES/NMB-001(A)

This ISM device complies with Canadian ICES-001 Class A.
Cet appareil ISM est conforme à la norme NMB-001 classe A du Canada.

CAT I	IEC Measurement Category I
CAT II (300 V)	IEC Measurement Category II

Korea's safety and EMC mark

China RoHS - Environmentally Green Product Label

China RoHS - Product with Toxic Substance 40 yr EPUP

The Chinese mark for paper-based packaging materials; Paperboard and Corrugated Fiberboard

Plastic Material Coding Identification.

Waste Electrical and Electronic Equipment (WEEE)

The crossed out wheeled bin symbol indicates that separate collection for waste electric and electronic equipment (WEEE) is required, as obligated by the EU DIRECTIVE and other National legislation.

Please refer to http://keysight.com/go/takeback to understand your Trade in options with Keysight in addition to product takeback instructions.

WARNING

A WARNING denotes a hazard. It calls attention to an operating procedure or practice, that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

CAUTION

A CAUTION denotes a hazard. It calls attention to an operating procedure or practice, that, if not correctly performed or adhered to could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

In This Manual

This manual describes the installation, front panel operation, SCPI programming, and functions of the Keysight 7.5 digit PXIe Digital Multimeter. It consists of the following chapters.

1. "Introduction"

   This chapter provides one page of general information followed by the tasks you must perform to set up your module and verify your installation was successful.

2. "Application Information"

   This chapter provides multimeter application information.

3. "Measurement Configuration"

   This section describes information to help you configure the multimeter for making measurements.

4. "Programming Basics"

   This chapter describes basic information on programming for the M1412A and contains a brief introduction to the SCPI programming language. It also provides the range and resolution information of the M1412A.

5. "Common (*) Commands"

   This chapter provides descriptions of the SCPI common commands available for the M1412A.

6. "Subsystem Commands"

   This chapter provides descriptions of the device-specific SCPI commands available for the M1412A.

7. "Error Messages"

   This chapter lists the error messages for the M1412A.

8. "Special Functions and Range Commands"

   This chapter provides descriptions of the device special functions and range commands available for the M1412A.

9. "Differences Between the M1412A and E1412A"

   This chapter describes the differences between the M1412A and E1412A.

10. "Verification Tests"

    This chapter provides information for the verification tests on the M1412A.

NOTE

For the specifications of the M1412A, refer to the Data Sheet.

To get the latest information, go to www.keysight.com and type the model number in the Search box.

NOTE

The information contained within this manual is subject to change without notice due to the future modifications.

The actual product and screen images on the M1412A may be different from the images shown in this manual.

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5 Common (*) Commands

6 Subsystem Commands

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8 Special Functions and Range Commands

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10 Verification Tests

1 Introduction

The Keysight M1412A digital multimeter (DMM) delivers high-performance measurement with fast, easy installation and configuration via the Keysight Connection Expert and the Soft Front Panel (SFP).

Keysight also supplies software drivers that allow you to support the modules in many popular PXIe chassis and programming environments. The SFP is the main interface to control the DMMs.

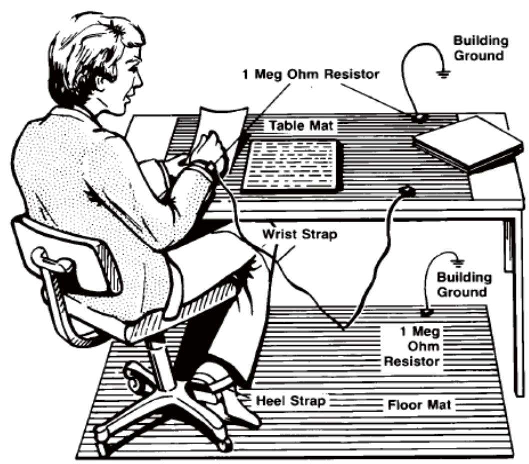
Related Documentation

For the latest specifications, documentation, software, and example programs, please see the Keysight web site at: www.keysight.com/find/pxie-dmm.

Unpack and Inspect the Module

CAUTION Keysight's PXIe chassis and instrument modules are shipped in materials that prevent static electricity damage. The modules should only be removed from the packaging in an anti-static area ensuring that correct anti-static precautions are taken. Store all modules in anti-static envelopes when not in use.

Electrostatic Discharge (ESD) Precautions



Electrostatic discharge (ESD) can damage or destroy electronic components. Use a static-safe workstation to perform all work on electronic assemblies. This figure shows a static-safe workstation using two types of ESD protection.

- Conductive table mat and wrist strap combination
- Conductive floor mat and heel strap combination

Both types, when used together, provide a significant level of ESD protection. Of the two, only the table mat and wrist strap combination provides adequate ESD protection when used alone. To ensure user safety, the static-safe accessories must provide at least 1 MΩ of isolation from ground.

WARNING DO NOT use these techniques for a static-safe workstation when working on circuitry with a voltage potential greater than 500 V.

Before Unpacking

The M1412A is designed to satisfy the IEC/EN61010-1 safety requirements and must only be installed in a PXIe chassis that is certified by a Nationally Recognized Testing Laboratory. The PXIe chassis must already be installed on a static-safe workbench so that you can install the module soon after unpacking.

Refer to the PXIe chassis manual for the chassis installation procedure and other details.

Inspect for Damage

After unpacking a module, carefully inspect it for any shipping damage. Report any damage to the shipping agent immediately, as such damage is not covered by the warranty (see warranty information at the beginning of this document).

CAUTION **To avoid damage when handling a module, do not touch any exposed components or connector pins.**

NOTE Visit www.keysight.com/find/tips for information on preventing damage to your Keysight equipment.

Return the Module for Service

To return a module for repair or service, follow the steps below.

1. Review the warranty information shipped with your product.
2. Contact Keysight to obtain a Return Material Authorization (RMA) and return address. For assistance in finding Keysight contact information, visit www.keysight.com/find/assist.
3. Write the following information on a tag and attach it to the malfunctioning equipment.
   - Name and address of the owner. A Post Office box is not acceptable as a return address.
   - Product model number (for example, M1412A)
   - Product serial number (for example, MYXXXXXXXX). The serial number label is located on the side of the module.
   - Description of the failure or service required.
4. Carefully pack the module in its original ESD bag and packing carton. If the original carton is not available, use bubble wrap or packing peanuts, place the instrument in a sealed container, and mark the container “FRAGILE.”
5. On the shipping label, write “ATTENTION REPAIR DEPARTMENT” and the RMA number.

NOTE If any correspondence is required, refer to the product by its serial number and model number.

Verify Shipment Content

The following item is included in this shipment.

Table 1-1 Shipment Content

Model number	Description	Quantity
M1412A	7.5 digit PXIe Digital Multimeter	1

Install the Software

NOTE Install the software prior to installing the PXIe modules in the chassis so that Keysight IO Libraries Connection Expert finds them.

Requirements

The following are required for installing the M1412A software.

- Controller (desktop PC, laptop PC, rackmount PC, or PXIe embedded computer) installed with Keysight IO Libraries Suite 2022 or later
- Windows 10 (64 bit) or Windows 11 (64 bit) operating system
- Microsoft .NET Framework 4.8 or later
- Keysight PXIe chassis that has already been set up

For setting up the controller and the PXIe chassis, refer to the PXIe chassis documentation.

NOTE A minimum of 1.5 GB of free space is required on the controller for installing the M1412A software. See “To Update the Firmware”.

Installation Process

Visit www.keysight.com/find/pxie-dmm to get the latest version of the M1412A software.

1. Copy the M1412A software installer into the controller.
2. Launch the M1412A software installer.
3. Follow the installer prompts to install the M1412A software.
4. Reboot the controller when prompted by the M1412A software installer.

If a firmware update is available, you can perform the firmware update by using SFP after the module installation. See “To Update the Firmware”.

Install the Module

NOTE

The M1412A multimeter must be installed in a PXIe chassis that has been certified by a Nationally Recognized Testing Laboratory.

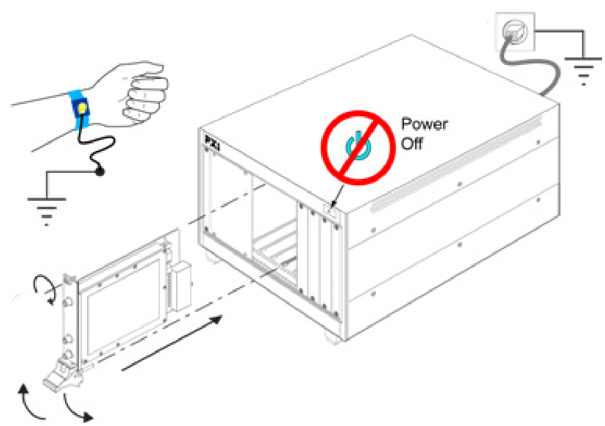
CAUTION

PXIe hardware does not support "hot-swap" (changing modules while power is applied to the chassis) capabilities. Before installing or removing a module to/from the chassis, power down the chassis to prevent damage to the module.

Place the chassis on a static-safe workstation (see "Electrostatic Discharge (ESD) Precautions") and position it so that there is ample space between the chassis fan intake and exhaust vents. Blockage by walls or obstructions affects the airflow needed for cooling. Use slot blockers and filler panels in empty slots to ensure proper operating temperatures.

For more information about precautions and cooling, refer to the PXIe chassis documentation.

An example of installation using a generic module is shown below. It may not reflect your module's actual size and chassis placement. Install the leftmost module first and continue installing modules from left to right according to the image below.



NOTE Before the module installation, make sure that the controller is turned off.

Procedure

1. Make sure that the power cord is plugged into a grounded outlet to establish earth ground and to prevent ESD.
2. Make sure that the chassis power switch is off.
3. If the chassis has multiple fan speed settings, ensure that the fans are set to automatic. Do not set the fan speed to low or turn them off.
4. Remove the filler panel that covers the slot in which you want to install the module.
5. Remove thread protectors from the top and bottom mounting screws of the module.
6. Hold the module by the injector/ejector handle, and slide it into the slot.
   - Install the module into the slot of the chassis by placing the module card edges into the front module guides (top and bottom).
   - Slide the module to the rear of the chassis and ensure that the injector/ejector handle is pushed down in the unlatched (downward) position.
   - Slide the module completely into the chassis. When you begin to feel resistance, push up on the injector/ejector handle to fully seat the module into the chassis.
7. Latch the module by pulling up on the injector/ejector handle and secure the front panel to the chassis using the module front-panel mounting screws.
8. Tighten the screws on the module front panel. Performance may suffer if the screws are not securely tightened.
9. Install all chassis covers, filler panels, and air scoops after installing the module. Also see the CAUTION below.

For more information on the module installation, refer to the PXIe chassis documentation.

CAUTION **Ensure that filler panels are installed in all empty slots. Missing filler panels will impact cooling of the chassis and may cause RFI (radio frequency interference) with other devices.**

Verify Operation of the Module

CAUTION

If you are using a remote controller (rackmount, desktop, or laptop PC), and you have installed the interface cable, you must power up the chassis before you power up the controller. When you power down your system, shut down the controller before you power down the chassis.

NOTE

Line frequency (power line frequency) must be set properly according to the AC power at your site. This setting is non-volatile and not changed by power-on or reset. The default is 60 Hz.

You must specify the line frequency by programming, if necessary.

To Check Communication

Perform the following procedure to check the communication between the module and the controller.

1. Make sure that the chassis and the controller are turned off.
2. If you are using a remote controller, connect a PXIe cable between the chassis and the controller.
3. Power up the chassis. Verify that the chassis fans are operating and free of obstructions that may restrict airflow.
4. Power up the controller.
5. Check that the controller automatically recognizes the module in the device manager; e.g. via **Start menu** > **Windows System Tools** > **Control Panel** > **Device Manager**. The module should be visible in the device tree.

   The controller might request a reboot. Reboot the controller, if requested.
6. Check if the module is also visible in the Keysight Connection Expert; e.g. via **Start menu** > **Keysight Connection Expert**.

   If something went wrong and the module is not shown in the PXIe section, it may be necessary to reboot the controller once more.

To Update the Firmware

If a firmware update is available, perform the update of the M1412A firmware. For details about the updating procedure, refer to the *M1412A Soft Front Panel User's Guide*.

To Perform a Self Test

You can perform the self test using the M1412 SFP.

NOTE Before performing the self test, disconnect cables from the measurement terminals.

1. Click **Start menu** > **Keysight M1412 7.5 Digit PXIe Digital Multimeter** > **M1412 SFP**. The Connect to Instrument dialog box will open.
2. In the list on the window, highlight the M1412A to connect, and click **Connect** to launch the M1412 SFP.
3. Select **Self Test** from the Utilities menu. The Self Test dialog box will open.
4. Click **Run Self Test** at the bottom of the Self Test dialog box to start the self test. When the self test is completed, the results will be displayed in the Self Test dialog box.

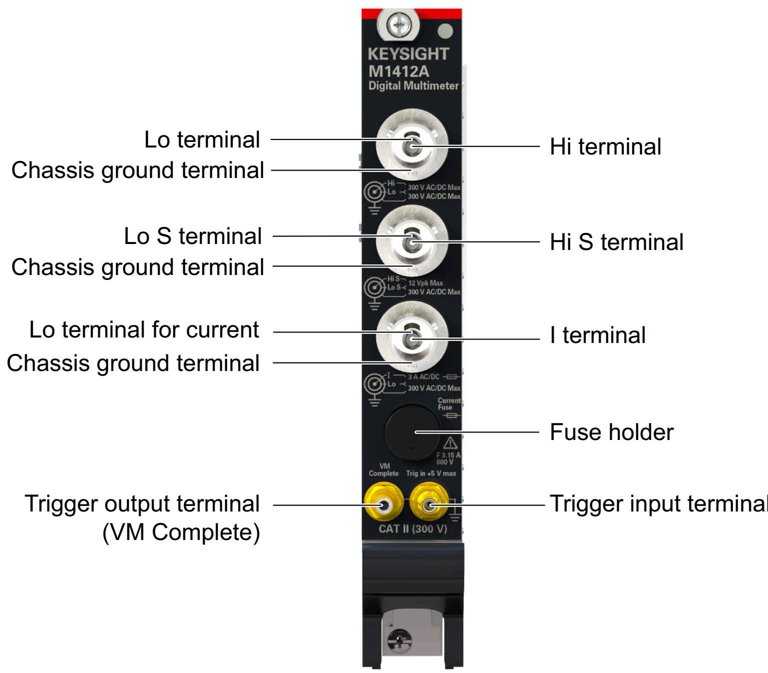
NOTE If the module fails the self test, it is defective. See "Return the Module for Service" to return the modules to Keysight.

CAUTION **Use the module within its ratings. If you input a signal above the rating, the module will be damaged.**

Front Panel Features

This section describes the connectors on the M1412A front panel.

Figure 1-1 M1412A Front Panel



NOTE High Sense and Low Sense are indicated by “Hi S” and “Lo S” respectively. Current is indicated by “I” in the above figure.

Measurement Terminals

WARNING

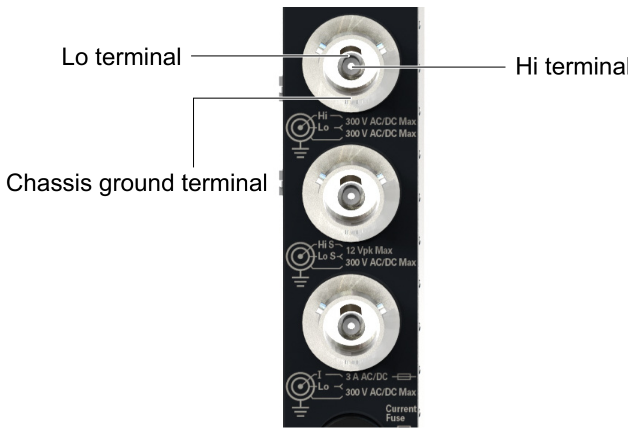
To avoid instrument damage and the risk of electric shock, do not exceed any of the Measurement Limits defined in the following section.

Pour éviter tout endommagement de l'instrument et risque d'électrocution, ne dépassez pas les limites de mesure définies dans la section suivante.

Hi and Lo

The top triaxial connector consists of a Hi terminal (center line), a Lo terminal (inner conductor), and a Chassis ground terminal (outer shield). This Hi-Lo terminal is used for DCV, 2-wire Resistance (RES or OHMS), 4-wire Resistance (FRES or FOHMS), and ACV measurement.

Figure 1-2 Top triaxial connector



The following table shows the maximum voltage between each terminal.

Table 1-2 Maximum voltage for each terminal

Terminals	Maximum Voltage
Hi to Lo	DC 300 V AC 300 Vrms
Hi to Chassis	DC 300 V AC 300 Vrms
Lo to Chassis	DC 300 V AC 300 Vrms

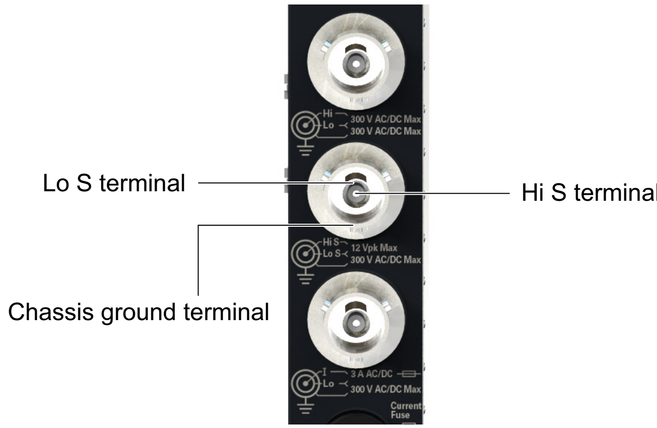
NOTE

For example, if DC 300 V is applied to the Hi terminal relative to the Lo terminal, the voltage of the Lo terminal relative to the Chassis must be less than 0 V. In this case, the voltage between the Hi terminal and the Chassis does not exceed 300 V.

Hi S and Lo S

The middle triaxial connector consists of a Hi S (Hi Sense) terminal (center line), a Lo S (Lo Sense) terminal (inner conductor), and a Chassis ground terminal (outer shield). This Hi S-Lo S terminal is used for 4-wire Resistance and 2nd DCV (DC2) measurement.

Figure 1-3 Middle triaxial connector



The following table shows the maximum voltage between each terminal.

Table 1-3 Maximum voltage for each terminal

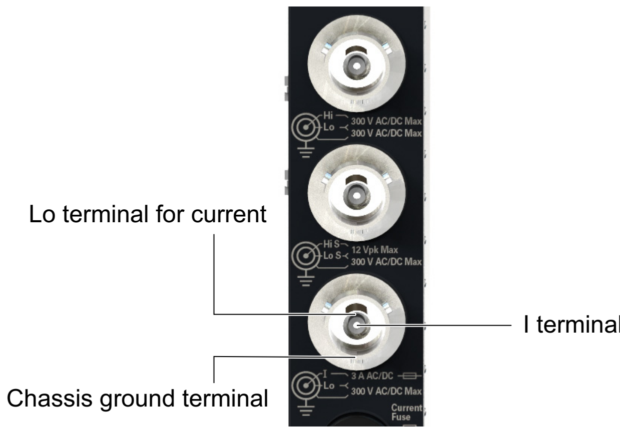
Terminals	Maximum Voltage
Hi S to Lo S	12 V peak
Hi S to Chassis	DC 300 V AC 300 Vrms
Lo S to Chassis	DC 300 V AC 300 Vrms
Lo to Lo S	2 V peak

NOTE For example, If DC 300 V is applied to the Hi S relative to the Chassis, the voltage of the Lo S terminal must be between 288 V and 300 V relative to the Chassis.

I and Lo

The bottom triaxial connector consists of an I (current) terminal (center line), a Lo terminal (inner conductor) for current, and a chassis ground (outer shield). This I-Lo terminal is used for DCI and ACI measurement.

Figure 1-4 Bottom triaxial connector



The following tables show the maximum voltage and current between each terminal.

Table 1-4 Maximum voltage between I and Chassis

Terminals	Maximum Voltage
I to Chassis	DC 300 V AC 300 Vrms

Table 1-5 Maximum current between I and Lo terminals

Terminals	Maximum Current
I to Lo	DC 3 A AC 3 Arms

CAUTION The Lo terminal of the Hi/Lo input (inner conductor) and the I/Lo input (inner conductor) are connected inside the module, thus they have the same voltage potential. The voltage applied to the Lo terminal of the Hi/Lo input appears on the Lo terminal of the I/Lo input as well, and vice versa.
For the above reason, deformed or dirty connectors may cause unintended hazards. To protect connectors from physical damage or dirt, use open caps that are furnished with M1412A for unused terminals.

SMB ⚠ The two bottom SMB terminals are the VM Complete output terminal (left) and the Trigger input terminal (right). The signal coming out from the VM Complete terminal is a negative pulse as default. The VM Complete pulse output is generated at the end of each sample. Trigger input is used as a measurement start trigger for the M1412A. The signal and specifications are described in “Triggering the Multimeter”.

Figure 1-5 SMB terminals

Fuse

The fuse holder has a fuse inside.

Fuse

You can change the fuse by extracting the holder from the module using a flathead screwdriver. You can access it via the module front panel.

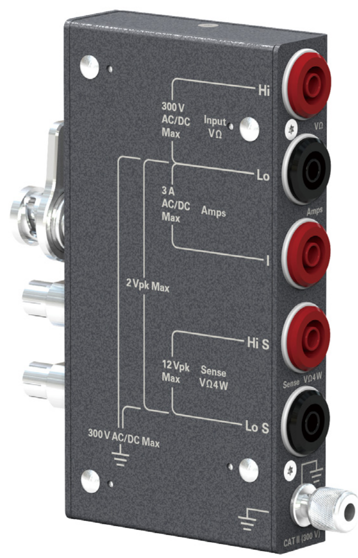
Fuse rating: 3.15 A, 600 V, fast acting (Keysight Part Number: 2110-1857)

Figure 1-6 Fuse holder

Accessories

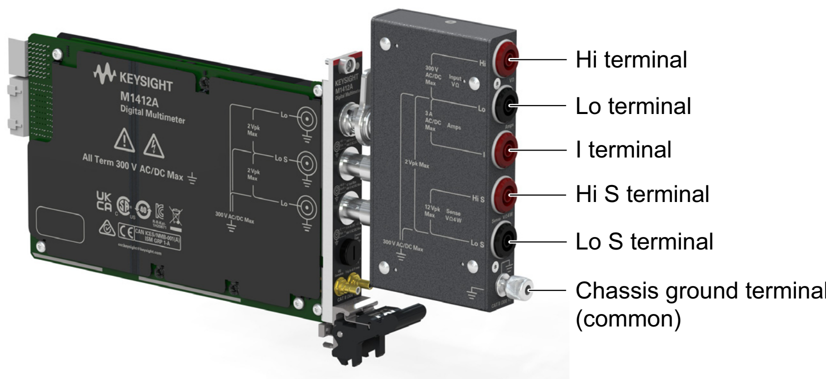
M1401A Triaxial – Banana Adapter provides the function to change the DUT interface from Triaxial to Banana.

Figure 1-7 M1401A Triaxial – Banana Adapter



From top to bottom, the terminals are Hi, Lo, I, Hi S, Lo S, and binding post, which is connected to the chassis common.

Figure 1-8 M1412A Front Panel with M1401A



NOTE High Sense and Low Sense are indicated by “Hi S” and “Lo S” respectively, then Current is indicated by “I” in the above figure.

CAUTION Please use a banana test leads that have the following ratings:

- 300 V or more for voltage measurement
- 3 A or more for current measurement
- IEC Measurement Category II for mains measurement

2 Application Information

This chapter provides the multimeter application information.

Measurement Tutorial

The M1412A multimeter is capable of making highly accurate measurements. In order to achieve the greatest accuracy, you must take the necessary steps to eliminate potential measurement errors. This section describes common errors found in measurements and gives suggestions to help you avoid these errors.

DC Voltage Measurements

Thermal EMF (Electromotive Force) Errors

Thermoelectric voltages are the most common source of error in low-level DC voltage measurements. Thermoelectric voltages are generated when you make circuit connections using dissimilar metals at different temperatures. Each metal-to-metal junction forms a thermocouple, which generates a voltage proportional to the junction temperature. You should take the necessary precautions to minimize thermocouple voltages and temperature variations in low-level voltage measurements. The best connections are formed using copper-to-copper crimped connections. Table 2-1 shows common thermoelectric voltages for connections between dissimilar metals.

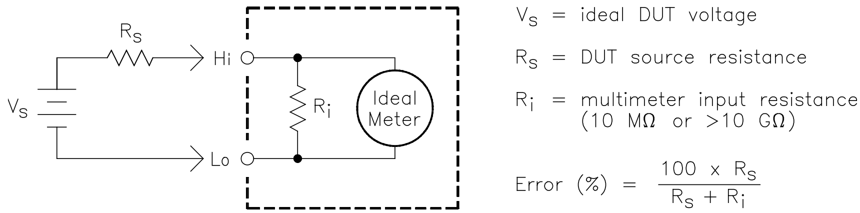
Table 2-1 **Thermoelectric Voltages**

Copper-to-... *	**Approx. µV/°C**
Copper	<0.3
Gold	0.5
Silver	0.5
Brass	3
Beryllium Copper	5
Aluminum	5
Kovar or Alloy 42	40
Silicon	500
Copper-Oxide	1000
Cadmium-Tin Solder	0.2
Tin-Lead Solder	5

* The M1412A input terminals are copper alloy.

Loading Errors (DC Voltage)

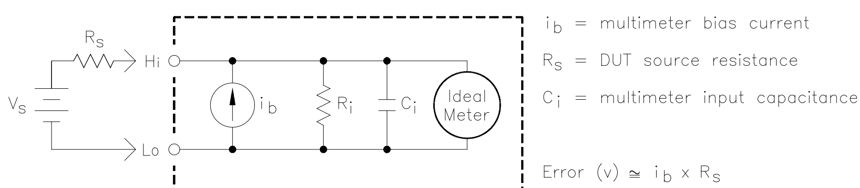
Measurement loading errors occur when the resistance of the device-under-test (DUT) is an appreciable percentage of the multimeter's own input resistance. The diagram below shows this error source.



To reduce the effects of loading errors, and to minimize noise pickup, you can set the multimeter's input resistance to greater than 10 GΩ for the 100 mV, 1 V, and 10 V ranges. The input resistance is maintained at 10 MΩ for the 100 V and 300 V ranges.

Leakage Current Errors

The multimeter's input capacitance will "charge up" due to input bias currents when the terminals are open-circuited (if the input resistance is 10 GΩ). The multimeter's measuring circuitry exhibits approximately 30 pA of input bias current for ambient temperatures from 0 °C to 30 °C. The bias current will double (×2) for every 8 °C change in ambient temperature above 30 °C. This current generates small voltage offsets dependent upon the source resistance of the DUT. This effect becomes evident for a source resistance of greater than 100 kΩ, or when the multimeter's operating temperature is significantly greater than 30 °C.



Rejecting Power Line Noise Voltages

A desirable characteristic of integrating analog-to-digital (A/D) converters is their ability to reject spurious signals. The integrating techniques reject power-line-related noise present with a DC signal on the input. This is called normal mode rejection or NMR. Normal mode noise rejection is achieved when the multimeter measures the average of the input by integrating it over a fixed period. If you set the integration time to a whole number of power line cycles (PLCs), these errors (and their harmonics) will average out to approximately zero.

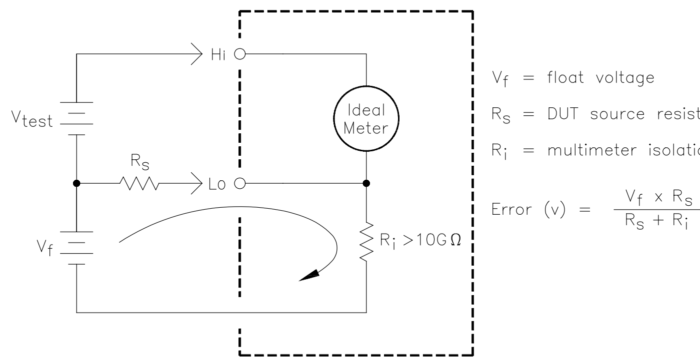
The power line frequency defaults to 60 Hz unless you specifically set it to 50 Hz with the `CAL:LFR` command. The multimeter determines the proper integration time based on which power line frequency is set. Table 2-2 shows the noise rejection achieved with various configurations. Select a longer integration time for better resolution and increased noise rejection.

Table 2-2 Noise Rejection

PLCs	Integration Time		NMR
	60 Hz	(50 Hz)	
0.02	334 µs	(400 µs)	NONE
0.2	3.34 ms	(4 ms)	NONE
1	16.7 ms	(20 ms)	60 dB
10	167 ms	(200 ms)	60 dB
100	1.67 s	(2 s)	60 dB

Common Mode Rejection (CMR)

Ideally, a multimeter is completely isolated from earth-referenced circuits. However, there is finite resistance between the multimeter's input Lo terminal and earth ground as shown below. This can cause errors when measuring small voltages, which are floating relative to earth ground.



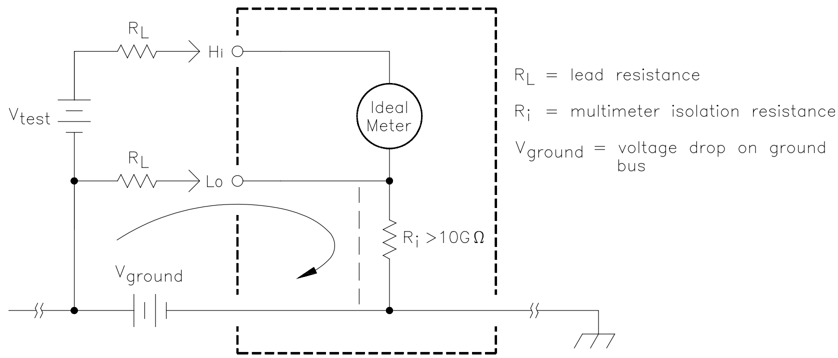
Noise Caused by Magnetic Loops

If you are making measurements near magnetic fields, you should take the necessary precautions to avoid inducing voltages in the measurement conductors. You should be especially careful when working near conductors carrying large currents. Use twisted-pair connections to the multimeter to reduce the noise pickup loop area, or dress the input cables as close together as possible. Also, loose or vibrating input cables will induce error voltages. Make sure your input cables are tied down securely when operating near magnetic fields. Whenever possible, use magnetic shielding materials or physical separation to reduce problematic magnetic field sources.

Noise Caused by Ground Loops

When measuring voltages in circuits where the multimeter and the DUT are both referenced to a common earth ground but at different points, a "ground loop" is formed. As shown below, any voltage difference between the two ground reference points (V_{ground}) causes a current to flow through the measurement leads. This causes errors such as noise and offset voltage (usually power-line related), which are added to the measured voltage.

The best way to eliminate ground loops is to maintain the multimeter's input isolation from earth; do not connect the input terminals to ground. If the multimeter must be earth-referenced, be sure to connect it, and the DUT, to the same common ground point. This will reduce or eliminate any voltage difference between the devices. Also, make sure the multimeter and the DUT are connected to the same electrical outlet whenever possible.



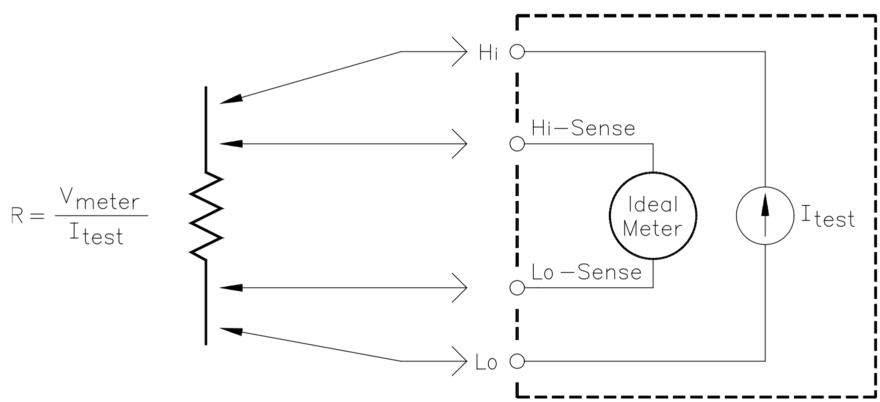
Resistance Measurements

The M1412A offers two methods for measuring resistance: 2-wire and 4-wire resistance. For both methods, the test current flows from the input Hi terminal and then through the resistor being measured. For 2-wire resistance, the voltage drop across the resistor being measured is sensed internally by the multimeter. Therefore, input cable resistance is also measured. For 4-wire resistance, separate “sense” connections are required. Since no current flows through the Hi-Lo “Sense” terminal cables, the resistances in these cables do not give a measurement error.

The errors discussed previously for DC voltage measurements also apply to resistance measurements. Additional error sources unique to resistance measurements are discussed in the following sections.

4-Wire Resistance Measurements

The 4-wire resistance method provides the most accurate way to measure small resistances. Errors due to test cable resistances and contact resistances are reduced using this method. 4-wire resistance is often used in automated test applications where long cable lengths, numerous connections, or switches exist between the multimeter and the DUT. The recommended connections for 4-wire resistance measurements are shown below.



Removing Field Wiring Resistance Errors in 2-Wire Resistance Measurements

Field wiring can cause an offset error in 2-wire resistance measurements. You can use the following procedure to minimize offset errors associated with field wiring resistance in 2-wire resistance measurements. Firstly, short the field wiring at the DUT location and measure the 2-wire lead resistance. This value is subtracted from subsequent DUT 2-wire resistance measurements. There are two ways to effectively null out the lead resistance. The first way is to characterize your field lead resistance by shorting the leads at the DUT location and measure and record the lead resistance. Then enable the math operation and store the 2-wire lead measurement value using the `CALCulate:NULL:OFFSet <value>` command (`CALC:STATe` must be `ON` to do this).

The following program shows SCPI examples used to store a `NULL` value.

Procedure	SCPI
Set it to the 2-wire resistance function.	`CONF:RES`
Short the lead resistance at the DUT location.	
Measure the 2-wire lead resistance.	`READ?`
Enter the lead resistance value into the computer.	
Set the math operation to NULL.	`CALCulate:FUNCtion NULL`
Turn the math operation ON.	`CALCulate:STATe ON`
Store the NULL offset value.	`CALCulate:NULL:OFFSet <value>`

Subsequent 2-wire resistance measurements will subtract the null offset value from the measurement thereby removing the lead resistance from the measurement.

The second way to store the 2-wire lead resistance as the `NULL` offset value is to let the multimeter automatically do this with the first measurement. The first measurement made after `CALCulate` function is set to `NULL` and the `STATe` is set to `ON` stores the measured value as the null offset.

Procedure	SCPI
Set it to the 2-wire resistance function.	`CONF:RES`
Short the lead resistance at the DUT location.	
Set the math operation to NULL.	`CALCulate:FUNCtion NULL`
Turn the math operation ON.	`CALCulate:STATe ON`
Measure the 2-wire lead resistance.	`READ?`
Enter the lead resistance value into the computer. The value is automatically stored in the multimeter's null offset register. *Remove the short from the lead resistance at the DUT location and connect leads to your DUT.*	
Make a 2-wire resistance measurement.	`READ?`
Enter the lead resistance value into the computer. The NULL value is subtracted from the measurement to more accurately provide the DUT resistance.	

Power Dissipation Effects

When measuring resistors designed for temperature measurements (or other resistive devices with large temperature coefficients), be aware that the multimeter will dissipate some power in the DUT. If power dissipation is a problem, you should select the multimeter's next higher measurement range to reduce the errors to acceptable levels. Table 2-3 shows several examples.

Table 2-3 DUT Power Dissipation

Range	Test Current	DUT Power at Full Scale
100 Ω	1 mA	100 μW
1 kΩ	1 mA	1 mW
10 kΩ	100 μA	100 μW
100 kΩ	10 μA	10 μW
1 MΩ	5 μA	25 μW
10 MΩ	500 nA	2.5 μW

Settling Time Effects

The M1412A has the ability to insert automatic measurement settling delays with the `TRIG:DEL` command. These delays are adequate for resistance measurements with less than 200 pF of combined cable and device capacitance. This is particularly important if you are measuring resistances above 100 kΩ. Settling due to RC time constant effects can take quite a long time. Some precision resistors and multi-function calibrators use large parallel capacitors (1000 pF to 0.1 μF) with high resistor values to filter out noise currents injected by their internal circuitry. Non-ideal capacitances in cables and other devices may have much longer settling times than expected just by RC time constants due to dielectric absorption (soak) effects. Errors will be measured when settling after the initial connection and after a range change.

Errors in High Resistance Measurements

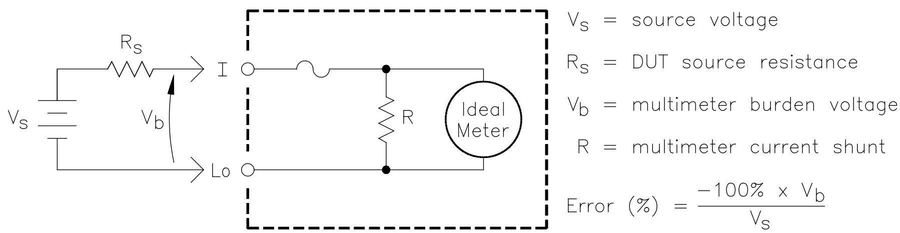
When measuring large resistances, significant errors can occur due to insulation resistance and surface cleanliness. You should take the necessary precautions to maintain a “clean” high-resistance system. Test cables and fixtures are susceptible to leakage due to moisture absorption in insulating materials and “dirty” surface films. Nylon and PVC are relatively poor insulators ($10^9\ \Omega$) when compared to PTFE insulators ($10^{13}\ \Omega$). Leakage from nylon or PVC insulators can easily contribute a 0.1% error when measuring a 1 MΩ resistance in humid conditions.

Making High-Speed DC and Resistance Measurements

The multimeter incorporates an automatic zero measurement procedure (autozero) to eliminate internal thermal EMF and bias current errors. Each measurement actually consists of a measurement of the input terminals followed by a measurement of the internal offset voltage. The internal offset voltage error is subtracted from the measurement for improved accuracy. This compensates for offset voltage changes due to temperature. For maximum reading speed, turn autozero off. This will more than double your reading speeds for DC voltage, resistance, and DC current functions. Autozero does not apply to other measurement functions.

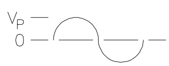
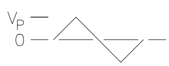
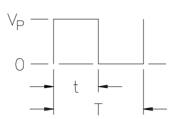
DC Current Measurement Errors

When you connect the multimeter in series with a test circuit to measure current, a measurement error is introduced. This error is caused by the multimeter's series burden voltage. A voltage is developed across the wiring resistance and current shunt resistance of the multimeter as shown below.



True RMS AC Measurements

True RMS (root mean square) responding multimeters, like the M1412A, measure the “heating” potential of an applied signal. Unlike an “average responding” measurement, a true RMS measurement can be used to determine the power dissipated in a resistance, even for non-sinusoidal signals. The power is proportional to the square of the measured true RMS voltage, independent of waveshape. An average responding AC multimeter is calibrated to read the same as a true RMS meter for sinewave inputs only. For other waveform shapes, an average responding meter will exhibit substantial errors as shown below.

Waveform Shape	AC RMS	AC+DC RMS	Average Responding Error
	$\frac{V_P}{\sqrt{2}} = \frac{V_P}{1.414}$	$\frac{V_P}{\sqrt{2}} = \frac{V_P}{1.414}$	Calibrated for 0 error
	$\frac{V_P}{\sqrt{3}} = \frac{V_P}{1.732}$	$\frac{V_P}{\sqrt{3}} = \frac{V_P}{1.732}$	−3.9%
	$V_P\sqrt{\frac{t}{T} - \frac{t^2}{T^2}}$	$V_P\sqrt{\frac{t}{T}}$	−46% for C.F. = 4

The multimeter’s AC voltage and AC current functions measure the AC-coupled true RMS value. This is in contrast to the AC+DC true RMS value shown above. Only the “heating value” of the AC components of the input waveform is measured (DC is rejected). For non-offset sinewaves, triangle waves, and square waves, the AC and AC+DC values are equal since these waveforms do not contain a DC offset. Non-symmetrical waveforms, such as pulse trains, contain DC voltages, which are rejected by AC-coupled true RMS measurements.

An AC-coupled true RMS measurement is desirable in situations where you are measuring small AC signals in the presence of large DC offsets such as when measuring AC ripple present on DC power supplies. There are situations, however, where you might want to know the AC+DC true RMS value. You can determine this value by combining results from DC and AC measurements as shown below. You should perform the DC measurement using at least 10 PLSs of integration for best AC rejection.

$$RMS_{(ac + dc)} = \sqrt{ac^2 + dc^2}$$

Crest Factor Errors (Non-Sinusoidal Inputs)

A common misconception is "if an AC multimeter is a true RMS instrument, the multimeter's sinewave accuracy specifications apply to all waveforms." However, in actuality, the shape of the input signal can dramatically affect measurement accuracy. A common way to describe signal waveshapes is the crest factor. The crest factor of a waveform is the ratio of its peak value to its RMS value.

Common Crest Factors

The crest factor for a sine wave is $\sqrt{2}$ =1.414. For a triangular wave, the crest factor is $\sqrt{3}$ = 1.732. For a square wave with pulse width t and duty cycle T, (see the graphic in the previous section), the crest factor is T/t.

For a pulse train, the crest factor is approximately equal to the square root of the inverse of the duty cycle. In general, the greater the crest factor, the greater the energy contained in higher-frequency harmonics. All multimeters exhibit measurement errors that are crest factor dependent. M1412A crest factor errors are shown in the AC Characteristics Accuracy Specifications listed in the Datasheet with the exception that crest factor errors are not specified for non-sine-wave input signals below 100 Hz when using the slow AC filter (3 Hz filter).

You can estimate the measurement error for a non-sinusoidal input signal shown below:

Total Error = Error (sine) + Error (crest factor) + Error (bandwidth)

Error (sine): error for sinewave as shown in Datasheet, Specifications.

Error (crest factor): crest factor additional error as shown in Datasheet.

Error (bandwidth): estimated bandwidth error as shown below.

$$ERROR_{(bandwidth)} = \frac{-(C.F.)^2 \times f}{4\pi \times BW} \times 100\%$$

C.F. = signal's crest factor
f = signal's fundamental frequency
BW = multimeter's -3 dB bandwidth
(600 kHz for the M1412A)

Example Calculate the approximate measurement error for a pulse train input with a crest factor of 3 and a fundamental frequency of 20 kHz. For this example, assume the multimeter's 90-day accuracy specifications:
±(0.05% + 0.03%).

$$\text{Total Error} = 0.08\% + 0.15\% + 2.4\% = 2.6\%$$

Loading Errors (AC Voltage)

In the AC voltage function, the input of the M1412A appears as a 1 MΩ resistance in parallel with 100 pF of capacitance. The cabling that you use to connect signals to the multimeter will also add additional capacitance and loading.

For low frequencies where $(f \times R_s) \le 15(10^6)\Omega \bullet \text{Hz}$:

$$\text{Error (\%)} = \frac{-100 \times R_s}{R_s + 1\ \text{M}\Omega}$$

For any frequency:

$$\text{Error (\%)} = 100 \times \left[\frac{1}{\sqrt{1 + \left(2\pi\ f\ C_{in} \cdot \frac{(1\ \text{M}\Omega)R_s}{1\ \text{M}\Omega + R_s}\right)^2}}\left(\frac{1\ \text{M}\Omega}{1\ \text{M}\Omega + R_s}\right) - 1\right]$$

Rs = source resistance
f = input frequency
Cin = input capacitance (100 pF) plus cable capacitance

AC Measurements Below Full Scale

You can make the most accurate AC measurements when the multimeter is at full scale of the selected range. Autoranging occurs at ≤10% and ≥120% of full scale. This enables you to measure some inputs at full scale on one range and 10% of full scale on the next higher range (e.g., 10 V on the 10 V range or 10 V on the 100 V range). The accuracy will be significantly different for these two cases. For the highest accuracy, you should specify the range to ensure the lowest range possible for the measurement (this turns autorange off).

Low-Level Measurement Errors

When measuring AC voltages less than 100 mV, be aware that these measurements are especially susceptible to errors introduced by extraneous noise sources. Exposed (unshielded) cabling will act as an antenna and a properly functioning multimeter will measure the signals received. The entire measurement path, including the power line, acts as a loop antenna. Circulating currents in the loop will create error voltages across any impedances in series with the multimeter's input. For this reason, you should apply low-level AC voltages to the multimeter through shielded cables. You should connect the shield to the input Lo terminal.

Make sure the multimeter and the AC source are connected to the same electrical outlet whenever possible. You should also minimize the area of any ground loops that cannot be avoided. Measurements of high-impedance sources are more susceptible to noise pickup than measurements of low-impedance sources. You can reduce the noise pick-up by placing a capacitor in parallel with the multimeter's input terminals. You may have to experiment to determine the correct capacitor value for your application since this capacitance will contribute to some loading error.

Most extraneous noise is not correlated with the input signal. You can determine the error as shown below.

$$\text{Voltage Measured} = \sqrt{\text{Vin}^2 + \text{Noise}^2}$$

Correlated noise, while rare, is especially detrimental because it will always add directly to the input signal. Measuring a low-level signal with the same frequency as the local power line is a common situation prone to this error.

AC Turnover Errors

Errors are generated when the multimeter’s input Lo terminal is driven with an AC voltage relative to earth. The most common situation where unnecessary turnover errors are created is when the output of an AC calibrator is connected to the multimeter “backward.” Ideally, a multimeter reads the same regardless of how the source is connected. However, both source and multimeter effects can degrade this ideal situation.

Because of the capacitance between the input Lo terminal and earth (approximately 200 pF for the M1412A), the source will experience different loading depending on how the input is applied. The magnitude of the error is dependent upon the source’s response to this loading. The multimeter’s measurement circuitry, while extensively shielded, responds differently in the backward input case due to slight differences in stray capacitance to earth. Because of this, the 100 V and 300 V AC ranges may latch up for high voltage, high frequency “backward” inputs. Therefore, only drive the high terminal when measuring AC voltages. You can use the grounding techniques described for DC common mode problems to minimize AC common mode voltages (see “Common Mode Rejection (CMR)”).

AC Current Measurement Errors

Burden voltage errors, which apply to DC current, also apply to AC current measurements. However, the burden voltage for AC current is larger due to the multimeter's series inductance and your measurement connections. The burden voltage increases as the input frequency increases. Some circuits may oscillate when performing current measurements due to the multimeter's series inductance and your measurement connections.

Making High-Speed AC Voltage or Current Measurements

The multimeter's AC voltage and AC current functions implement three different low-frequency filters. These filters allow you to trade low-frequency accuracy for faster reading speed. The *fast filter* settles in 0.1 seconds, and is useful for frequencies above 200 Hz. The *medium filter* settles in 1 second, and is useful for measurements above 20 Hz. The *slow filter* settles in 5 seconds, and is useful for frequencies above 3 Hz.

With a few precautions, you can perform AC measurements at speeds up to 500 readings per second. Use manual ranging to eliminate autoranging delays. By setting the preprogrammed settling (trigger) delays to 0, the fast (200 Hz) filter will allow up to 500 readings per second, and the medium (20 Hz) and slow (3 Hz) filters will allow up to 50 readings per second. However, the measurement might not be very accurate since the filter is not fully settled. In applications where sample-to-sample levels vary widely, the medium filter (20 Hz) will settle adequately at almost 1 reading per second, and the fast filter (200 Hz) will settle adequately at almost 10 readings per second.

If the sample-to-sample levels are similar, little settling time is required for each new reading. Under this specialized condition, the medium filter will provide reduced accuracy results at 50 readings per second, and the fast filter will provide reduced accuracy results at 500 readings per second. Additional settling time may be required when the DC level varies from sample to sample.

DC Blocking Circuitry

The multimeter's DC blocking circuitry has a settling time constant of 0.2 seconds. This time constant only affects measurement accuracy when DC offset levels vary from sample to sample. If maximum measurement speed is desired in a scanning system, you may want to add an external DC blocking circuit to those channels with significant DC voltages present. This circuit can be as simple as a resistor and a capacitor.

Frequency and Period Measurement Errors

The multimeter uses a reciprocal counting technique to measure frequency and period. This method generates a constant measurement resolution for any input frequency. The multimeter's AC voltage measurement section performs input signal conditioning. All frequency counters are susceptible to errors when measuring low-voltage, low-frequency signals. The effects of both internal noise and external noise pickup are critical when measuring “slow” signals. The error is inversely proportional to frequency. Measurement errors will also occur if you attempt to measure the frequency (or period) of an input following a DC offset voltage change. You must allow the multimeter's input DC blocking capacitor to fully settle before making frequency measurements.

3 Measurement Configuration

This section describes information to help you configure the multimeter for making measurements.

M1412A / E1412A Mode

The M1412A covers all of the functions that the E1412 has. The SCPI Service Manager of the M1412 works with 2 modes: M1412A mode and E1412A mode. In each mode, the parameters written in Table 3-1 are different.

Table 3-1 Different Parameters between M1412A Mode and E1412A Mode

Parameters	Remarks
Trigger Delay	Trigger delay is the delay time between receiving the trigger and beginning the measurement. The value is different depending on the function.
Range (DCI measurement)	1 μA to 1 mA is not defined (cannot be used) for E1412A mode.
Range (RES and FRES measurement)	The 10 Ω range and 1GΩ range are not defined (cannot be used) for E1412A mode.
NPLC	0.000025 (50 Hz) or 0.000030 (60 Hz) to 1 PLC with 0.000025 (50 Hz) or 0.000030 (60 Hz) resolution and integers from 1 to 100 can be used for M1412A mode. 0.000025 (50 Hz) or 0.000030 (60 Hz) to 0.02 PLC cannot be used for E1412A mode. (See Table 3-9 for details)
Aperture (DC measurement)	In the M1412A mode, the following settings can be used. 500 ns to 16.7 ms (60 Hz) or 20 ms (50 Hz). 500 ns resolution. 16.7 ms (60 Hz) or 20 ms (50 Hz) to 2.0 s. 16.7 ms (60 Hz) or 20 ms (50 Hz) resolution. 500 ns to 400 μs cannot be used for E1412A mode. (See Table 3-10 for details)
Aperture (FREQ and PER measurement)	0.001 s cannot be used for E1412A mode.

Setting the Line Frequency Reference

You must set the line frequency reference to the line frequency of the power source to your mainframe for maximum normal mode rejection (NMR). NMR is the multimeter's ability to reject power line frequency noise in a DC voltage or resistance measurement. You should set the multimeter's line frequency reference to the exact power line frequency (50, 60, or 400 Hz). Failure to set the line frequency reference to that of your source will cause reading errors.

You use the `CALibration:LFRequency` command to set the line frequency reference. The default setting after factory shipment is 60 Hz. If you use 50 Hz or 400 Hz you need to set the line frequency reference for maximum NMR. Specifying 400 Hz actually sets the line frequency reference to 50 Hz since 50 Hz is a sub harmonic of 400 Hz. Executing a `CALibration:LFRequency?` will return `+50` after executing `CAL:LFR 400` to set the line frequency reference to 400 Hz.

The line frequency reference setting is also useful when the device being measured operates at a different frequency than the multimeter. For example, if the multimeter has a power line frequency reference of 60 Hz and the device being measured has a power line frequency of 50 Hz, maximum NMR is achieved by setting the multimeter's reference frequency to 50 Hz by executing:

```
CAL:LFR 50
```

Filter Bandwidth

The M1412A has three different AC filter bandwidths that enable you to either optimize low-frequency accuracy or achieve faster AC settling times for AC voltage or AC current measurements. You can select 200 Hz (Fast), 20 Hz (Medium), or 3 Hz (Slow). For example, if the minimum frequency value in the input voltage is 30 Hz, then Filter Bandwidth=20 Hz or 3 Hz should be selected. The settling time (the duration needed for the measurement value to be settled) is shorter if a higher bandwidth is selected.

Table 3-2 AC Filter Bandwidth

AC Signal Filters	AC Filter Bandwidth Selected	Max Reading Rate for Adequate Settling
3 Hz to 300 kHz	Slow (3 Hz)	1 reading/5 seconds
20 Hz to 300 kHz	Medium (20 Hz)	1 reading/second
200 Hz to 300 kHz	Fast (200 Hz)	9.8 readings/second

NOTE These reading rates account for only the AC filter's behavior. See "DC Blocking Circuitry" for the effect of DC blocking circuitry.

- The AC filter selection is stored in volatile memory. The default is the medium filter (20 Hz - 300 kHz) at power-on or after a module reset.
- The `CONFigure and MEASure:`*`<function>`*`?` commands automatically select the medium (20 Hz) filter.
- Use the `[:SENSe]:DETector:BANDwidth 3|20|200|MIN|MAX` command to change the AC filter selection following a `CONFigure` command. The `MIN` parameter will select the 3 Hz filter and the `MAX` parameter will select the 200 Hz filter.

DC Input Resistance

The M1412A's input resistance is normally fixed at 10 MΩ for all DC voltage ranges to minimize noise pickup. You can set the input resistance to greater than 10 GΩ for the 100 mV, 1 V, and 10 V DC ranges to reduce the effects of measurement loading errors. You can select increased input resistance using the `INPut:IMPedance:AUTO ON` command and this applies to the DC voltage function only.

Table 3-3 DC Voltage Input Resistance

	DC Input Resistance 100 mV, 1 V, 10 V Ranges	DC Input Resistance 100 V and 300 V Ranges
`INP:IMP:AUTO OFF` (DEFAULT)	10 MΩ	10 MΩ
`INP:IMP:AUTO ON`	>10 GΩ	10 MΩ

- The input resistance setting is stored in volatile memory. `INPut:IMPedance:AUTO OFF` is set at power-on and after a module reset.
- The `CONFigure` command and the `MEASure:<function>?` command automatically turn `AUTO OFF`. Use `INPut:IMPedance:AUTO ON` after a `CONFigure` command to set it `ON`.

Resolution

Resolution is expressed in terms of the number of digits the multimeter can measure. You can set the resolution to 4.5, 5.5, 6.5, or 7.5 digits by specifying the integration time (PLCs or aperture time), which is the period the multimeter's analog-to-digital (A/D) converter samples the input signal for a measurement. To increase measurement accuracy and improve noise rejection, specify more PLCs (longer integration time). To increase measurement speed, specify fewer PLCs (shorter integration time). This applies to all measurement functions.

Resolution (DC)

For DC (DCV, DCI, and RES/FRES function) measurement, resolution is one of the settings for the sense function. By specifying resolution as a physical value, it is translated to integration time for the corresponding range.

- Resolution is stored in volatile memory. The multimeter sets itself to 10 PLCs at power-on or after a module reset.
- DC voltage ratio measurements use both the Hi-Lo input terminals (input signal) and the Hi-Lo "Ω 4 W Sense" terminals (the reference signal). The resolution specified applies to the input signal applied to the Hi-Lo input terminals for ratio measurements and not the reference signal applied to the "Sense" terminals.
- Set the resolution using the following commands:

```
CONFigure:<function> <range>|MIN|MAX,<resolution>|MIN|MAX
MEASure:<function>? <range>|MIN|MAX,<resolution>|MIN|MAX
[:SENSe]:<function> <resolution>|MIN|MAX
```

Table 3-4 to Table 3-6 shows the relations between resolution and integration time (aperture or PLC) for each DC function when in M1412A mode. DCV Resolution is different from that of E1412A mode. A shorter integration time would be selected if the same resolution is used. The DCI, RES/FRES resolution table is the same as that of E1412A mode, except for the ranges that are not defined in E1412A mode. For the resolution value of E1412A mode, see "Multimeter Range and Resolution Tables".

Table 3-4 DCV Resolution for M1412A mode

Range	Maximum Reading	100 PLCs	10 PLCs	1 PLC	0.2 PLC	0.06 PLC	0.2 PLC	0.006 PLC	0.002 PLC	0.001 PLC
		7.5 digit	6.5 digit	5.5 digit	5.5 digit	4.5 digit	4.5 digit	4.5 digit	4.5 digit	4.5 digit
100 mV	120 mV	1 nV	3 nV	10 nV	30 nV	50 nV	100 nV	300 nV	1 µV	3 µV
1 V	1.2 V	10 nV	30 nV	100 nV	300 nV	500 nV	1 µV	3 µV	10 µV	30 µV
10 V	12 V	100 nV	300 nV	1 µV	3 µV	5 µV	10 µV	30 µV	100 µV	300 µV
100 V	120 V	1 µV	3 µV	10 µV	30 µV	50 µV	100 µV	300 µV	1 mV	3 mV
300 V	303 V	3 µV	10 µV	30 µV	100 µV	150 µV	300 µV	1 mV	3 mV	10 mV

Table 3-5 DCI Resolution for M1412A mode

Range	Maximum Reading	100 PLCs	10 PLCs	1 PLC	0.2 PLC	0.02 PLC
		6.5 digit	6.5 digit	5.5 digit	5.5 digit	4.5 digit
1 µA	1.2 µA	300 fA	1 pA	3 pA	10 pA	100 pA
10 µA	12 µA	3 pA	10 pA	30 pA	100 pA	1 nA
100 µA	120 µA	30 pA	100 pA	300 pA	1 nA	10 nA
1 mA	1.2 mA	300 pA	1 nA	3 nA	10 nA	100 nA
10 mA	12 mA	3 nA	10 nA	30 nA	100 nA	1 µA
100 mA	120 mA	30 nA	100 nA	300 nA	1 µA	10 µA
1 A	1.2 A	3 nA	1 µA	3 µA	10 µA	100 µA
3 A	3.03 A	900 nA	3 µA	9 µA	30 µA	300 µA

Table 3-6 RES/FRES Resolution for M1412A mode

Range	Maximum Reading	100 PLCs	10 PLCs	1 PLC	0.2 PLC	0.02 PLC
		6.5 digit	6.5 digit	5.5 digit	5.5 digit	4.5 digit
10 Ω	12 Ω	3 μΩ	10 μΩ	30 μΩ	100 μΩ	1 mΩ
100 Ω	120 Ω	30 μΩ	100 μΩ	300 μΩ	1 mΩ	10 mΩ
1 kΩ	1.2 kΩ	300 μΩ	1 mΩ	3 mΩ	10 mΩ	100 mΩ
10 kΩ	12 kΩ	3 mΩ	10 mΩ	30 mΩ	100 mΩ	1 Ω
100 kΩ	120 kΩ	30 mΩ	100 mΩ	300 mΩ	1 Ω	10 Ω
1 MΩ	1.2 MΩ	300 mΩ	1 Ω	3 Ω	10 Ω	100 Ω
10 MΩ	12 MΩ	3 Ω	10 Ω	30 Ω	100 Ω	1 kΩ
100 MΩ	100 MΩ	30 Ω	100 Ω	300 Ω	1 kΩ	10 kΩ
1 GΩ	1.2 GΩ	3 kΩ	10 kΩ	30 kΩ	100 kΩ	1 MΩ

Resolution (AC)

For AC measurement, the resolution is not changed by the bandwidth settings. Measurement is always executed with 6.5 digit resolution. There are no differences between M1412A mode and E1412A mode.

Table 3-7 ACV Resolution

Range	Maximum Reading	Resolution
		6.5 digit
100 mV	120 mV	100 nV
1 V	1.2 V	1 μV
10 V	12 V	10 μV
100 V	120 V	100 μV
300 V	315 V	1 mV

Table 3-8 ACI Resolution

Range	Maximum Reading	Resolution
		6.5 digit
1 A	1.2 A	1 μA
3 A	3.15 A	3 μA

Integration Time

Integration time is the period during which the multimeter's analog-to-digital (A/D) converter samples the input signal for a measurement. Integration time affects the measurement resolution (for better resolution, use a longer integration time), and measurement speed (for faster measurement, use a shorter integration time).

- Integration time applies to DC voltage, DC current, resistance, and 4-wire resistance functions only. The number of power line cycles (NPLC) is the integration time setting for the multimeter DC measurement.
- The integration time for the math operations is the same as the integration time for the measurement function in use.
- Except for the `FREQuency` and `PERiod` functions, integration time is usually specified as the NPLC. The default NPLC is 10. You can also specify an integration time in seconds for DC voltage, DC current, resistance, 4-wire resistance, frequency, and period using the aperture time command for each function. Aperture time has a direct correlation to NPLC (except for the `FREQuency` and `PERiod` functions do not use NPLC) and is shown in the tables. See the `[:SENSe]:FREQ:APER` and `[:SENSe]:PER:APER` commands for setting frequency and period aperture time.
- The integration time is stored in volatile memory. The multimeter selects 10 PLCs at power-on or after a module reset. See the following information for the `FREQuency` and `PERiod` aperture time.
- Only integral numbers of PLCs (1, 10, or 100 PLCs) provide normal mode (line frequency noise) rejection.
- NPLCs are not applicable to the `FREQuency` and `PERiod` functions. Frequency and period measurements set the resolution by specifying the aperture time. The aperture time for the `FREQuency` and `PERiod` functions default to 100ms. Specify an aperture time of 10 ms for 4 digits, 100 ms for 5.5 digits, or 1 second for 6.5 digits of resolution.
- Set the integration time using the following commands:

  `[:SENSe]:<function>:NPLC <number>`
  (`NPLC`s are not applicable for the `FREQ` and `PER` functions)
  `[:SENSe]:<function>:APER <seconds>`

NPLC (DC)

NPLC (Number of Power Line Cycles) is the integration time setting for M1412A DC measurement. The following values can be used for the NPLC setting for M1412A mode.

Table 3-9 NPLC Value

Mode	Value
M1412A	0.000025 (50 Hz) or 0.000030 (60 Hz) to 1. 0.000025 (50 Hz) or 0.000030 (60 Hz) resolution. Integer number of 1 to 100
E1412A	0.02 to 1. 0.000025 (50 Hz) or 0.000030 (60 Hz) resolution. Integer number of 1 to 100

Aperture (DC)

In the case of aperture type, if autozero is on, input and internal zero will be measured with the specified integration (aperture) time one each.

Table 3-10 Aperture Time

Mode	Value [s]
M1412A	500 n to 16.7 m (60 Hz) or 20 m (50 Hz). 500 n resolution. 16.7 m (60 Hz) or 20 m (50 Hz) to 2.0. 16.7 m (60 Hz) or 20 m (50 Hz) resolution
E1412A	0.4 m to 16.7 m (60 Hz) or 20 m (50 Hz). 500 n resolution. 16.7 m (60 Hz) or 20 m (50 Hz) to 2.0. 16.7 m (60 Hz) or 20 m (50 Hz) resolution

Aperture (Frequency/Period)

In the case of FREQ or PER measurement, aperture means the gate time that the number of edges are counted.

Table 3-11 Aperture Time for FREQ/PER

Mode	Value [s]
M1412A	0.001, 0.01, 0.1, 1
E1412A	0.01, 0.1, 1

Autozero

Autozero is a method to accurately measure DC input signal. The multimeter measures the DC signal (DCV, DCI, RES, and FRES) input and the module internal zero reference alternately. The multimeter internally disconnects the input signal following each measurement and takes a zero reading when autozero is enabled. This prevents offset voltages present on the multimeter's input circuitry from affecting measurement accuracy. Autozero is enabled as the default setting. Autozero behavior differs according to the number of NPLC and Aperture (type) settings.

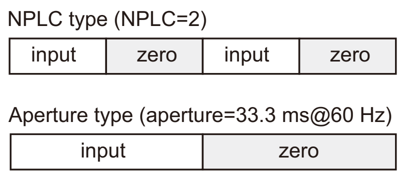
Table 3-12 Autozero Behavior

Type	Integration time length	Behavior
NPLC	Less than or equal to 1 PLC	The multimeter measures the input signal with a specified integration time. It then measures the internal zero with a specified integration time.
NPLC	More than 1 PLC	The multimeter measures the input signal with 1 PLC integration time, then measures the internal zero with 1 PLC integration time. It then iterates this behavior for the specified number of PLCs.
Aperture	Any integration time	The multimeter measures the input signal with a specified integration time. It then measures the internal zero with a specified integration time. (Same as the case of the NPLC type with less than or equal to 1 PLC)

With autozero enabled measurement, the zero measurement result will be subtracted from the input measurement result. In the case of NPLC measurement with more than 1 PLC, the result will be averaged. For example, consider the case where the integration time is 2 PLCs for the NPLC type, or 33.3 ms@60 Hz. For the NPLC type, measurement for input and zero with 1 PLC integration time is executed alternately. Then the final measurement value is calculated using 4 measurement results.

On the other hand, in the case of the Aperture type, 33.3 ms of input and zero measurement is executed, then the final measurement result is calculated by subtracting the zero value from the input value.

Figure 3-1 Autozero Measurement Type with Same Integration Time Setting



The multimeter has the following autozero settings. In the case of DC measurement, with any settings, some zero value is used to calculate the final measurement result.

Table 3-13 Autozero Settings

Setting	Commands (example)	Description
On	`SENSe:VOLTage:ZERO:AUTO ON`	The multimeter measures the zero value every time the DUT (input) measurement occurs and subtracts each zero measurement from each input measurement.
Off	`SENSe:VOLTage:ZERO:AUTO OFF`	The multimeter uses the offset value that is acquired at the last autozero measurement for each function of each range. In the case of the first autozero off measurement, the last offset autocalibration (ACAL) measurement result of the corresponding function of the corresponding range is used as a zero value and this zero value is subtracted from the measured data.
Once	`SENSe:VOLTage:ZERO:AUTO ONCE`	The multimeter executes one zero measurement and sets autozero off. The zero measurement result is used for all subsequent measurement result subtraction until the next change to the function, range, or integration time.

- When autozero is disabled (`OFF`), the multimeter takes one zero reading and subtracts it from all subsequent measurements. It takes a new zero reading each time you change the function, range, or integration time. You can disable autozero on DC voltage, DC current, and 2-wire resistance measurements only (it is always disabled for ACV and ACI functions). Autozero is always enabled when you select 4-wire resistance or ratio measurements.

- The autozero mode is stored in volatile memory. The multimeter automatically enables autozero at power-on and after a module reset.
- In the case of the NPLC type, if the autozero is enabled and integration time is greater than 1 PLC, input and internal zero are measured alternately by each 1 PLC.
- In the case of the aperture type, if autozero is enabled, input and internal zero will be measured with a specified integration (aperture) time one each.
- Use the following command to disable autozero or select the `ONCE` parameter. The `OFF` and `ONCE` parameters have a similar effect. Autozero `OFF` does not perform a new zero measurement. Autozero `ONCE` performs an immediate zero measurement.

  ```
  [SENSe:VOLTage:]ZERO:AUTO OFF|ONCE|ON
  ```

Ranging

The multimeter has an autorange function for DC and AC measurements. Autorange is a function where the multimeter automatically searches for the best range for the input signal.

- The multimeter has autorange mode enabled at power-on and after a module reset. If the user specifies a range, autorange is disabled and the specified range is used.
- The multimeter will provide an overload indication by returning `“9.90000000E+37”` if the input signal is greater than the present range can measure and autoranging is disabled or if it is at the maximum range setting.
- The multimeter uses one range for all inputs between 3 Hz and 300 kHz for the frequency and period functions. The multimeter determines an internal resolution based on a 3 Hz signal. If you query the range, the multimeter will respond with `“3Hz”`. Frequency and period measurements return `“0”` with no input signal applied.
- The specified range applies to the signal connected to the Input terminals for ratio measurements. Autoranging is automatically selected for reference voltage measurements on the Sense terminals.
- You can set the range using any of the following commands:

```
CONFigure:<function> <range>|MIN|MAX|DEF,<resolution>|MIN|MAX
|DEF
MEASure:<function>? <range>|MIN|MAX|DEF,<resolution>|MIN|MAX|
DEF
[:SENSe]:<function>:RANGe <range>|MIN|MAX
[:SENSe]:<function>:RANGe:AUTO OFF|ON
```

Autorange (DC)

Basically, in DC measurement (DCV, DCI, RES, and FRES), the multimeter goes one range higher if the input exceeds 120% of the range. On the other hand, it goes one range lower if the input falls below 10% of the range. Table 3-14 to Table 3-16 describe the threshold for switching the range up and down for each DC measurement.

Table 3-14 DCV Auto Ranging Threshold

Range [V]	Threshold to upper range	Threshold to lower range
100 m	120%	-
1	120%	10%
10	120%	10%
100	120%	10%
300	-	33.3% (100 V)

Table 3-15 DCI Auto Ranging Threshold

<table>
<tr><th rowspan="2">Range [A]</th><th colspan="2">Threshold to upper range</th><th colspan="2">Threshold to lower range</th></tr>
<tr><th>M1412A mode</th><th>E1412A mode</th><th>M1412A mode</th><th>E1412A mode</th></tr>
<tr><td>1 μ</td><td>120%</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>10 μ</td><td>120%</td><td>-</td><td>10%</td><td>-</td></tr>
<tr><td>100 μ</td><td>120%</td><td>-</td><td>10%</td><td>-</td></tr>
<tr><td>1 m</td><td colspan="2">120%</td><td>10%</td><td>-</td></tr>
<tr><td>10 m</td><td colspan="2">120%</td><td colspan="2">10%</td></tr>
<tr><td>100 m</td><td colspan="2">120%</td><td colspan="2">10%</td></tr>
<tr><td>1</td><td colspan="2">120%</td><td colspan="2">10%</td></tr>
<tr><td>3</td><td colspan="2">-</td><td colspan="2">33.3% (1 A)</td></tr>
</table>

Table 3-16 RES, FRES Auto Ranging Threshold

<table>
<tr><th rowspan="2">Range [Ω]</th><th colspan="2">Threshold to upper range</th><th colspan="2">Threshold to lower range</th></tr>
<tr><th>M1412A mode</th><th>E1412A mode</th><th>M1412A mode</th><th>E1412A mode</th></tr>
<tr><td>10</td><td>120%</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>100</td><td colspan="2">120%</td><td>10%</td><td>-</td></tr>
<tr><td>1 k</td><td colspan="2">120%</td><td colspan="2">10%</td></tr>
<tr><td>10 k</td><td colspan="2">120%</td><td colspan="2">10%</td></tr>
<tr><td>1 M</td><td colspan="2">120%</td><td colspan="2">10%</td></tr>
<tr><td>10 M</td><td colspan="2">120%</td><td colspan="2">10%</td></tr>
<tr><td>100 M</td><td>120%</td><td>-</td><td colspan="2">10%</td></tr>
<tr><td>1 G</td><td>-</td><td>-</td><td colspan="2">10%</td></tr>
</table>

Autorange (AC)

Basically, in AC measurement (ACV, ACI, and FREQ/PER), the multimeter goes one range higher if the input exceeds 120% of the range (RMS value). On the other hand, the multimeter goes one range lower if the input falls below 10% of the range (RMS value). Table 3-17 and Table 3-18 describe the threshold for switching the range up and down for each AC measurement.

Table 3-17 ACV Auto Ranging Threshold

Range [V]	Threshold to upper range	Threshold to lower range
100 m	120% (RMS)	-
1	120% (RMS)	10% (RMS)
10	120% (RMS)	10% (RMS)
100	120% (RMS)	10% (RMS)
300	-	33.3% (100 Vrms)

Table 3-18 ACI Auto Ranging Threshold

Range [A]	Threshold to upper range	Threshold to lower range
1	120% (RMS)	-
3	-	33.3% (1 Arms)

For the FREQ/PER function, if autorange is enabled, autorange for ACV works. The threshold of autorange is the same as the ACV autorange threshold. After it finishes searching for the best range, the frequency or period measurement starts.

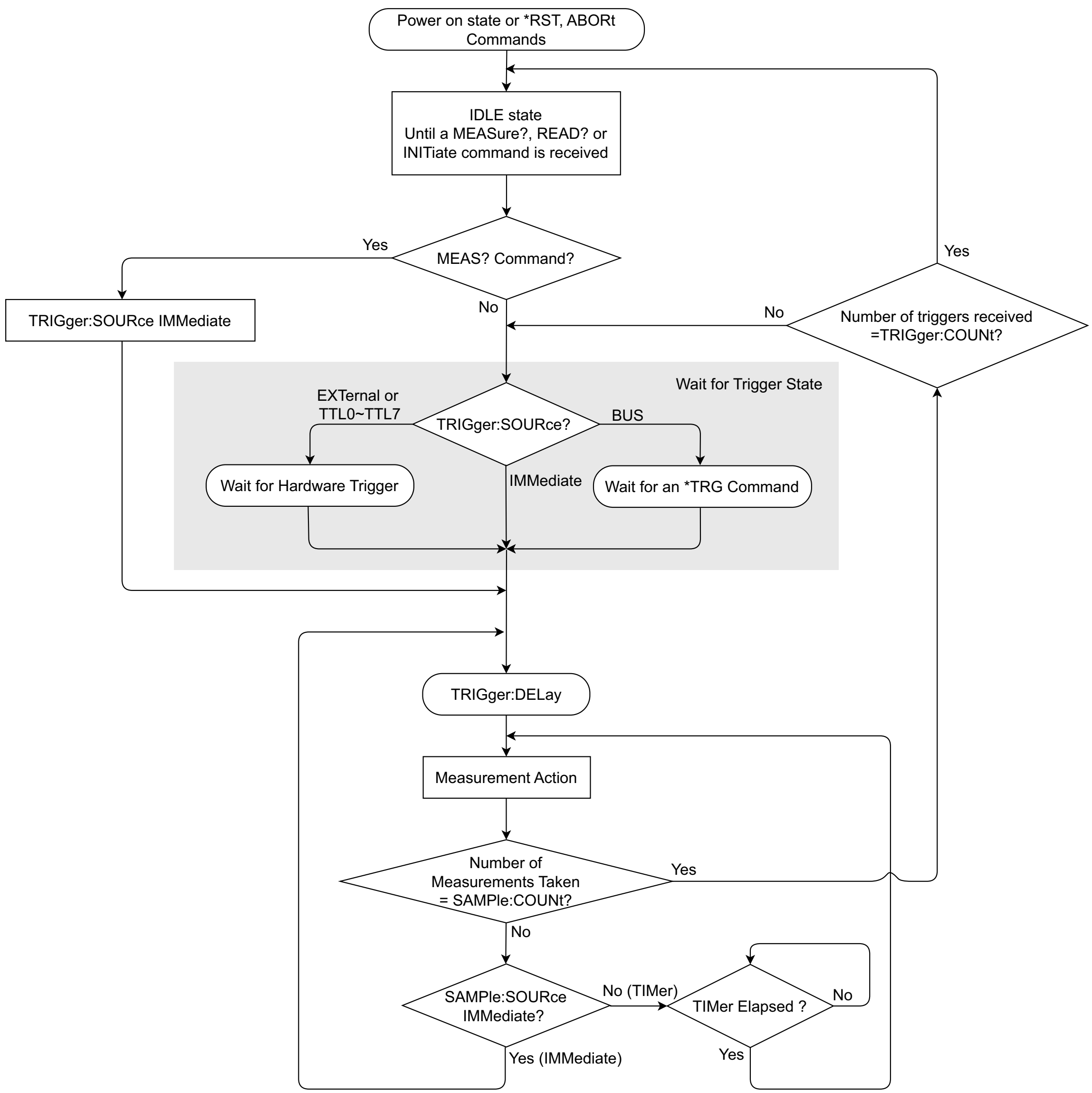
Triggering the Multimeter

This section discusses the multimeter's trigger system and outlines the different triggering configurations and programming methods used to control the trigger system. Keep in mind that you do not have to program the trigger system to make measurements. You can avoid having to learn the information in this section by using the default trigger configuration set by the `MEASure` and `CONFigure` commands. However, you will need the information in this section to take advantage of the flexibility of the M1412A trigger system when using the `CONFigure` command.

The multimeter's trigger system synchronizes measurements with specified internal or external events. The trigger system also allows you to specify the number of triggers that will be accepted the number of readings per trigger (sample count), and the delay after a trigger is received (trigger delay).

Figure 3-2 shows the multimeter's trigger system and the programming commands that control the trigger system. The multimeter operates in one of two trigger states. When you are configuring the multimeter for measurements, the multimeter must be in the idle state. After configuring the multimeter, the multimeter must be placed in the wait-for-trigger state.

Figure 3-2 Multimeter Triggering Flow Chart



Triggering the multimeter is a multi-step process that offers triggering flexibility.

1. You must configure the multimeter for the measurement by selecting the function, range, resolution, etc.
2. You must specify the source from which the multimeter will accept the trigger. The multimeter will accept a BUS trigger by the `*TRG` command, an external trigger from the front panel “Trig” SMB connector, an immediate trigger from the multimeter’s internal trigger system, or a PXIe chassis backplane PXI trigger.
3. You must make sure that the multimeter is ready to accept a trigger from the specified trigger source (this is called the wait-for-trigger state) by issuing a `READ?` or `INIT` command. A `MEASure` command always uses an immediate trigger (see the flow chart in Figure 3-2).

Trigger Source

The `TRIGger:SOURce` *<source>* command configures the multimeter’s trigger system to respond to the specified source. The following trigger sources are available:

Table 3-19 Trigger Source

Trigger Source	Description
BUS	`*TRG` command
EXTernal	External trigger input on the front panel
IMMediate (default)	The trigger signal is generated inside the module. The trigger is always active when the module is ready to receive the trigger.
PXI[0:7] /TTL[0:7]	PXIe backplane trigger.

The multimeter goes into the wait-for-trigger state by sending the `INIT` command. The trigger source must be specified before sending the `INIT` command. If the multimeter is in the wait-for-trigger state, only the specified trigger source can work as the trigger.

Bus Triggering

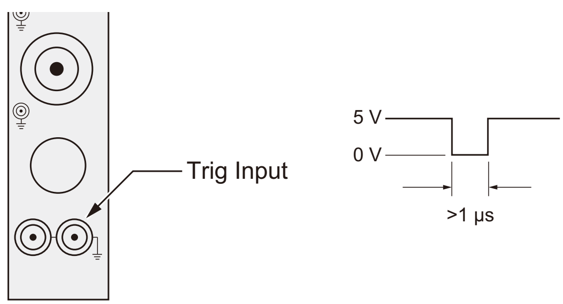
The multimeter is triggered by the `*TRG` command. This mode is selected with the `TRIGger:SOURce BUS` command.

External Triggering

If EXTernal is selected, an external trigger input on the multimeter front panel is used as the trigger source. The polarity is negative and it is edge sensitive (normally high, detecting a negative edge of the trigger input).

Use `TRIGger:SOURce EXTernal` to set the trigger source to external.

- The trigger signal must be a low-true pulse with a pulse width greater than 1 µs. The accepted trigger signal level is 5 V TTL.



- The multimeter takes one reading (or the number specified by `SAMPle:COUNt`) for each external trigger received on the front panel “Trig” SMB connector.

Immediate Triggering

If IMMediate trigger is specified, the multimeter starts sampling immediately after the `INIT` command is received.

The trigger signal is always present in the internal triggering mode. This mode is selected with the `TRIGger:SOURce IMMediate` command.

- The multimeter takes one reading (or the number specified by `SAMPle:COUNt`) immediately after a `READ?` or `INITiate` command. The multimeter takes only one reading immediately following a `MEAS?` command.

- See the triggering process diagram in Figure 3-2.

PXI[0:7] Triggering

If PXI[0:7] is selected, the PXI trigger on the PXIe backplane is used as the trigger source. The polarity is negative and it is edge sensitive (normally high, detecting a negative edge of the trigger input).

The multimeter also accepts TTL[0:7]. TTL<n> is an alias of PXI<n>.

Wait-for-Trigger State

You must place the multimeter in the wait-for-trigger state after you have configured it and selected a trigger source. A trigger will not be accepted until the multimeter is in this state. The measurement sequence begins when the multimeter is in the wait-for-trigger state and it receives a trigger.

You can place the multimeter in the wait-for-trigger state by executing one of the following commands:

```
READ?
INITiate
```

NOTE The multimeter requires approximately 5 ms of setup time after you send a command to change to the wait-for-trigger state. Any triggers that occur during this setup time are ignored.

Trigger Count

The `TRIGger:COUNt <number>` command sets the number of triggers to be received by the multimeter after the multimeter is initiated by the `INIT` command. Use the number parameter to set the trigger count to a value between 1 and 50,000.

The total number of data points by one initiate (`INIT` command) would be `TRIGger:COUNt * SAMPle:COUNt`. There is a limitation to the total number of buffered points. You must set `TRIGger:COUNt` and `SAMPle:COUNt` while considering the following limitations.

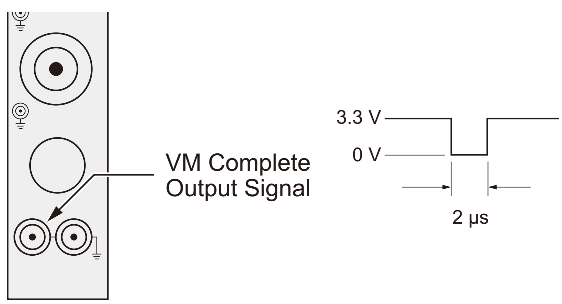
Table 3-20 Maximum Buffered Points

Condition	Maximum Sample Points
DC, PLC≤1	2,000,000
DC, 1<PLC≤10	100,000
DC, 10<PLC≤100	50,000
ACV, ACI	200,000
Frequency, Period	1,000,000

VM Complete

The VM Complete signal is a trigger output signal that notifies you when a measurement is finished. The multimeter has a VM Complete output terminal on the front panel.
The signal level is 3.3 V CMOS (active low signal) and the pulse width is 2 μs.

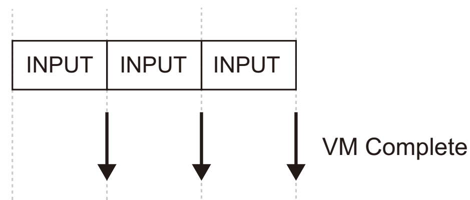
Figure 3-3 VM Complete Pulse



The output timing of VM Complete is shown in the following figures.

In the case of DC measurement without autozero or AC measurement, the VM Complete pulse is generated right after each DUT measurement is finished as shown in Figure 3-4.

Figure 3-4 DC Measurement with Autozero Disabled, and AC Measurement



In the case of DC measurement with autozero, the VM Complete pulse is generated right after the final DUT measurement is finished, just before the final zero measurement is started. Figure 3-5 shows the output timing of a VM Complete pulse for aperture type autozero measurement.

Figure 3-5 Aperture Type DC Measurement

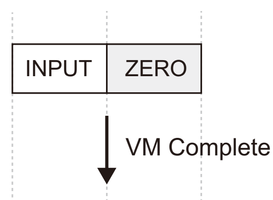
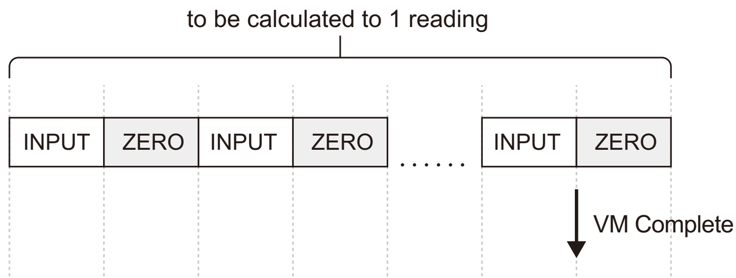


Figure 3-6 shows the output timing of a VM Complete pulse for NPLC type autozero measurement. In the same way as the aperture type, VM Complete is generated right after the final DUT measurement is finished, just before the final zero measurement is started.

Figure 3-6 NPLC Type DC Measurement



NOTE The VM Complete pulse can be output to the PXI[0:7] trigger, by using the `OUTPut:TRIGger` command.

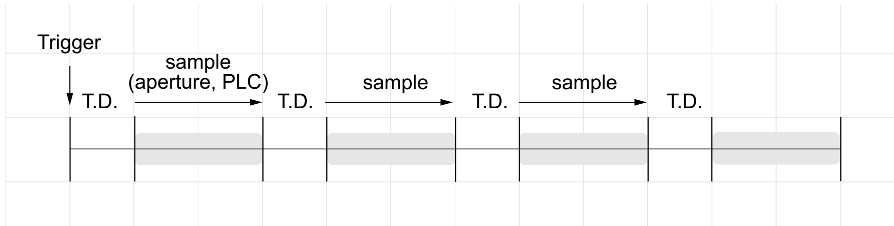
Sample Source (SAMPle:SOURce)

The multimeter has 2 types of sample source settings, IMMediate and TIMer.

IMMediate

If the sample source is set to IMMediate, the trigger delay (T.D.) is always inserted before each sampling.

Figure 3-7 IMMediate Sampling Action



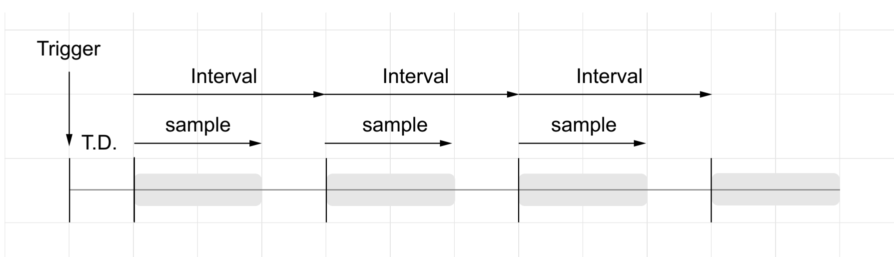
After receiving the trigger, the multimeter starts sampling as shown in Figure 3-7. Each sampling is executed after the specified trigger delay has passed. The sequence of measurement finishes after the final point of sampling has finished. The number of points to be acquired is set by `SAMPle:COUNt`, which is described in “Sample Count”.

In the case of autorange measurement, the sample duration can be longer than expected. This is because searching for the best range starts after the trigger delay has passed, and some amount of time is needed to change the range. In that case, the trigger delay for the next sample starts after the current sample finishes.

TIMer

If the sample source is TIMer, the trigger delay is inserted before the first sampling only. The start timing of each sample is controlled by the Interval parameter. In general, the next sample starts right after the interval when the last sample finishes. It is prohibited to set an interval value that is shorter than the duration of one sample.

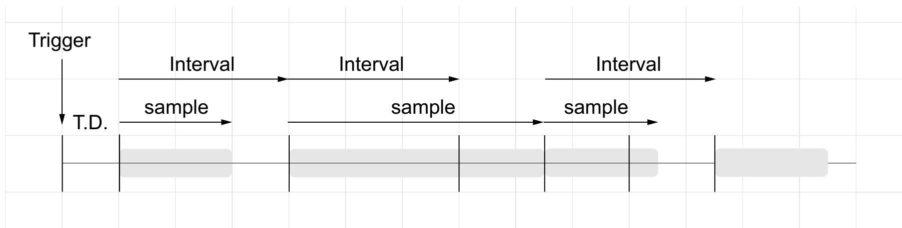
Figure 3-8 TIMer Sampling Action



The sequence of measurement finishes after the final point of sampling is finished. For the final point, the interval is not used. In the case of COUNt=1, behavior of the IMMediate and TIMer sampling action is the same.

If autorange measurement is enabled, the sample duration can be longer than the interval. In that case, the next point of sampling starts after the current sampling is finished.

Figure 3-9 TIMer Sampling Action with Autorange Enabled



The interval value is specified with `SAMPle:TIMer <interval>`. The minimum is 1 µs, and the maximum is 3600 s.

There is a limitation to the resolution (step) for an interval value.

Table 3-21 Resolution for TIMer Interval Setting

Interval [s]	Resolution [s]
~1.0	1 µ
~10	10 µ
~100	100 µ
~1000	1 m
~3600.0	10 m

Sample Count

The `SAMPle:COUNt <number>` command designates the number of readings per trigger. The default and minimum value is 1. The maximum value is may differed depending on the measurement conditions. (These values would be changed). See the following Table 3-22 for the maximum Sample Count.

Table 3-22 Maximum Sample Count

Condition	Maximum Sample Points
DC, PLC≤1	2,000,000
DC, 1<PLC≤10	100,000
DC, 10<PLC≤100	50,000
ACV, ACI	200,000
Frequency, Period	1,000,000

Trigger Delay

The trigger delay is the wait time before the sample starts. The timing of the trigger delay insertion differs depending on the `SAMPle:SOURce` setting.

You can specify a fixed trigger delay value by using the `TRIGger:DELay` command. If `TRIGger:DELay:AUTO on` (true) is selected, the trigger delay value is automatically determined by the multimeter. It differs depending on the module mode (M1412A or E1412A), function, and integration time (aperture/PLC). Table 3-24 to Table 3-30 show the trigger delay values (default trigger delays) for each condition.

In the following tables regarding DC measurement, the Integration Time Categories A, B, and C refer to the following conditions.

Table 3-23 Integration Time Category

Integration Time Category	Integration Time (written as T)
A	T < 0.06 PLC (1.0 ms for 60 Hz or 1.2 ms for 50 Hz)
B	0.06 PLC (1.0 ms for 60 Hz or 1.2 ms for 50 Hz) ≤ T < 1 PLC (16.7 ms for 60 Hz or 20 ms for 50 Hz)
C	T ≥ 1 PLC (16.7 ms for 60 Hz or 20 ms for 50 Hz)

Table 3-24 DCV Trigger Delay

Range	Integration Time Category	M1412A Mode [s]	E1412A Mode [s]
All	A	100 μ	1 m
	B	130 μ	1 m
	C	160 μ	1.5 m

Table 3-25 DCI Trigger Delay

Range	Integration Time Category	M1412A Mode [s]	E1412A Mode [s]
< 1 mA	A	1 m	1 m
	B	1 m	1 m
	C	1.5 m	1.5 m
≥ 1 mA	A	100 μ	1 m
	B	130 μ	1 m
	C	160 μ	1.5 m

Table 3-26 RES Trigger Delay

Range	Integration Time Category	M1412A Mode [s]	E1412A Mode [s]
10 Ω	A	80 µ	–
	B	100 µ	–
	C	130 µ	–
100 Ω	A	80 µ	1 m
	B	100 µ	1 m
	C	130 µ	1.5 m
1 kΩ	A	110 µ	1 m
	B	130 µ	1 m
	C	160 µ	1.5 m
10 kΩ	A	130 µ	1 m
	B	160 µ	1 m
	C	190 µ	1.5 m
100 kΩ	A	540 µ	1 m
	B	670 µ	1 m
	C	800 µ	1.5 m
1 MΩ	A	5 m	10 m
	B	6 m	10 m
	C	7.5 m	15 m
10 MΩ	A	60 m	100 m
	B	70 m	100 m
	C	84 m	100 m

Range	Integration Time Category	M1412A Mode [s]	E1412A Mode [s]
100 MΩ	A	60 m	100 m
	B	70 m	100 m
	C	84 m	100 m
1 GΩ	A	60 m	–
	B	70 m	–
	C	84 m	–

Table 3-27 FRES Trigger Delay

Range	Integration Time Category	M1412A Mode [s]	E1412A Mode [s]
10 Ω	A	1 m	–
	B	1 m	–
	C	1.5 m	–
100 Ω	A	1 m	1 m
	B	1 m	1 m
	C	1.5 m	1.5 m
1 kΩ	A	1 m	1 m
	B	1 m	1 m
	C	1.5 m	1.5 m
10 kΩ	A	1 m	1 m
	B	1 m	1 m
	C	1.5 m	1.5 m

Range	Integration Time Category	M1412A Mode [s]	E1412A Mode [s]
100 kΩ	A	1 m	1 m
	B	1 m	1 m
	C	1.5 m	1.5 m
1 MΩ	A	10 m	10 m
	B	10 m	10 m
	C	15 m	15 m
10 MΩ	A	100 m	100 m
	B	100 m	100 m
	C	100 m	100 m
100 MΩ	A	100 m	100 m
	B	100 m	100 m
	C	100 m	100 m
1 GΩ	A	100 m	–
	B	100 m	–
	C	100 m	–

Table 3-28 ACV Trigger Delay

Range	Bandwidth [Hz]	M1412A Mode [s]	E1412A Mode [s]
All	3	5.0	7.0
	20	1.0	1.0
	200	0.1	0.6

Table 3-29 ACI Trigger Delay

Range	Bandwidth [Hz]	M1412A Mode [s]	E1412A Mode [s]
All	3	5.0	7.0
	20	1.0	1.0
	200	0.1	0.6

Table 3-30 FREQ/PER Trigger Delay

Range	M1412A Mode [s]	E1412A Mode [s]
All	1.0	1.0

NOTE

The default delay time is automatically updated whenever you change the function or range. However, once you specify a delay time value, the value does not change until you specify another value, reset the multimeter, or send the `CONF` or `MEAS` command.

You can specify a shorter delay time than the default values shown. However, the shorter settling time may not produce accurate measurements.

Measurement Functions

This section contains information to help you use the following functions for making measurements.

Table 3-31 Measurement Functions

Function	Remarks
DCV	DC voltage
DCI	DC current
RES, FRES	DC resistance with 2-wire or 4-wire
ACV	AC voltage
ACI	AC current
FREQ, PER	Frequency or Period value of ACV signal
RAT	Voltage ratio measurement with DCV and DC2 terminals
DCV+DC2	DCV and DC2 can be measured simultaneously.
DCI+DC2	DCI and DC2 can be measured simultaneously.

DCV

You can measure the DC voltage applied between the Hi and Lo terminals.

Connection

The DUT must be connected between the Hi and Lo terminals. One of the examples to convert the triaxial terminal to a coaxial terminal is to use the N1254A-103 (1250-2650).

Table 3-32 **Accessory to Convert triaxial Terminal to Co-ax Terminal**

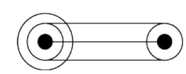
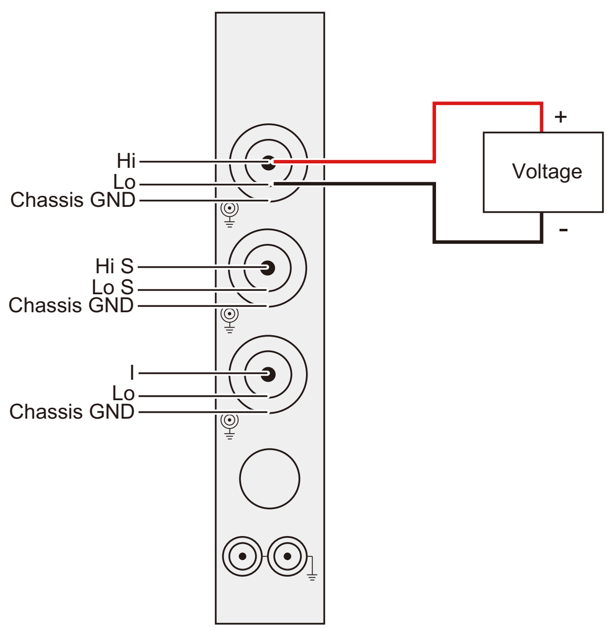
Item	Description	Qty	Part number	Illustration
N1254A-103	Triaxial (m) - Coaxial (f)	1	1250-2650	
N1254A-104	Triaxial (f) - Coaxial (m)	1	1250-2651	

Figure 3-10 **DCV Connection**



NOTE High Sense and Low Sense are indicated by “Hi S” and “Lo S” respectively. The Current is indicated by “I” in the figures of this section.

Range

The DCV function has the following ranges shown in Table 3-33. Each range has an over-range value, which is the maximum limit of each range. If the input voltage exceeds the over-range value with the multimeter fixed-range setting, the measurement value is shown as Overload (or +/-9.9E37).

Table 3-33 DCV Range

Range [V]	Over range
100 m	120%
1	120%
10	120%
100	120%
300	101%

Input Impedance Mode

The M1412A has an Input Impedance mode for measurements in DCV. If this mode is enabled, the input impedance for each range is automatically determined by the multimeter. In the case of the 100 mV, 1 V, and 10 V range, input impedance is set to high (>10 GΩ). In the case of the 100 V and 300 V range, input impedance is set to 10 MΩ.

If the mode is disabled, the input impedance is always 10 MΩ regardless of the selected DC voltage range.

DCI

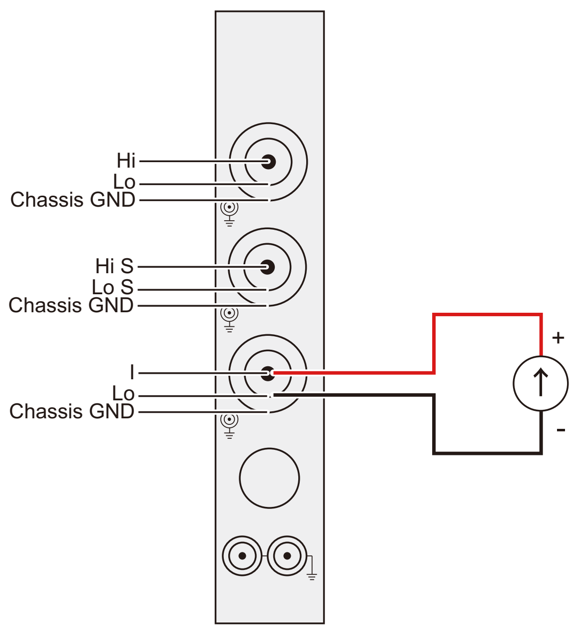
The DCI measurement function is used to measure the DC current applied to the I Terminal. The Lo terminal is used as the return path for the applied current. The Lo terminal on the top triaxial connector is electrically connected to the Lo terminal on the bottom triaxial connector inside the module. However, using the Lo terminal on the bottom triaxial connector is recommended.

There are shunt resistors inside the multimeter. The input current flows into these shunt resistors, and the voltages between these shunt resistors are measured. The measured voltage value is calculated from the current value, by using the known shunt resistor values. The shunt resistor values are different depending on the range. See the values shown in Table 3-34.

Connection

The DUT must be connected between the I and Lo terminals.

Figure 3-11 DCI Connection



Range

The DCI function has the following ranges shown in Table 3-34. Each range has an over-range value, which is the maximum limit of each range. If the input current exceeds the over-range value with the M1412A fixed range setting, the measurement value is shown as Overload (or +/-9.9E37). If E1412A mode is used with the SCPI Service Manager, the range from 1 μA to 1 mA cannot be used as the E1412A does not support the range between 1 μA and 1 mA.

Table 3-34 DCI Range

Range [A]	Over range	Shunt Resistor [Ω]	Remarks
1 μ	120%	1 k	Not supported with E1412A mode
10 μ	120%	1 k	Not supported with E1412A mode
100 μ	120%	1 k	Not supported with E1412A mode
1 m	120%	100	Not supported with E1412A mode
10 m	120%	8.14	
100 m	120%	2.1	
1	120%	0.1	
3	101%	0.1	

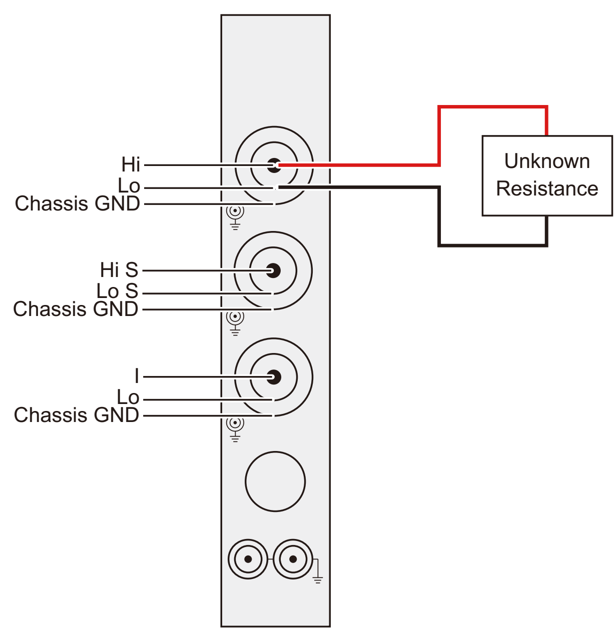
RES (2-Wire Resistance) and FRES (4-Wire Resistance)

The RES and FRES measurements are functions to measure the DC resistance between the Hi and Lo terminals. The M1412A applies a test current from the Hi terminal to the DUT, then measures the voltage between the High side of the DUT and the Low side of the DUT. In the case of RES (2-wire resistance) measurement, the voltage between the Hi and Lo terminals is measured. In the case of FRES (4-wire resistance) measurement, the voltage between the Hi S and Lo S terminals is measured.

Connection

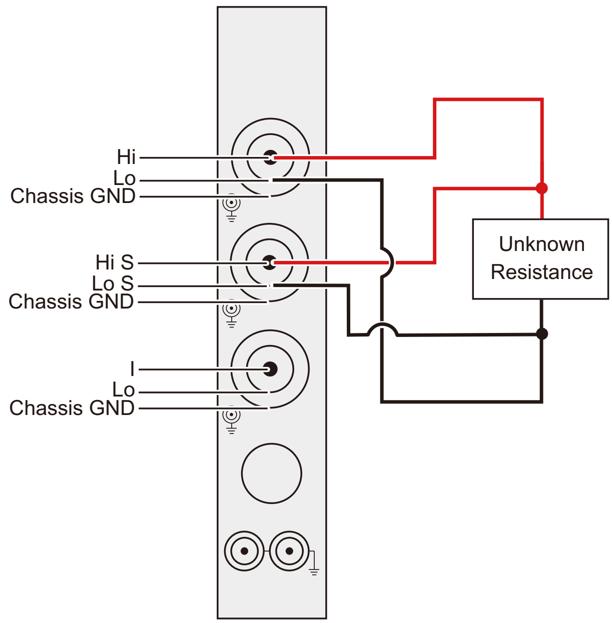
In the case of RES measurement, the DUT must be connected between the Hi and Lo terminals.

Figure 3-12 RES Connection



In the case of FRES measurement, the DUT must be connected between the Hi and Lo terminals. Connect the Hi S terminal to the High side of the DUT and connect the Lo S terminal to the Low side of the DUT. The voltage between the Hi S and Lo S terminals is measured.

Figure 3-13 FRES Connection



Range, Test Current

The RES/FRES function has the following ranges shown in Table 3-35. Each range has an over-range value, which is the maximum limit of each range. If the input resistance exceeds, the over-range value with the M1412A fixed-range setting, the measurement value is shown as Overload (or +/-9.9E37). If E1412A mode is used with the SCPI Service Manager, the 10 Ω and 1 GΩ ranges are not used as the E1412A does not support those ranges.

Table 3-35 REF/FRES Range

Range [Ω]	Over range	Remarks
10	120%	Not supported with E1412A mode
100	120%	
1 k	120%	
10 k	120%	
100 k	120%	
1 M	120%	
10 M	120%	
100 M	120%	10 MΩ is connected parallelly inside module.
1 G	120%	Not supported with E1412A mode 10 MΩ is connected parallelly inside module.

The test current is the current supplied to the DUT during RES/FRES measurement. The same test current value as the E1412A is used for each range.

Table 3-36 RES/FRES Test Current

Range [Ω]	Test Current [A]	Remarks
10	10 m	Not supported with E1412A mode
100	1 m	
1 k	1 m	
10 k	100 μ	
100 k	10 μ	
1 M	5 μ	
10 M	500 n	
100 M	500 n	10 MΩ is connected parallelly inside module.
1 G	500 n	Not supported with E1412A mode 10 MΩ is connected parallelly inside module.

In the case of the 100 MΩ range and 1 GΩ range, a 10 MΩ resistance is connected in parallel inside the module to measure the DUT resistance value. The voltage between these parallel resistors is measured, and the M1412A calculates the DUT resistor value from the measured voltage, considering that the module's internal 10 MΩ resistor is connected in parallel to the DUT.

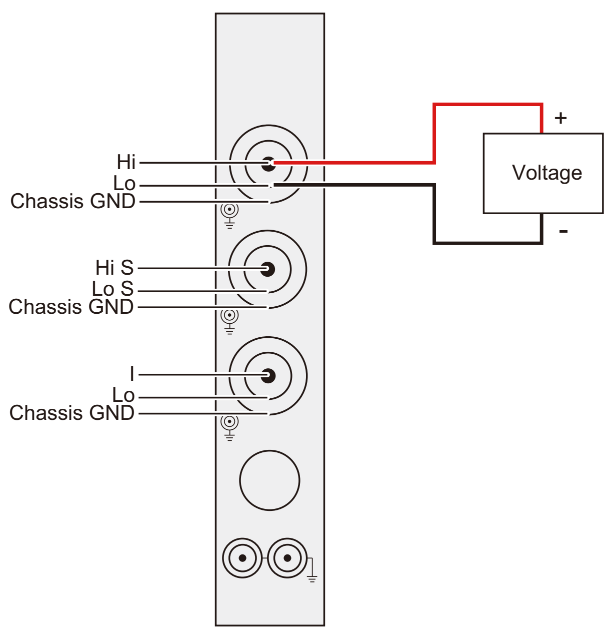
ACV

ACV measurement is a function to measure the AC voltage applied between the Hi and Lo terminals. The measured value for ACV is a calculated RMS (root mean square) value. ACV input is sampled using an ADC on the module with its fastest speeds (2 MSa/s). Then, RMS calculation is performed using Hardware and Software.

Connection

The DUT must be connected between the Hi and Lo terminals.

Figure 3-14 ACV Connection



Range

The ACV function has the following ranges shown in Table 3-37. Each range has an over-range value, which is the maximum limit of each range. If the input voltage (RMS value) exceeds the over-range value with the M1412A fixed-range setting, the measurement value is shown as Overload (or +/-9.9E37).

Table 3-37 ACV Range

Range [V]	Over range
100 m	120%
1	120%
10	120%
100	120%
300	101%

Filter Bandwidth

Filter bandwidth is the setting to specify the minimum frequency value for voltage applied to the multimeter. You can select 200 Hz (Fast), 20 Hz (Medium), or 3 Hz (Slow). For example, if the minimum frequency value of the input voltage is 30 Hz, then Bandwidth=20 Hz or 3 Hz should be selected. The settling time (the duration needed for the measurement value be settled) is shorter if a higher bandwidth is selected.

Table 3-38 AC Filter Bandwidth

AC Signal Filters	AC Filter Bandwidth Selected	Max Reading Rate for Adequate Settling
3 Hz to 300 kHz	Slow (3 Hz)	1 reading/5 seconds
20 Hz to 300 kHz	Medium (20 Hz)	1 reading/second
200 Hz to 300 kHz	Fast (200 Hz)	9.8 readings/second

ACI

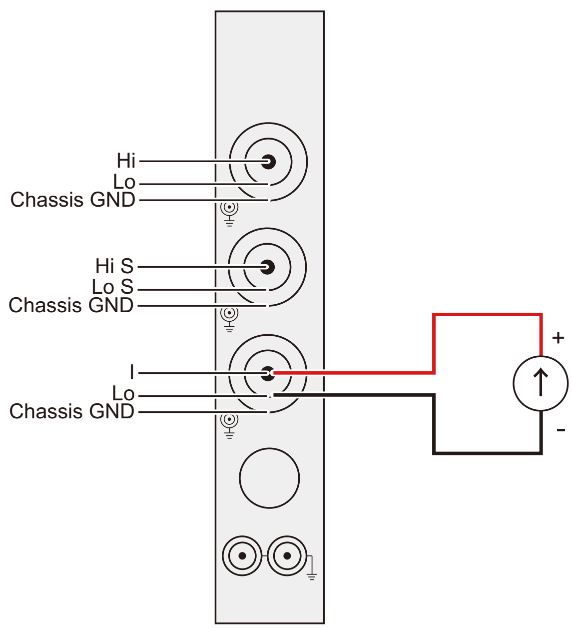
ACI measurement is a function to measure the AC current applied between the I and Lo terminals. The Lo terminal on the top triaxial connector is electrically connected to the Lo terminal on the bottom triaxial connector inside the module. However, using the Lo terminal on the bottom triaxial is recommended.

The measured value for ACI is a calculated RMS (root mean square) value. ACI input is sampled using an ADC on the module with its fastest speeds (2 MSa/s). Then RMS calculation is performed using Hardware and Software.

Connection

The DUT must be connected between the I and Lo terminals.

Figure 3-15 **ACI Connection**



Range

The ACV function has the following ranges shown in Table 3-39. Each range has an over-range value, which is the maximum limit of each range. If the input voltage (RMS value) exceeds the over-range value with the M1412A fixed-range setting, the measurement value is shown as Overload (or +/-9.9E37).

Table 3-39 ACI Range

Range [A]	Over range
1	120%
3	101%

Bandwidth Filter

In ACI mode, the bandwidth should be set as an ACV measurement. See “Filter Bandwidth”.

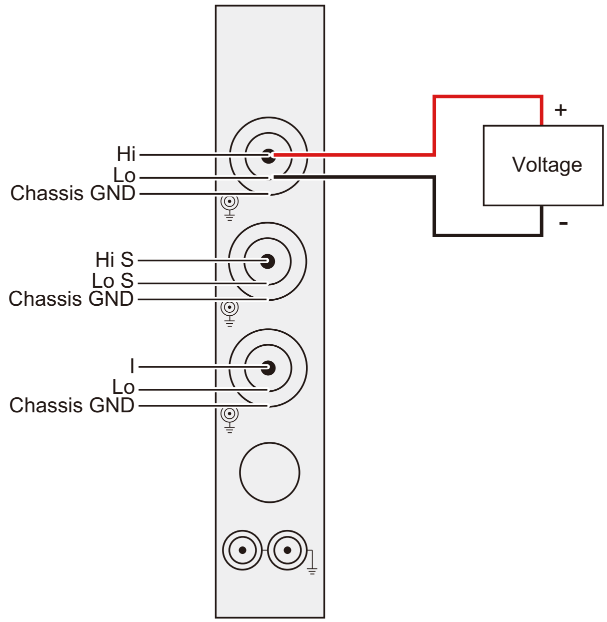
FREQ and PER

FREQ measurement is a function to measure the frequency of an ACV applied between the Hi and Lo terminals. PER is the function to measure the period of ACV applied between the Hi terminal and Lo terminal. The period value is obtained by calculating the reciprocal value of the frequency.

Connection

The DUT must be connected between the Hi and Lo terminals.

Figure 3-16 FREQ and PER Connection



Range

The FREQ/PER function has the following ranges shown in Table 3-40. The range of FREQ/PER is the same as the ACV as FREQ/PER measures the frequency or period of the ACV signal.

The over-range value of the FREQ/PER function is different from that of ACV. If the sampled ACV value exceeds the limit shown in Table 3-40 for each range, then the measured frequency or period value is shown as Overload (or +9.9E37)

Table 3-40 FREQ/PER Range

Range [V]	Over range (as an immediate Voltage value) [V]
100 m	284 m
1	2.84
10	28.4
100	284
300	852

RAT

RAT measurement is a function to measure the ratio of the voltage applied to the Hi-Lo terminals (DCV) and the Hi S-Lo S terminals (DC2). The ratio of the voltage is calculated by dividing the DCV voltage by the DC2 voltage. The range of the Hi-Lo terminals can be both a fixed range and an auto range. The range of the Hi S-Lo S terminals is an auto range for RAT measurement.

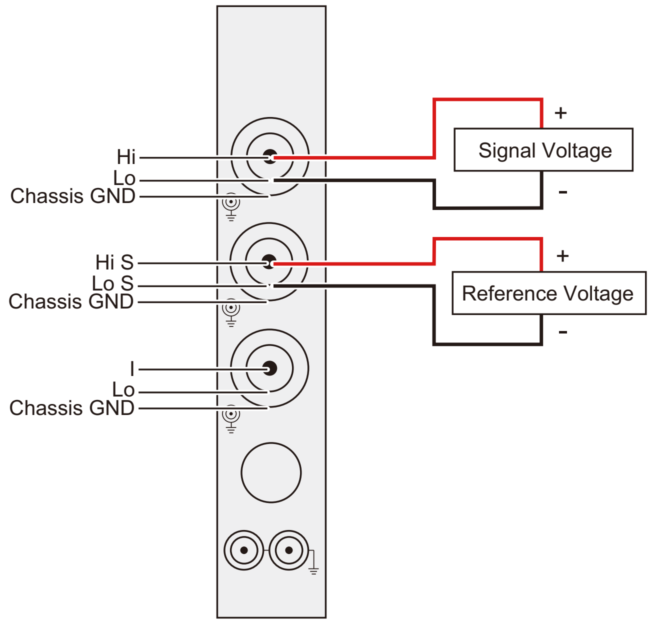
You must take care to ensure that the voltage between the Lo and Lo S terminals does not exceed 2 V.

NOTE It is recommended to fix the voltage difference between the Lo and Lo S terminals during measurement, in order not to exceed this voltage limitation.

Connection

The DUT must be connected between the Hi and Lo terminals, and the Hi S and Lo S terminals.

Figure 3-17 RAT Connection



Range

The RAT function has the following ranges shown in Table 3-41 and Table 3-42. The range of the Hi-Lo terminal is the same as for DCV. Although the range of the Hi S-Lo S terminal is 100 mV, 1 V, or 10 V, it is automatically selected by the module to ensure the best-fit range. You cannot select a range for the Hi S-Lo S terminal.

The over-range function also works in the RAT function. If either of the input voltages exceeds the over-range limit, the result is shown as Overrange (or +/-9.9E37). In the case of the Hi S-Lo S terminal, the range is automatically selected, then only the over-range for the 10 V range is valid. For example, if the 100 mV range is selected at first and the input is 1.0 V, the Hi S-Lo S terminal automatically selects the 1.0 V range, and over-range is not triggered.

Table 3-41 Hi-Lo Terminal Range of RAT Measurement

Range [V]	Over range
100 m	120%
1	120%
10	120%
100	120%
300	105%

Table 3-42 Hi S-Lo S Terminal Range of RAT Measurement

Range [V]	Over range
100 m	-
1	-
10	120%

DCV + DC2

DCV + DC2 (Second DCV) measurement is a function to measure two of DC voltages simultaneously. Two DC voltages applied to the Hi–Lo terminals (DCV) and the Hi S–Lo S terminals are measured. Different range settings including having autorange enabled or disabled can be used for DCV + DC2. In addition, the autozero setting can be set independently for both DCV and DC2.

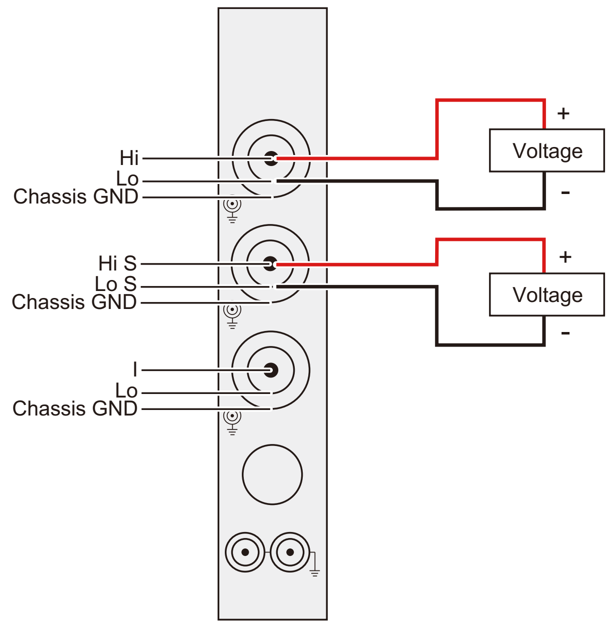
You must take care to ensure that the voltage between the Lo and Lo S terminals does not exceed 2 V.

NOTE It is recommended to fix the voltage difference between the Lo and Lo S terminals during measurement, in order not to exceed this voltage limitation.

Connection

The DUT must be connected between the Hi and Lo terminals, and the Hi S and Lo S terminals.

Figure 3-18 **DCV + DC2 Connection**



Range

The DCV + DC2 function has the following ranges shown in Table 3-43 and Table 3-44. The range of the Hi-Lo terminal is the same as for DCV. The range of the Hi S-Lo S terminal is 100 mV, 1 V, or 10 V.

The over-range function also works in the DCV + DC2 function. The over-range status will be added separately. If the input voltage exceeds the over-range limit, the result is shown as Overrange (or +/-9.9E37).

Table 3-43 Hi-Lo Terminal Range of DCV + DC2 Measurement

Range [V]	Over range
100 m	120%
1	120%
10	120%
100	120%
300	105%

Table 3-44 Hi S-Lo S Terminal Range of DCV + DC2 Measurement

Range [V]	Over range
100 m	120%
1	120%
10	120%

DCI + DC2

DCI + DC2 (Second DCV) measurement is a function to measure the DC current and DC voltage simultaneously. The DC current applied between the I and Lo terminals and the DC voltage applied to the Hi S-Lo S terminals are measured. Different range settings including having autorange enabled or disabled can be used for DCI + DC2. In addition, the autozero setting can be set independently for both DCI and DC2.

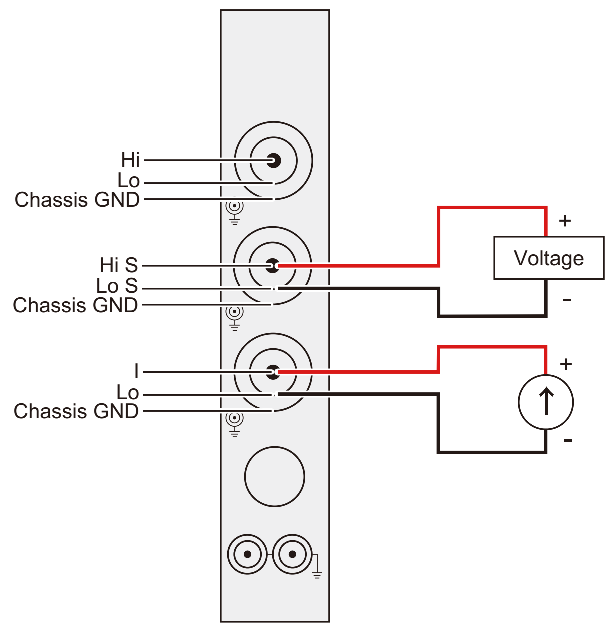
You must take care to ensure that the voltage between the Lo and Lo S terminals does not exceed 2 V.

NOTE It is recommended to fix the voltage difference between the Lo and Lo S terminals during measurement, in order not to exceed this voltage limitation.

Connection

The DUT must be connected between the I and Lo terminals, and the Hi S and Lo S terminals.

Figure 3-19 DCI + DC2 Connection



Range

The DCI + DC2 function has the following ranges shown in Table 3-34 and Table 3-44. The range of the I-Lo terminal is the same as for DCI. The range of the Hi S-Lo S terminal is 100 mV, 1 V, or 10 V.

The over-range function also works in the DCI + DC2 function. The over-range status will be added separately. If the input voltage exceeds the over-range limit, the result is shown as Overrange (or +/-9.9E37).

4 Programming Basics

This chapter describes basic information on programming for the M1412A and provides the range and resolution information of the M1412A and E1412A.

The Standard Commands for Programmable Instruments (SCPI) and IEEE 488.2 Common (*) Commands apply to the M1412A 7.5 Digit PXIe Digital Multimeter.

Command Types

Commands are separated into two types: IEEE 488.2 Common Commands and SCPI Commands.

Common Command Format

The IEEE 488.2 standard defines the common commands that perform functions such as reset, self-test, and status byte query. The common commands are four or five characters in length, always begin with an asterisk (*), and may include one or more parameters. The command keyword is separated from the first parameter by a space. Some examples of common commands are shown below:

```
*RST
*ESR 32
*STB?
```

SCPI Command Format

The SCPI commands perform functions such as making measurements, querying instrument states, and retrieving data. The SCPI commands are grouped into command subsystem structures. A command subsystem structure is a hierarchical structure that usually consists of a top-level (or root) command and one or more low-level commands and their parameters. The following example shows the root command `CALibration` and its lower-level subsystem commands.

```
CALibration
:COUNt?
:DATE?
:LFRequency 50|60|MIN|MAX
:LFRequency? [MIN|MAX]
:SECure:CODE
:SECure:STATe OFF|ON,
:SECure:STATe?
:STRing
:STRing?
:VALue
:VALue?
:ZERO:AUTO ON|OFF
:ZERO:AUTO
```

`CALibration` is the root command, `COUNt?`, `LFRequency`, `LFRequency?`, `SECure`, `STRing`, `STRing?`, `VALue`, and `VALue?` are second-level commands, and `CODE`, `STATe` and `STATe?` are third-level commands.

Command Separator

A colon (:) always separates one command from the next lower-level command as shown below:

```
CALibration:SECure:STATe?
```

Colons separate the root command from second-level commands (`CALibration:SECure`) and second-level commands from third-level commands (`SECure:STATe?`).

Abbreviated Commands

The command syntax shows most commands as a mixture of upper- and lower-case letters. The upper-case letters indicate the abbreviated spelling for the command. For shorter program lines, send the abbreviated form. For better program readability, you may send the entire command. The instrument will accept either the abbreviated form or the entire command. For example, if the command syntax shows `MEASure`, then `MEAS` and `MEASURE` are both acceptable forms. Other forms of MEASure, such as `MEASU` or `MEASUR` will generate an error. Additionally, SCPI commands are case insensitive. Therefore, you can mix upper- and lower-case letters in commands: The forms `MEASURE`, `measure`, and `MeAsUrE` are all acceptable.

Implied Commands

Implied commands are those which appear in square brackets ([ ]) in the command syntax. (Note that the brackets are not part of the command; do not send them to the instrument.) Suppose you send a second-level command but do not send the preceding implied command. In this case, the instrument assumes you intend to use the implied command, and it responds as if you had sent it.

Examine the partial `[:SENSe]:` subsystem shown below:

```
[:SENSe]:
FUNCtion “” (e.g., = VOLT:AC)
FUNCtion?
RESistance
:RANGe |MIN|MAX
:RANGe? [MIN|MAX]
```

The root command `SENSe` is an implied command. For example, to set the multimeter’s function to AC voltage, you can send either of the following command statements:

`SENS:FUNC “VOLT:AC”` or `FUNC “VOLT:AC”`

Parameters

Parameter Types

The following table contains explanations and examples of parameter types you might see later in this chapter.

Table 4-1 Parameter

Type	Explanations and Examples
Numeric	Accepts all commonly used decimal representations of number including optional signs, decimal points, and scientific notation. 123, 123E2, -123, -1.23E2, .123, 1.23E-2, 1.23000E-01. Special cases include MINimum, MAXimum, and DEFault.
Boolean	Represents a single binary condition that is either true or false. ON, OFF, 1, 0
Discrete	Selects from a finite number of values. These parameters use mnemonics to represent each valid setting. An example is the TRIGger:SOURce command where source can be BUS, EXT, or IMM.

Optional Parameters

Parameters shown within square brackets ([ ]) are optional parameters. (Note that the brackets are not part of the command; do not send them to the instrument.) If you do not specify a value for an optional parameter, the instrument chooses a default value. For example, consider the `TRIGger:COUNt?` [MIN|MAX] command. If you send the command without specifying a `MINimum` or `MAXimum` parameter, the current `TRIGger:COUNt` value is returned. If you send the MIN parameter, the command returns the minimum trigger count allowable. If you send the MAX parameter, the command returns the maximum trigger count allowable. Be sure to place a space between the command and the parameter.

Linking Commands

Linking IEEE 488.2 Common Commands with SCPI Commands: Use only a semicolon between the commands. For example:

`RST;RES:NPLC 100` or `SAMP:COUNt 25;WAI`

Linking Multiple SCPI Commands From the Same Subsystem: Use only a semicolon between commands within the same subsystem. For example, to set trigger count, trigger delay, and the trigger source that are all set using the `TRIGger` subsystem, send the following SCPI string:

```
TRIG:COUNt 10;DELay .05;SOURce TTLT4
```

Linking Multiple SCPI Commands of Different Subsystems: Use both a semicolon and a colon between commands of different subsystems. For example, a `SAMPle` and `OUTPut` command can be sent in the same SCPI string linked with a semicolon and colon (;:) as follows:

```
SAMP:COUNt 10;:OUTP:TTLT4 ON
```

SCPI Conventions and Data Formats

The SCPI conventions shown in the below table are used throughout this document. Data programmed or queried from the instrument is coded in ASCII. The data may contain numeric values or character strings.

Convention	Description
Angle bracket < >	Items within angle brackets are parameter abbreviations. For example, ‘<NR1>’ indicates a specific form of numerical data.
Vertical bar |	Vertical bars separate alternative parameters. For example, <VOLT|CURR> indicates that either VOLT or CURR must be placed there.
Square brackets [ ]	Items within square brackets are optional. The representation [SOURce:]VOLTage means that SOURce: may be omitted.
‘<NR1>’	Digits with an implied decimal point to at the right of the least-significant digit. Example: 273
‘<NR2>’	Digits with an explicit decimal point. Example: 27.3
‘<NR3>’	Digits with an explicit decimal point and an exponent. Example: 2.73E+02
‘<NRf>’	Extended format that includes ‘<NR1>’, ‘<NR2>’ and ‘<NR3>’. Examples: 273, 27.3, 2.73E+02
‘<NRf+>’	Expanded decimal format that includes ‘<NRf>’, DEF, MIN, and MAX. Examples: 273, 27.3, 2.73E+02. DEF, MIN, and MAX are the default, minimum, and maximum values defined by the range specification of the parameter.
‘<NDN>’	Non-decimal numeric value. May be represented in binary preceded by “#B”, octal preceded by “#Q”, or hexadecimal preceded by “#H”. Examples: 29 (decimal), #B11101 (binary), #Q35 (octal), #H1D (hexadecimal)
‘<Bool>’	Boolean data. Can be numeric (0, 1), or named (OFF, ON).
‘<SPD>’	String program data. Programs string parameters enclosed in single or double quotes.
‘<String>’	‘<SPD>’ or ‘<SRD>’

Convention	Description
‘<CPD>’	Character program data. Programs discrete parameters. Accepts both short form and long form.
‘<CRD>’	Character response data. Returns discrete parameters. Only the short form of the parameter is returned.
‘<AARD>’	Arbitrary ASCII response data. Permits the return of un-delimited 7-bit ASCII. This data type has an implied message terminator.
‘<Block>’	Arbitrary block response data. Permits the return of definite length and indefinite length arbitrary response data. This data type has an implied message terminator.

Multimeter Range and Resolution Tables

The following tables list the voltage, current, and resistance ranges available for the multimeter. The tables also show the associated resolution values versus aperture time in seconds or integration time in PLCs for each range.

Table 4-2 DC Voltage Resolution versus Integration Time or Aperture Time

M1412A Mode		**Integration Time in PLCs Aperture Time for 60 Hz Line Frequency (seconds)**								
Range	**Maximum Reading**	**100 PLCs 1.67 s**	**10 PLCs 167 ms**	**1 PLC 16.7 ms**	**0.2 PLC 3.33 ms**	**0.06 PLC 1.00 ms**	**0.02 PLC 0.333 ms**	**0.006 PLC 0.100 ms**	**0.002 PLC 0.0333 ms**	**0.001 PLC 0.017 ms**
100 mV	120 mV	1 nV	3 nV	10 nV	30 nV	50 nV	100 nV	300 nV	1 µV	3 µV
1 V	1.2 V	10 nV	30 nV	100 nV	300 nV	500 nV	1 µV	3 µV	10 µV	30 µV
10 V	12 V	100 nV	300 nV	1 µV	3 µV	5 µV	10 µV	30 µV	100 µV	300 µV
100 V	120 V	1 µV	3 µV	10 µV	30 µV	50 µV	100 µV	300 µV	1 mV	3 mV
300 V	303 V	3 µV	10 µV	30 µV	100 µV	150 µV	300 µV	1 mV	3 mV	10 mV

E1412A Mode		**Integration Time in PLCs Aperture Time for 60 Hz Line Frequency (seconds)**				
Range	**Maximum Reading**	**100 PLCs 1.67 s**	**10 PLCs 167 ms**	**1 PLC 16.7 ms**	**0.2 PLC 3.33 ms**	**0.02 PLC 0.333 ms**
100 mV	120 mV	30 nV	100 nV	300 nV	1 µV	10 µV
1 V	1.2 V	300 nV	1 µV	3 µV	10 µV	100 µV
10 V	12 V	3 µV	10 µV	30 µV	100 µV	1 mV
100 V	120 V	30 µV	100 µV	300 µV	1 mV	10 mV
300 V	303 V	100 µV	300 µV	3 mV	10 mV	100 mV

Table 4-3 DC Current Resolution versus Integration Time or Aperture Time

M1412A Mode		**Integration Time in PLCs Aperture Time for 60 Hz Line Frequency (seconds)**				
Range	**Maximum Reading**	**100 PLCs 1.67 s**	**10 PLCs 167 ms**	**1 PLC 16.7 ms**	**0.2 PLC 3.33 ms**	**0.02 PLC 0.333 ms**
1 μA	1.2 μA	300 fA	1 pA	3 pA	10 pA	100 pA
10 μA	12 μA	3 pA	10 pA	30 pA	100 pA	1 nA
100 μA	120 μA	30 pA	100 pA	300 pA	1 nA	10 nA
1 mA	1.2 mA	300 pA	1 nA	3 nA	10 nA	100 nA
10 mA	12 mA	3 nA	10 nA	30 nA	100 nA	1 μA
100 mA	120 mA	30 nA	100 nA	300 nA	1 μA	10 μA
1 A	1.2 A	300 nA	1 μA	3 μA	10 μA	100 μA
3 A	3.03 A	900 nA	3 μA	9 μA	30 μA	300 μA

E1412A Mode		**Integration Time in PLCs Aperture Time for 60 Hz Line Frequency (seconds)**				
Range	**Maximum Reading**	**100 PLCs 1.67 s**	**10 PLCs 167 ms**	**1 PLC 16.7 ms**	**0.2 PLC 3.33 ms**	**0.02 PLC 0.333 ms**
10 mA	12 mA	3 nA	10 nA	30 nA	100 nA	1 μA
100 mA	120 mA	30 nA	100 nA	300 nA	1 μA	10 μA
1 A	1.2 A	300 nA	1 μA	3 μA	10 μA	100 μA
3 A	3.03 A	900 nA	3 μA	9 μA	30 μA	300 μA

Table 4-4 2-Wire and 4-Wire Resistance Resolution versus Integration Time or Aperture Time

M1412A Mode		**Integration Time in PLCs Aperture Time for 60 Hz Line Frequency (seconds)**				
Range	**Maximum Reading**	**100 PLCs 1.67 s**	**10 PLCs 167 ms**	**1 PLC 16.7 ms**	**0.2 PLC 3.33 ms**	**0.02 PLC 0.333 ms**
10 Ω	12 Ω	3 μΩ	10 μΩ	30 μΩ	100 μΩ	1 mΩ
100 Ω	120 Ω	30 μΩ	100 μΩ	300 μΩ	1 mΩ	10 mΩ
1 kΩ	1.2 kΩ	300 μΩ	1 mΩ	3 mΩ	10 mΩ	100 mΩ
10 kΩ	12 kΩ	3 mΩ	10 mΩ	30 mΩ	100 mΩ	1 Ω
100 kΩ	120 kΩ	30 mΩ	100 mΩ	300 mΩ	1 Ω	10 Ω
1 MΩ	1.2 MΩ	300 mΩ	1 Ω	3 Ω	10 Ω	100 Ω
10 MΩ	12 MΩ	3 Ω	10 Ω	30 Ω	100 Ω	1 kΩ
100 MΩ	120 MΩ	30 Ω	100 Ω	300 Ω	1 kΩ	10 kΩ
1 GΩ	1.2 GΩ	3 kΩ	10 kΩ	30 kΩ	100 kΩ	1 MΩ

E1412A Mode		**Integration Time in PLCs Aperture Time for 60 Hz Line Frequency (seconds)**				
Range	**Maximum Reading**	**100 PLCs 1.67 s**	**10 PLCs 167 ms**	**1 PLC 16.7 ms**	**0.2 PLC 3.33 ms**	**0.02 PLC 0.333 ms**
100 Ω	120 Ω	30 μΩ	100 μΩ	300 μΩ	1 mΩ	10 mΩ
1 kΩ	1.2 kΩ	300 μΩ	1 mΩ	3 mΩ	10 mΩ	100 mΩ
10 kΩ	12 kΩ	3 mΩ	10 mΩ	30 mΩ	100 mΩ	1 Ω
100 kΩ	120 kΩ	30 mΩ	100 mΩ	300 mΩ	1 Ω	10 Ω
1 MΩ	1.2 MΩ	300 mΩ	1 Ω	3 Ω	10 Ω	100 Ω
10 MΩ	12 MΩ	3 Ω	10 Ω	30 Ω	100 Ω	1 kΩ
100 MΩ	120 MΩ	30 Ω	100 Ω	300 Ω	1 kΩ	10 kΩ

Table 4-5 AC Voltage: Range versus Resolution

M1412A Mode	**Resolution Choices versus Range**		
Range	**MIN**	**DEF, power-on, and *RST setting**	**MAX**
100 mV	3 nV	3 nV	3 nV
1 V	30 nV	30 nV	30 nV
10 V	300 nV	300 nV	300 nV
100 V	3 μV	3 μV	3 μV
300 V	30 μV	30 μV	30 μV

E1412A Mode	**Resolution Choices versus Range**		
Range	**MIN**	**DEF, power-on, and *RST setting**	**MAX**
100 mV	100 nV	1 μV	10 μV
1 V	1 μV	10 μV	100 μV
10 V	10 μV	100 μV	1 mV
100 V	100 μV	1 mV	10 mV
300 V	1 mV	10 mV	100 mV

Table 4-6 AC Current: Range versus Resolution

M1412A Mode	**Resolution Choices versus Range**		
Range	**MIN**	**DEF, power-on, and *RST setting**	**MAX**
1 A	300 nA	300 nA	300 nA
3 A	900 nA	900 nA	900 nA

E1412A Mode	**Resolution Choices versus Range**		
Range	**MIN**	**DEF, power-on, and *RST setting**	**MAX**
1 A	1 μA	10 μA	100 μA
3 A	3 μA	30 μA	300 μA

5 Common (*) Commands

This chapter provides descriptions of the SCPI common commands available for the M1412A.

The commands defined by IEEE 488.2 standard are common to all instruments. For additional information, refer to IEEE 488.2-1987 standard.

Introduction to Common (*) Commands

The common commands are defined by the IEEE 488.2 standard. They are implemented by all instruments that comply with the IEEE 488.2 standard. They provide some of the basic instrument functions, such as instrument identification and resetting, reading the instrument setup, and determining how status is read and cleared.

The common commands can be received and processed by the instrument whether they are sent over the interface as separate program messages or within other program messages. If an instrument subsystem has been selected and a common command is received by the instrument, the instrument remains in the selected subsystem. For example, if the program message "`:SENSe:FUNCtion "VOLT:DC"; *CLS; VOLTage:RANGe 1`" is received by the instrument, the instrument sets the DC voltage function, clears the status information, and then sets the 1 V range.

In contrast, if a root level command or some other subsystem command is within the program message, you must re-enter the original subsystem after the command. For example, the program message "`:SENSe:VOLTage:RANGe 1; *CLS; :SENSe:VOLTage:RANGe:AUTO ON`" sets the 1 V range, clears the status information, and then sets the auto range mode. In this example, `:SENSe` must be sent again after the `*CLS` command in order to re-enter the `SENSe` subsystem and set the count.

*CAL?

This query command performs self-calibration (autocal) and returns the execution result.

NOTE Open the measurement terminals before starting the self-calibration.

Syntax *CAL?

Query Response *result*

result is 0 or 1 and indicates the calibration result. The response data type is NR1.

0: Passed

1: Failed

Comments

- Self-calibration takes under a minute to complete.
- Self-calibration compensates for drift caused by time and temperature changes in DC voltage and resistance measurements, and it adjusts some aspects of other measurement functions.
- Following the self-calibration, the instrument returns to the state it was in before the self-calibration.

*CLS

This command clears the status byte register, the standard event status register, the questionable signal register, and the error queue. This clears the corresponding summary bits (2, 3, 5, and 7) in the status byte register. This command does not clear the enable registers. For the SCPI status system, see "Status System Register Diagram of the M1412A".

Syntax *CLS

Comments

- Executable when Initiated: Yes
- Coupled Command: No
- Related Command: `STATus:PRESet`
- `*RST` Condition: None

*ESE (Standard Event Status Enable)

This command sets the bits of the standard event status enable register. This command sets the bits of the standard even status enable register. The bits that are set determine which events of the standard event status enable register are allowed to set the ESB (event summary bit) of the status byte register. Setting a bit to 1 enables the corresponding event. For the SCPI status system, see “Status System Register Diagram of the M1412A”.

Syntax

*ESE *enable_number*

*ESE?

Parameter

Parameter	Type	Unit	Range of Value
enable_number	NR1 or NDN		0 - 255. A decimal value that is the sum of the binary-weighted values for the desired bits, or a hexadecimal, octal, or binary value.

Query Response

enable_number

enable_number is the sum of the binary-weighted values of the enable register bits. The response data type is NR1.

Comments

- The `*CLS` (clear status) command will not clear the enable register, but it does clear all bits in the event register.
- The `:STATus:PRESet` command does not clear the bits in the status byte register.
- Executable when Initiated: Yes
- Coupled Command: No
- Related Commands: `*ESR?`, `*SRE`, `*STB?`
- `*RST` Condition: Unaffected
- Power-On Condition: No events are enabled.

Example

Enable all error events.

`*ESE 60`	*Enable error events.*

*ESR? (Standard Event Status Register)

This query returns the current contents of the standard event status register. The event register is a read-only register, which stores (latches) all standard events. Reading the standard event status register clears it. For the SCPI status system, see "Status System Register Diagram of the M1412A".

Syntax *ESR?

Query Response *register*

register is the binary-weighted sum of all bits set in the register. The register is then cleared (all bits 0). For example, if bit 3 (decimal value = 8) and bit 7 (decimal value = 128) are enabled, the query command will return 136. The response data type is NR1.

Comments

- To be reported to the standard event status register, the corresponding bits in the event register must be enabled using the `*ESE` command.
- Once a bit is set, it remains set until cleared by reading the event register or the `*CLS` (clear status) command.
- Executable when Initiated: Yes
- Coupled Command: No
- `*RST` Condition: None
- Power-On Condition: The register is cleared.

*IDN? (Identification Number)

This query command returns the instrument's (mainframe) identification string, which contains four comma-separated fields.

Syntax *IDN?

Query Response Keysight Technologies, *model, serial, revision*

Parameter	Description
model	Module model number
serial	Module serial number
revision	Firmware revision number

The firmware revision field will change whenever the firmware is revised.
The format is x.x.x.x

The first two numbers indicate the major revision number, and they are incremented when functional changes are made.

The last two numbers indicate the functional improvement level. The response data type is AARD.

NOTE

`*IDN?` returns identification information for the M1412A multimeter.
The response consists of four fields:
Keysight Technologies,M1412A,SN00000000,0.1.2.3
The first two fields identify this instrument as model number M1412A manufactured by Keysight Technologies.
The third field is the serial number of the multimeter.
The last field indicates the revision level of the inguard-outguard firmware.

Comments

- Executable when Initiated: Yes
- Coupled Command: No
- *RST Condition: None
- Power-On Condition: The register is cleared.

*LRN? (Learn)

This query command returns an ASCII string of all of the commands required to put the instrument into its current state.

Syntax *LRN?

Query Response *resultCommands*

resultCommands is an ASCII string of the SCPI commands, delimited with semicolons (";") between commands. The response data type is block.

*OPC (Operation Complete)

This command starts monitoring pending operations, and sets/clears the Operation Complete (OPC) bit in the standard event status register as follows:

- If there is no pending operation, the OPC bit is set to 1.
- If there are any pending operations, the OPC bit is set to 0. The bit will be set to 1 again when all pending operations are completed.

The `*OPC` command is required to enable the OPC bit. To stop monitoring pending operations (disable OPC bit), execute the `*CLS` command.

Syntax

*OPC

*OPC?

Query Response

1

The query returns 1 if the instrument has completed all pending operations sent before this command. The response data type is NR1.

Comments

- `*OPC` causes the M1412A to wait for all pending operations to complete, after which the Operation Complete bit (bit 0) in the standard event status register is set.
- The OPC suspends any other activity on the bus until the multimeter completes all commands sent to it prior to the `*OPC` command.
- Executable when Initiated: Yes
- Coupled Command: No
- Related Commands: `*WAI`
- `*RST` Condition: None

*RCL (Recall)

This command restores the instrument to a state that was previously stored in one of the memory locations 0 through 9 with the `*SAV` command.

Syntax *RCL *memory*

Parameter

Parameter	Type	Unit	Range of Value
memory	NR1		One of the memory locations 0 to 9.

Comments

- You cannot restore the instrument state from a storage location that is empty or was deleted. You can only recall a state from a location that contains a previously stored state.
- The `*RST` command does not affect the configurations stored in memory. Once a state is stored, it remains until it is overwritten or deleted.

*RST (Reset)

This command performs an instrument reset. This command resets the volatile memory of the instrument to its initial state.

`*RST` resets the M1412A as follows:

- Sets all commands to their `*RST` state.
- Aborts all pending operations.

`*RST` does not affect:

- The output queue
- The Service Request and standard event status enable register
- The enable unmasks for the questionable signal registers
- Calibration data

Syntax *RST

Comment This command cancels any measurement or output trigger actions currently in progress, and resets the waiting-for and trigger bits in the status operation condition register.

- Executable when Initiated: Yes

*SAV (Save)

This command stores the current state of the instrument to the specified location in non-volatile memory. Up to 10 states can be stored in memory locations 0 through 9. Any state previously stored in the same location will be overwritten. Use the `*RCL` command to retrieve instrument states.

Syntax *SAV *memory*

Parameter

Parameter	Type	Unit	Range of Value
memory	NR1		One of the memory locations 0 to 9.

Comments

- If a particular state is desired at power-on, it should be stored in location 0. It will then be automatically restored at power-on if the Output Power-On state is set to `*RCL 0`. Data described in “Non-Volatile Settings” is not affected by the `*SAV` command.
- The `*RST` command does not affect the configurations stored in memory. Once a state is stored, it remains until it is overwritten or deleted.

CAUTION This command causes a write cycle to non-volatile memory. Non-volatile memory has a finite maximum number of write cycles. Programs that repeatedly cause write cycles to non-volatile memory can eventually exceed the maximum number of write cycles and cause the memory to fail.

*SRE (Service Request Enable)

`*SRE unmask` specifies which bits of the status byte register are enabled (unmasked) to generate an IEEE-488.1 service request. Event and summary bits are always set and cleared in the status byte register regardless of the unmask value. unmask is the sum of the decimal weights of the bits to be enabled, allowing these bits to pass through to the summary bit RQS (bit 6 in the status byte). Setting a bit to 1 enables the corresponding event. For the SCPI status system, see "Status System Register Diagram of the M1412A".

Syntax *SRE *unmask*

*SRE?

Parameter

Parameter	Type	Unit	Range of Value
unmask	NR1 or NDN		0 - 255. A decimal value that is the sum of the binary-weighted values for the desired bits, or a hexadecimal, octal, or binary value.

Query Response *unmask*

unmask is the binary-weighted sum of all bits set in the register. For example, if bit 3 (decimal value = 8) and bit 7 (decimal value = 128) are enabled, the query command will return 136 (8+128). The response data type is NR1.

Comments

- Executable when Initiated: Yes
- Coupled Command: No
- `*RST` Condition: Unaffected
- Power-On Condition: No bits are enabled.

Example Enable service request on message available bit.

```
*SRE 16
```

*STB? (Read Status Byte)

`*STB?` returns the value of the status byte register. The RQS bit (bit 6 in the status byte having decimal weight 64) is set if a service request is pending. This query reads the status byte register, which contains the status summary bits and the output queue MAV bit. The status byte register is a read-only register and the bits are not cleared when it is read. For the SCPI status system, see "Status System Register Diagram of the M1412A".

Syntax *STB?

Query Response *register*

register is the binary-weighted sum of all bits set in the register. For example, if bit 1 (decimal value = 2) and bit 4 (decimal value = 16) are set (and the corresponding bits are enabled), this command will return 18 (2+16). The response data type is NR1.

Comments

- Executable when Initiated: Yes
- Coupled Command: No
- Related Command: `*SRE`
- `*RST` Condition: None

*TRG (Trigger)

This common command generates a trigger when the trigger subsystem has BUS selected as its source. The command has the same effect as the Group Execute Trigger (`GET`) command.

Syntax *TRG

*TST? (Self Test)

`*TST?` causes the M1412A to execute its internal self-test and returns a value indicating the results of the test. A zero response indicates that the self-test passed. Any non-zero response indicates that the test failed. Use the `SYST:ERR?` command to read the error and description from the error queue. Note the error number and description returned in the error message. See "Error Messages", for information on interpreting the error number and description response(s). The settings for all SCPI commands are unchanged by this command.

Syntax *TST?

Query Response *result*

result is 0 or 1 and indicates the self-test result. The response data type is NR1.

0: All tests passed

1: One or more tests failed

Comments

- Executable when Initiated: No
- Coupled Command: No
- `*RST` Condition: None

*WAI (Wait To Continue)

This command instructs the instrument not to process any further commands until all pending operations are completed. Pending operations are as defined under the `*OPC` command.

Syntax *WAI

Comments

- `*WAI` can be aborted only by sending the instrument a Device Clear command.
- Executable when Initiated: Yes
- Coupled Command: No
- Related Commands: `*OPC`, `*OPC?`
- `*RST` Condition: None

6 Subsystem Commands

This chapter provides descriptions of the device-specific SCPI commands available for the M1412A.

CALCulate Subsystem

There are five math operations available (AVERage, DB, DBM, LIMit, and NULL), but only one can be enabled at a time. Each performs a mathematical operation on every reading or stores data on a series of readings. The selected math operation remains in effect until you disable it, change functions (even if the same sense function is specified by the `SENS:FUNC` command, it is regarded as function change), turn off the power, or perform a remote interface reset. The math operations use one or more internal registers. You can preset the values in some of the registers, while others hold the results of the math operation. The following table shows the allowable combinations of math/measurement functions. Each "✓" indicates an allowable combination. If you choose a math operation that is not allowed with the present measurement function, math is turned off. If you select a valid math operation and then change to one that is invalid, a "Settings conflict" error is generated over the remote interface on initiating the instrument. For null and dB measurements, you must turn on the math operation before writing to their math registers.

Table 6-1 Valid Math/Measurement Function Combinations Measurements

Function	DCV	ACV	DCI	ACI	Ω2W	Ω4W	Freq	Per	Ratio
AVERage	✓	✓	✓	✓	✓	✓	✓	✓	✓
DB	✓	✓							
DBM	✓	✓							
LIMit	✓	✓	✓	✓	✓	✓	✓	✓	✓
NULL	✓	✓	✓	✓	✓	✓	✓	✓	

Two Ways to Store the NULL Offset Value

- You can enter a specific number into the null register using the `CALCulate:NULL:OFFSet<value>` command. Any previously stored value is replaced with the new value. Use the following commands to activate the NULL function and input a null value. The calculate state must be enabled before you can store a value in the null register.

`CONF:<function>`	
`CALCulate:FUNCtion NULL`	*Set the math function to NULL.*
`CALCulate:STATe ON`	*Enable the math operation.*
`CALCulate:NULL:OFFSet<value>`	*Store a null offset value.*

- Another way to enter a null value is to let the multimeter store the first reading in the register. After you enable the NULL function with the `CALC:STATe ON` command, the first measurement you obtain will be zero (if you have not stored a value as described in the previous bullet point). The measured value is stored as the NULL offset value and subtracted from itself to result in the zero reading. All subsequent measurements will have the offset value subtracted from them. If you previously stored a NULL offset value using `CALC:NULL:OFFS` as in the commands in the above bullet point, the first reading does not overwrite the stored offset value but returns with the previous offset value subtracted.

`CONF:<function>`	
`CALCulate:FUNCtion NULL`	*Set the math function to NULL.*
`CALCulate:STATe ON`	*Enable the math operation.*
	**** Set up the system to generate the offset of concern (e.g. short input leads for 2-wire resistance measurements that will follow) ****
`READ?`	*Measures and stores the offset value.*

- The M1412A supports the Keysight Truevolt–style null offset setting. When the automatic reference selection is ON (`[:SENSe]:<function>:NULL:VALue:AUTO ON`), the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:<function>:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
When the automatic null value selection is disabled (OFF), the null value is specified by `[:SENSe]:<function>:NULL:VALue`.
When the NULL function is enabled (`[:SENSe]:<function>:NULL:STATe ON`), the instrument enables automatic null value selection.

:CALCulate:AVERage:AVERage?

`CALCulate:AVERage:AVERage?` reads the average of all readings taken since `AVERage` was enabled (`CALC:FUNC AVER` and `CALC:STAT ON` commands). The average value is cleared when `AVERage` is enabled, when the power is turned off, or after the multimeter is reset. The average value is stored in volatile memory.

Syntax :CALCulate:AVERage:AVERage?

Comment

- The `ABORt`, `SENSe:FUNC:ON` and `SENSe:<function>:RANGe` commands do not clear the stored values.

Example Query the average of all readings taken since the AVERage math operation was enabled.

`CALC:AVER:AVER?`	*Query the average of all readings.*

:CALCulate:AVERage:COUNt?

`CALCulate:AVERage:COUNt?` reads the number of readings taken since `AVERage` was enabled (`CALC:FUNC AVER` and `CALC:STAT ON` commands). The count value is cleared when `AVERage` is enabled by the `CALC:FUNC AVER` and `CALC:STAT ON` commands, when the power is turned off, or after a remote interface reset. The number of readings taken is stored in volatile memory.

Syntax :CALCulate:AVERage:COUNt?

Comment

- The `ABORt`, `SENSe:FUNC:ON` and `SENSe:<function>:RANGe` commands do not clear the stored values.

Example Query the number of readings since the AVERage math operation was enabled.

`CALC:AVER:COUN?`	*Query number of readings.*

:CALCulate:AVERage:MAXimum?

`CALCulate:AVERage:MAXimum?` reads the maximum value found from an `AVERage` operation. The max value is cleared when `AVERage` is enabled (`CALC:FUNC AVER` and `CALC:STAT ON` commands), when the power is turned off, or after the multimeter is reset. The maximum value is stored in volatile memory.

Syntax :CALCulate:AVERage:MAXimum?

Comment

- The `ABORt`, `SENSe:FUNC:ON` and `SENSe:<function>:RANGe` commands do not clear the stored values.

Example Query the maximum value found during an AVERage math operation.

`CALC:AVER:MAX?`	*Query the max value.*

:CALCulate:AVERage:MINimum?

`CALCulate:AVERage:MINimum?` reads the minimum value found from an AVERage operation. The min value is cleared when `AVERage` is enabled (`CALC:FUNC AVER` and `CALC:STAT ON` commands), when the power is turned off, or after the multimeter is reset. The minimum value is stored in volatile memory.

Syntax :CALCulate:AVERage:MINimum?

Comment

- The `ABORt`, `SENSe:FUNC:ON` and `SENSe:<function>:RANGe` commands do not clear the stored values.

Example Query the minimum value found during an AVERage math operation.

`CALC:AVER:MIN?`	*Query the min value.*

:CALCulate:DB:REFerence

`CALCulate:DB:REFerence` *`reference`* stores a relative value in the dB relative register. You must turn on the math operation, e.g., execute `CALC:STAT ON` before writing to the math register. The dB reference is stored in volatile memory.

Syntax :CALCulate:DB:REFerence *reference*

:CALCulate:DB:REFerence? [*reference*]

Parameter

Parameter	Type	Unit	Range of Value
reference	NRf+		value | MINimum (–200) | MAXimum (200) | DEFault (0) Query does not support *reference*=value.

- The E1412A does not support the “DEFault” parameter.
- *reference* value unit is dBm. The corresponding voltage is calculated using the reference resistance specified in `CALCulate:DBM:REFerence` with following formula.

$$reference\ voltage = \sqrt{10^{\left(\frac{dBm}{10}\right)} \times reference\ resistance \times 1mW}$$

Query Response *reference*

reference returns the current setting of the reference value. If a parameter is specified, *reference* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Example Set the DB reference value.

`CALC:STAT ON`	*Turn on the math operation.*
`CALC:FUNC DB`	*Select the DB math operation. You can select the calculate function at any time before or after enabling the calculate state.*
`CALC:DB:REF 60`	*Sets DB reference to 60 dBm.*

Query the db reference value set for the db math operation.

`CALC:DB:REF?`	*Query the DB reference value.*

:CALCulate:DBM:REFerence

`CALCulate:DBM:REFerence` *`reference`* selects the dBm reference value. Choose from 50, 75, 93, 110, 124, 125, 135, 150, 250, 300, 500, 600, 800, 900, 1000, 1200, or 8000 Ω. You must turn on the math operation, e.g., execute `CALC:STAT ON` before writing to the math register. The dBm reference is stored in non-volatile memory.

Syntax

:CALCulate:DBM:REFerence *reference*

:CALCulate:DBM:REFerence? [*reference*]

Parameter

Parameter	Type	Unit	Range of Value
reference	NRf+		value | MINimum (50) | MAXimum (8000) | DEFault (600) Query does not support *reference*=value.

- The E1412A does not support the “DEFault” parameter.
- When the specified value is not in the value list, the smallest value that exceeds the input is automatically selected and applied (e.g., when 601 is specified, 800 is set).

Query Response

reference

reference returns the current setting of the dBm reference. If a parameter is specified, *reference* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comment

- `*RST` does not change the dBm reference value stored in non-volatile memory.

Example

Set the dBm reference value.

`CALC:STAT ON`	*Turn on the math operation.*
`CALC:DBM:REF 135`	*Sets DBM reference to 135 Ω.*
`CALC:FUNC DBM`	*Select the DBM math operation.* *You can select the calculate function at any time before or after enabling the calculate state.*

Query the dBm reference value set for the dBm math operation.

`CALC:DBM:REF?`	*Query the DBM reference value.*

:CALCulate:FUNCtion

`CALCulate:FUNCtion` *`function`* selects the math function to be used. One function is enabled at a time with NULL as the default. The selected function must be enabled with `CALC:STATe` ON.

Syntax

:CALCulate:FUNCtion *function*

:CALCulate:FUNCtion?

Parameter

Parameter	Type	Unit	Range of Value
function	CPD		AVERage | DB | DBM | LIMit | NULL

Query Response

function

function returns the multimeter to determine the present math function. Returns AVER, DB, DBM, LIM, or NULL. The response data type is CRD.

Comments

- `*RST` Condition: NULL
- The `CALC:STAT` command does not change the `CALC:FUNC` state.

Example

Set the calculate math function to make upper and lower limit tests on each measurement.

```
CALC:FUNC LIM           Set calculate function to limit.
CALC:LIM:LOWer 0        Set the lower limit to test against.
CALC:LIM:UPPer 50       Set the upper limit to test against.
CALC:STATe ON           Enable the limit math operation.
```

Query the calculate math function.

```
CALC:FUNC?              Query the calculate function.
```

:CALCulate:LIMit:LOWer[:DATA]

`CALCulate:LIMit:LOWer` *`limit`* sets the lower limit for limit testing. You must turn on the math operation, e.g., execute `CALC:STAT ON` before writing to the math register. The lower limit is stored in volatile memory.

Syntax :CALCulate:LIMit:LOWer[:DATA] *limit*

:CALCulate:LIMit:LOWer[:DATA]? [*limit*]

Parameter

Parameter	Type	Unit	Range of Value
limit	NRf+	V, A, MOHM (1E6), OHM, MHz (1E6), Hz, s	value | MINimum (see the below table) | MAXimum (see the below table) | DEFault (0) Query does not support *limit*=value.

- The E1412A does not support the “DEFault” parameter.
- The limit depends on the current sense function. The following table shows the relation between sense functions and the MIN and MAX limit values.

Sense Function	MAX	MIN
DCV	1200	–1200
DCI	3.6	–3.6
ACV	1200	–1200
ACI	3.6	–3.6
RATio	+inf (double)	–inf (double)
FREQ	1200E3	–1200E3
PERiod	1.2	–1.2

Sense Function	MAX	MIN
RES	120E6 for E1412A mode 1.2E9 for M1412A mode	–120E6 for E1412A mode –1.2E9 for M1412A mode
FRES	120E6 for E1412A mode 1.2E9 for M1412A mode	–120E6 for E1412A mode –1.2E9 for M1412A mode

- The `*RST`, `SENSe:FUNC:ON`, `CONFigure`, and `MEASure` commands clear the limit value and set 0.
- If the `CALC:LIM:LOW:DATA` value is larger than the `CALC:LIM:UPP:DATA` value, no error is asserted.

Query Response *limit*

limit returns the lower limit value for the limit math function. If a parameter is specified, *limit* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Example Set the lower limit.

`CALC:STAT ON`	*Turn on the math operation.*
`CALC:LIM:LOW 1000`	*Set the lower limit.*
`CALC:FUNC LIM`	*Select the LIMit math operation.* *You may choose to set the math function after setting STATe ON.*

Query the lower limit set for the LIMit math operation.

`CALC:LIM:LOW?`	*Query the lower limit.*

:CALCulate:LIMit:UPPer[:DATA]

`CALCulate:LIMit:UPPer` *`limit`* sets the upper limit for limit testing. You must turn on the math operation, e.g., execute `CALC:STAT ON` before writing to the math register. The upper limit is stored in volatile memory.

Syntax

:CALCulate:LIMit:UPPer[:DATA] *limit*

:CALCulate:LIMit:UPPer[:DATA]? [*limit*]

Parameter

Parameter	Type	Unit	Range of Value
limit	NRf+	V, A, MOHM (1E6), OHM, MHz (1E6), Hz, s	value | MINimum (see the below table) | MAXimum (see the below table) | DEFault (0) Query does not support *limit*=value.

- The E1412A does not support the “DEFault” parameter.
- The limit depends on the current sense function. The following table shows the relation between sense functions and the MIN and MAX limit values.

Sense Function	MAX	MIN
DCV	1200	–1200
DCI	3.6	–3.6
ACV	1200	–1200
ACI	3.6	–3.6
RATio	+inf (double)	–inf (double)
FREQ	1200E3	–1200E3
PERiod	1.2	–1.2

Sense Function	MAX	MIN
RES	120E6 for E1412A mode 1.2E9 for M1412A mode	–120E6 for E1412A mode –1.2E9 for M1412A mode
FRES	120E6 for E1412A mode 1.2E9 for M1412A mode	–120E6 for E1412A mode –1.2E9 for M1412A mode

- The `*RST`, `SENSe:FUNC:ON`, `CONFigure`, and `MEASure` commands clear the limit value and set 0.
- If the `CALC:LIM:LOW:DATA` value is larger than the `CALC:LIM:UPP:DATA` value, no error is asserted.

Query Response *limit*

limit returns the upper value for the limit math function. If a parameter is specified, *limit* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Example Set the upper limit.

`CALC:STAT ON`	*Turn on the math operation.*
`CALC:LIM:UPP 3000`	*Set the upper limit.*
`CALC:FUNC LIM`	*Select the LIMit math operation.* *You may choose to set the math function after setting STATe ON.*

Query the upper limit set for the LIMit math operation.

`CALC:LIM:UPP?`	*Query the upper limit.*

:CALCulate:NULL:OFFSet

`CALCulate:NULL:OFFSet` *`offset`* stores a null value in the multimeter's null register. The null value is stored in volatile memory. See "Two Ways to Store the NULL Offset Value" for another way to store the offset value.

Syntax

:CALCulate:NULL:OFFSet *offset*

:CALCulate:NULL:OFFSet? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	V, A, MOHM (1E6), OHM, MHz (1E6), Hz, s	value | MINimum (–120% of the highest range) | MAXimum (120% of the highest range) | DEFault (0) Query does not support *offset*=value.

- The E1412A does not support the "DEFault" parameter.

Query Response

offset

offset returns the null offset value for NULL math function. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Example

Set the null offset value.

`CALC:FUNC NULL`	*Set math function to NULL.* *You may choose to set the math function after setting STATe ON.*
`CALC:STAT ON`	*Turn on the math operation.*
`CALC:NULL:OFFS 500`	*Set the null offset to 500.*

Query the null offset value set for the NULL math operation.

`CALC:NULL:OFFS?`	*Query the null offset value.*

:CALCulate[:STATe]

`CALCulate[:STATe] state` enables or disables the selected math function. The state is stored in volatile memory.

Syntax

:CALCulate[:STATe] *state*

:CALCulate[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state returns the state of the math function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Example

Enable the currently selected calculate math function.

`CALC:STAT ON`	*The selected or default math function is enabled.*

Query whether a math function state is on or off.

`CALC:STAT?`	*Query the math function state.*

CALibration Subsystem

:CALibration:COUNt?

`CALibration:COUNt?` queries the multimeter to determine the number of times a point calibration has occurred. A complete calibration of the multimeter increases the count by the number of points calibrated. It is not a record of complete calibrations. The count is stored in non-volatile memory.

Syntax :CALibration:COUNt?

Comment

- `*RST` does not change the calibration count stored in non-volatile memory.

Example Query the number of occurrences of point calibrations.

`CAL:COUN?` *Query the calibration count.*

:CALibration:LFRequency

`CALibration:LFRequency` *`frequency`* sets the line frequency to either 50 Hz or 60 Hz.

Syntax :CALibration:LFRequency *frequency*

:CALibration:LFRequency? *frequency*

Parameter

Parameter	Type	Unit	Range of Value
frequency	NRf+		value | MINimum (50) | MAXimum (60) | DEFault (60) Query does not support *frequency*=value.

- The E1412A does not support the “DEFault” parameter.
- The command does not support the “Hz” suffix unit.

Query Response *frequency*

frequency returns the line frequency setting. This command returns +50 for the line frequency set to 400, because 400 is an even multiple of 50. The response data type is NR1.

Comments

- The feature of the command is the same as `SYSTem:LFRequency`.
- An improper line frequency setting will cause reading errors to occur.
- You must execute the `CAL:LFR` command with a parameter of 50 or 400 to change the line frequency setting to 50 Hz. Specifying 400 Hz sets the line frequency to 50 Hz since 400 is an even multiple of 50.
- Default Setting: 60 Hz
- This command setting is not changed by a power off or the `*RST` command.

Example Set the line frequency to 50 Hz.

`CAL:LFR 50`	*Change the line frequency.*

Query the line frequency setting.

`CAL:LFR?`	*Query the line frequency.*

:CALibration:ZERO:AUTO

`CALibration:ZERO:AUTO` *`mode`* enables or disables the autozero mode. Autozero applies to DC voltage, DC current, and 2-wire resistance measurements only. 4-wire resistance and DC voltage ratio measurements automatically enable the autozero mode.

Syntax :CALibration:ZERO:AUTO *mode*

:CALibration:ZERO:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
mode	boolean		OFF | 0 | ONCE | ON | 1 (default)

Query Response *mode*

mode returns the autozero mode. Returns “0” (OFF or ONCE) or “1” (ON). The response data type is NR1.

Comments

- You can use “0” for OFF and “1” for ON in the mode parameter.
- The ON parameter enables autozero. This is the default parameter, which causes the multimeter to internally disconnect the input signal following each measurement and make a zero measurement. The zero reading is subtracted from the input signal reading to prevent offset voltages present on the multimeter’s input circuitry from affecting measurement accuracy.
- The OFF parameter disables autozero. In this mode the multimeter takes one zero measurement and subtracts it from all subsequent input signal measurements prior to a change in function, range or integration time. A new zero measurement is made following a change in function, range or integration time. This mode increases measurement speed because a zero measurement is not made for each input signal measurement.
- Autozero ONCE issues an immediate zero measurement and can be used to get an update on the zero measurement for a specific input signal measurement. This helps to increase measurement speed since you update the zero reading without making zero measurements for every measurement.
- `*RST` Condition: `CALibrate:ZERO:AUTO ON` (autozero enabled)

CONFigure Subsystem

The CONFigure command subsystem is the most concise way to configure measurements. Like the MEASure? queries, CONFigure command uses default measurement configuration values. However, the CONFigure command does not automatically start measurements, so you can modify measurement attributes before initiating the measurement.

Default Settings for the CONFigure Subsystem

The CONFigure command subsystem selects the function, range, and resolution in one command. Specify in the measurement's units (V, A, Hz, OHM, and so on). All other parameters are always set to their default values (below).

Measurement Parameter	Default Setting
AC Input Filter (bandwidth)	20 Hz (medium filter)
Auto Zero	OFF if resolution setting results in NPLC < 1 ON if resolution setting results in NPLC >= 1
Range	AUTO (including voltage range for frequency and period measurements)
Samples per Trigger	1 sample
Trigger Count	1 trigger
Trigger Delay	AUTO
Trigger Source	Immediate
Math Function	Disabled
Null State	Disabled

:CONFigure?

The `CONFigure?` command queries the multimeter for the configuration set by the most recent `CONFigure` or `MEASure` command.

Syntax :CONFigure?

Query Response *response*

response returns a quoted string to the output buffer in the following format: " ,"

Comments

- When the multimeter is configured for current, voltage, or resistance measurements, `CONFigure?` returns the function followed by the selected range and resolution. For example:

  "CURR:AC +1.000000E+00,1.000000E-05"

  "CURR +1.000000E+00,1.000000E-05"

  "VOLT:AC +2.000000E+02,1.000000E-06"

  "VOLT +3.000000E+02,1.000000E-06"

  "VOLT:RAT +3.000000E+02,1.000000E-06"

  "FRES +100.0000E+03,1.000000E-05"

  "RES +1.000000E+03,1.000000E-03"

  "FREQ +3.000000+00,3.000000E-05"

  "PER +3.333330E-01,3.333330E-06"

- If you specify DEF, MIN, or MAX for the range or resolution parameters in `CONFigure` or `MEASure`, the `CONFigure?` command returns the selected value.
- Related Commands: `CONFigure`, `MEASure`

Example Query the multimeter configuration.

`CONF:FRES 900,MAX`	*Function: 4-wire resistance; range selected: 1 kΩ; MAX resolution: 100 mΩ.*
`CONF?`	*Query configuration.*

String returned:
`"FRES +1.000000E+003,1.000000E-1"`

:CONFigure:CURRent:AC

`CONFigure:CURRent:AC [range[,resolution]]` selects the AC current function and allows you to specify the measurement range and resolution.

Syntax :CONFigure:CURRent:AC [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	A	value | MINimum (1) | MAXimum (3) | DEFault (auto range) | AUTO
resolution	NRf+	A	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault

See Table 4-6 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange.
- The MIN and MAX parameters select the minimum or maximum values for range and resolution:

  For range: MIN = 1; MAX = 3

  For resolution: MIN selects the best resolution (the smallest value) for the selected range.

  MAX selects the worst resolution (the largest value) for the selected range.
- To select an autorange, specify AUTO or DEF for range or do not specify a value for the range and resolution parameters (see the next bullet point). In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.

- To specify the MIN or MAX resolution while autoranging, you must specify the AUTO or DEF parameter for range and specify MIN or MAX, e.g., `CONF:CURR:AC DEF,MIN`, `CONF:CURR:AC DEF,MAX`, `CONF:CURR:AC AUTO,MIN`, or `CONF:CURR:AC AUTO,MAX` (you cannot omit the range parameter DEF or AUTO). This prevents the MIN or MAX resolution from being interpreted as a range setting.
- Related Commands: `FETCh?`, `INITiate`, `READ?`
- This command does not support the “Amp” unit but can use “A”.

Example Make AC current measurements.

`CONF:CURR:AC 3,MAX`	*Function: AC current; range selected: 3 A; MAX resolution: 0.3 mA.*
`SAMP:COUN 3`	*Take 3 readings; trigger source is IMMediate by default.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; query the readings.*

:CONFigure:CURRent[:DC]

`CONFigure:CURRent[:DC] [range[,resolution]]` selects the DC current function and allows you to specify the measurement range and resolution.

Syntax :CONFigure:CURRent[:DC] [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	A	value | MINimum (0.01 for E1412A mode, 1E-6 for M1412A mode) | MAXimum (3) | DEFault (auto range) | AUTO
resolution	NRf+	A	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-3 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range to accept that input.
- The AUTO option for the range parameter enables an autorange and will not accept a resolution parameter but will default to 10 PLCs for the integration time.
- The DEF option for the range parameter will also enable an autorange. The DEF option for the resolution parameter defaults to 10 PLCs for the integration time.
- To select an autorange, specify AUTO or DEF for range or do not specify a value for the range and resolution parameters (the next bullet point). In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify the MIN or MAX resolution while autoranging, you must specify the AUTO or DEF parameter for range and specify MIN or MAX, e.g., `CONF:CURR:DC DEF,MIN`, `CONF:CURR:DC DEF,MAX`, `CONF:CURR AUTO,MIN`, or `CONF:CURR AUTO,MAX` (you cannot omit the range parameter DEF or AUTO). This prevents the MIN or MAX resolution from being interpreted as a range setting.
- Related Commands: `FETCh?`, `INITiate`, `READ?`
- This command does not support the "Amp" unit but can use "A".

Example

Make DC current measurements.

`CONF:CURR 3,MAX`	*Function: DC current; range selected: 3 A; MAX resolution: 0.3 mA.*
`SAMP:COUN 3`	*Take 3 readings; trigger source is IMMediate by default.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; query the readings.*

:CONFigure:FREQuency

`CONFigure:FREQuency [range[,resolution]]` selects the frequency function.

Syntax :CONFigure:FREQuency [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	Hz	value | MINimum (3) | MAXimum (3) | DEFault (3)| AUTO (DEF)
resolution	NRf+	Hz	value | MINimum | MAXimum | DEFault

- Only a 3 Hz range can be selected.

- E1412A mode

  The measurement resolution is shown below:

Parameter	Aperture (ms)	Resolution (Range 3 Hz)
MAX	10	3E-4
DEF	100	3E-5
MIN	1000	3E-6

- M1412A mode

  The measurement resolution is shown below:

Parameter	Aperture (ms)	Resolution (Range 3 Hz)
MAX	1	3E-4
DEF	100	3E-6
MIN	1000	3E-7

Comments

- The range of the frequency function is between 3 Hz and 300 kHz.
- The aperture is calculated by range and resolution (e.g., in M1412A mode, `CONF:FREQ 100, 0.001` sets the aperture to 10 ms because resolution / range equals 10 ppm).
- A frequency measurement returns “0” if no input is applied.
- The range and resolution settings are listed above for the MIN, MAX, DEF, and AUTO parameters.
- The range and resolution will be set to default after the module is reset (`*RST`).

:CONFigure:FRESistance

`CONFigure:FRESistance [`*`range`*`[,`*`resolution`*`]]` selects the 4-wire resistance function and allows you to specify the measurement range and resolution.

Syntax :CONFigure:FRESistance [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	OHM	value | MINimum (100 for E1412A mode, 10 for M1412A mode) | MAXimum (100E6 for E1412A mode, 1E9 for M1412A mode) | DEFault (auto range) | AUTO
resolution	NRf+	OHM	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-4 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal’s maximum expected resistance. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.

- To select an autorange, specify AUTO or DEF for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify the AUTO or DEFault parameter: `CONF:FRES DEF,MIN`, `CONF:FRES DEF,MAX`, `CONF:FRES AUTO,MIN`, or `CONF:FRES AUTO,MAX` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting.
- Related Commands: `FETCh?`, `INITiate`, `READ?`
- Unlike other functions, autozero is enabled regardless of the resolution setting.

Example Make 4-wire resistance measurements.

`CONF:FRES 1500,MAX`	*Function: 4-wire resistance; range selected: 10 kΩ; MAX resolution: 1 Ω.*
`SAMP:COUN 3`	*Take 3 readings; trigger source is IMMediate by default.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; query the readings.*

:CONFigure:PERiod

`CONFigure:PERiod [range[,resolution]]` selects the period function.

Syntax :CONFigure:PERiod [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	s	value | MINimum | MAXimum | DEFault | AUTO (DEF)
resolution	NRf+	s	value | MINimum | MAXimum | DEFault

- E1412A mode
  Only a 0.333333 second range can be selected. The range values are MINimum (3.33333E-1) | MAXimum (3.33333E-1) | DEFault (3.33333E-1) | AUTO (3.33333E-1).

  The measurement resolution is shown below:

Parameter	Aperture (ms)	Resolution (Range 0.333333 s)
MAX	10	3.33333E-5
DEF	100	3.33333E-6
MIN	1000	3.33333E-7

- M1412A mode
  Only a 0.333333333 second range can be selected. The range values are MINimum (3.33333333E-1) | MAXimum (3.33333333E-1) | DEFault (3.33333333E-1) | AUTO (3.33333333E-1).

  The measurement resolution is shown below:

Parameter	Aperture (ms)	Resolution (Range0.333333333 s)
MAX	1	3.33333333E-5
DEF	100	3.33333333E-7
MIN	1000	3.33333333E-8

Comments

- The range of the period function is between 333.333 ms and 3.33 μs.
- A period measurement returns “0” if no input is applied.
- The range and resolution settings are listed above for the MIN, MAX, DEF, and AUTO parameters.
- The range and resolution will be set to default after the module is reset (`*RST`).

:CONFigure:RESistance

`CONFigure:RESistance [range[,resolution]]` selects the 2-wire resistance function and allows you to specify the measurement range and resolution.

Syntax :CONFigure:RESistance [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	OHM	value | MINimum (100 for E1412A mode, 10 for M1412A mode) | MAXimum (100E6 for E1412A mode, 1E9 for M1412A mode) | DEFault (auto range) | AUTO
resolution	NRf+	OHM	resolution NRf+ ohm value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-4 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected resistance. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.
- To select an autorange, specify AUTO or DEF for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify the AUTO or DEFault parameter: `CONF:RES DEF,MIN`, `CONF:RES DEF,MAX`, `CONF:RES AUTO,MIN`, or `CONF:RES AUTO,MAX` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting.
- Related Commands: `FETCh?`, `INITiate`, `READ?`

Example Make 2-wire resistance measurements.

`CONF:RES 850,MAX`	*Function: 2-wire resistance; range selected: 1 kΩ; MAX resolution: 0.1 Ω.*
`SAMP:COUN 3`	*Take 3 readings; trigger source is IMMediate by default.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; query the readings.*

:CONFigure:VOLTage:AC

`CONFigure:VOLTage:AC [range[,resolution]]` selects the AC-coupled RMS voltage function and allows you to specify the measurement range and resolution.

Syntax :CONFigure:VOLTage:AC [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (auto range) | AUTO
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault

See Table 4-5 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected voltage. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange.
- The MIN and MAX parameters select the minimum or maximum values for range:

  For range: MIN = 0.1 V; MAX = 300 V

  For resolution: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.
- To select an autorange, specify AUTO or DEF for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify the MIN or MAX resolution while autoranging, you must specify AUTO or DEFault for range: `CONF:VOLT:AC DEF,MIN`, `CONF:VOLT:AC DEF,MAX`, `CONF:VOLT:AC AUTO,MIN`, or `CONF:VOLT:AC AUTO,MAX` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting.
- This command does not support the "Volt" unit but can use "V".

Example Make AC voltage measurements.

`CONF:VOLT:AC 0.54,MAX`	*Function: AC voltage; range selected: 1 V; MAX resolution: 100 μV.*
`SAMP:COUN 3`	*Take 3 readings; trigger source is IMMediate by default.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; query the readings.*

:CONFigure[:VOLTage[:DC]]

`CONFigure[:VOLTage[:DC]] [`*`range`*`[,`*`resolution`*`]]` selects the DC voltage function and allows you to specify the range and resolution.

Syntax :CONFigure[:VOLTage[:DC]] [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (auto range) | AUTO
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-2 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected voltage. The multimeter then selects the correct range to accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.
- The MIN and MAX parameters select the minimum or maximum value for range and resolution:

  For range: MIN = 100 mV; MAX = 300 V.

  For resolution: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.
- To select an autorange, specify AUTO or DEFault for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.

- To specify a MIN or MAX resolution while autoranging, you must specify AUTO or DEFault for range: `CONF:VOLT:DC DEF,MIN`, `CONF:VOLT:DC DEF,MAX`, `CONF:VOLT:DC AUTO,MIN`, or `CONF:VOLT:DC AUTO,MAX` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting.
- Related Commands: `FETCh?`, `INITiate`, `READ?`
- This command does not support the “Volt” unit but can use “V”.

Example Make DC voltage measurements.

`CONF:VOLT 0.825,MAX`	*Function: DC voltage; range selected: 1 V; MAX resolution: 100 µV.*
`SAMP:COUN 3`	*Take 3 readings; trigger source is IMMediate by default.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; query the readings.*

:CONFigure[:VOLTage[:DC]]:RATio

`CONFigure[:VOLTage[:DC]]:RATio [`*`range`*`[,`*`resolution`*`]]` configures the multimeter for DC voltage ratio measurements with the specified range and resolution.

$$\text{DC:DC RATio} = \frac{\text{DC signal voltage}}{\text{DC reference voltage}} = \frac{\text{Hi and Lo input}}{\text{Sense Hi and Lo input}}$$

The ratio is calculated from the voltage applied to the Hi and Lo input terminals divided by the reference voltage applied to the “Sense” Hi and Lo terminals. The autorange is automatically selected for the reference voltage measurement on the “Sense” Hi and Lo terminals. The specified range in the command applies to the signal connected to the Hi and Lo input terminals.

Syntax :CONFigure[:VOLTage[:DC]]:RATio [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range (Hi-Lo input)	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (auto range) | AUTO
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-2 for resolution choices.

NOTE An autorange on the “Sense” terminals is in the range of 100 mV to 10 V only. The maximum voltage you can apply to the “Sense” terminals is 12 V.

Comments

- To select a standard measurement range, specify range as the input signal’s maximum expected voltage. The multimeter then selects the correct range to accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.
- The MIN and MAX parameters select the minimum or maximum values for range and resolution:

  For range: MIN = 0.1; MAX = 300.

  For resolution: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.
- This command does not support the “Volt” unit but can use “V”.
- Unlike other functions, autozero is enabled regardless of the resolution setting.

DATA Subsystem

:DATA:POINts?

The `INITiate` command uses internal memory to store readings prior to a `FETCh?` command, e.g., when a measurement is initiated by the `INITiate` command. You can query the number of stored readings in memory by sending the `DATA:POINts?` command.

Syntax DATA:POINts?

Example

```
FUNC “VOLT”,“VOLT:DC2” TRIG:COUN 10 TRIG:DEL MIN INIT *OPC?
DATA:POINTS? < +20

FORM:ELEM:SENS:TIME ON TRIG:COUN 10 TRIG:DEL MIN INIT *OPC?
data:poin? < +20
```

FETCh Subsystem

:FETCh?

The `FETCh?` command retrieves measurements stored in the module's internal memory by the most recent `INITiate` command and places them in the output buffer. This command is most commonly used with `CONFigure`.

Syntax :FETCh?

Query Response *sens[,timestamp][,status][,dc2Sens][,dc2Timestamp][,dc2Status]*

- Readings sent to the output buffer can consist of two different lengths (bytes or characters) in Real ASCII format: ±1.23456E±12 or ±1.234567E±12.
- When `SENS:FUNC “VOLT:DC”,“VOLT:DC2”` or `SENS:FUNC “CURR:DC”,“VOLT:DC2”` is specified, the *dc2* value is also returned. The value format is the same with *sense* data.

  For example:
  ±1.23456E±12,6.54321±12,±1.234567E±12,6.54321±12,±1.23456E±12,
  6.54321±12
- When `FORM:ELEM:SENS:TIME:STAT ON` is specified, the *timestamp* value is also returned. The value format is the same with *sense* data.

  For example:
  ±1.23456E±12,+0.00000E+0,±1.234567E±12,+1.00000E-1,
  ±1.23456E±12,+2.00000E-1
- Any combinations of *dc2*, *timestamp*, *secondary* elements are allowed.

Comment

- Execute `INITiate` before sending the `FETCh?` command to place the multimeter in the wait-for-trigger state. If the multimeter has not taken any data (e.g., if `INITiate` has not been executed), or if some settings have been altered since the last `FETCh?` (e.g., changing function), the “Data corrupt or stale” error will be generated.

NOTE If you do not alter any settings, you could "FETCh?" the same data over and over again without error.

- Related Commands: CONFigure, INITiate, READ?
- *RST Condition: Executing FETCh? after *RST generates error "Data corrupt or stale" (*RST places the multimeter in the idle state).

Example Transfer stored readings to output buffer.

`CONF:VOLT:DC`	*Function: DC voltage.*
`SAMP:COUN 100`	*100 readings per trigger.*
`INIT`	*Store readings in internal memory; trigger source is IMMediate by default.*
`FETC?`	*Place readings in output buffer.*

FORMat Subsystem

:FORMat:BORDer

Used for binary block transfers only. Selects the byte order for binary block transfers with `MEASure?`, `READ?`, and `FETCh?`.

Syntax :FORMat:BORDer *byte_order*

:FORMat:BORDer?

Parameter

Parameter	Type	Unit	Range of Value
byte_order	CPD		SWAPped | NORMal (default).

Query Response *byte_order*

byte_order returns NORM or SWAP. The response data type is CRD.

Comments

- In the NORMal byte order (default, big endian) the most-significant byte (MSB) of each data point is assumed first. For the IEEE-754 double precision format, byte 1 to byte 8 are sent in this order.
- In the SWAPped byte order (little endian) the least-significant byte (LSB) of each data point is assumed first. For the IEEE-754 double precision format, byte 8 to byte 1 are sent in this order. Most PCs use the “swapped” byte order.
- The byte order setting is stored in non-volatile memory and does not change when the power has been turned off. The default value is restored after a Reset (`*RST`).

Example Select the swapped byte order.

```
FORMat:BORDer SWAP
```

:FORMat[:DATA]

Specifies the data format to be either ASCii or REAL. This command affects the data format of the `MEASure?`, `READ?`, and `FETCh?` commands only.

Syntax

:FORMat[:DATA] *format*[,*length*]

:FORMat[:DATA]?

Parameters

Parameter	Type	Unit	Range of Value
format	CPD		ASCii | REAL
length	NP1		8 (ASCii) | 9 (ASCii) | 64 (REAL)

Query Response

format,length

format,length returns the data format like ASC,8, ASC,9, or REAL,64. The response data type is CRD.

Comments

- If ASCii is specified, numeric data is transferred as ASCii characters. The numbers are separated by commas as specified in IEEE 488.2.
- If REAL is specified, numeric data is transferred as REAL binary data in IEEE 488.2 definite-length block format. The *length* parameter is optional, but “64” is the default and only allowed value. The byte order is controlled by `FORMat:BORDer`.

In the E1412A mode, the default value is ASC,8 and in general mode, the default value is ASC,9. When `*RST` is performed or the power is turned on, format is set as the default value specified above.

Example

The following two commands both specify the 64-bit REAL data format.

```
FORM:DATA REAL,64
FORM:DATA REAL
```

:FORMat:ELEMent[:SENSe]:STATus[:STATe]

Show/hide status data along with the measurement results returned by the `FETCh?` command.

Syntax

:FORMat:ELEMent[:SENSe]:STATus[:STATe] *state*

:FORMat:ELEMent[:SENSe]:STATus[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response

state

state returns whether status data is displayed in measurement results. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- When 1 is specified, status data is added to the values returned by the `FETCh?` command.
- When 0 is specified, status data does not appear in the values returned by the `FETCh?` command.

Example

Configure AC voltage measurements, and set status data to be returned with the measurement values. Then make two measurements and send them to the instrument’s output buffer.

```
CONF:VOLT:AC 100
FORM:ELEM:STATus:STAT 1
TRIG:DEL 0.2
SAMP:COUN 2
INIT
FETC?
```

Typical Response:

```
+8.54530000E+01, +1.00000000E+03, +8.54530000E+01,
+1.00000000E+03
```

:FORMat:ELEMent[:SENSe]:TIME[:STATe]

Show/hide timestamp data along with the measurement results returned by the `FETCh?` command.

Syntax

:FORMat:ELEMent[:SENSe]:TIME[:STATe] *state*

:FORMat:ELEMent[:SENSe]:TIME[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response

state

state returns whether timestamp data is displayed in measurement results. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- When 1 is specified, timestamp data is added to the values returned by the `FETCh?` command.
- When 0 is specified, timestamp data does not appear in the values returned by the `FETCh?` command.

Example

Configure DC voltage measurements, and set timestamp data to be returned with the measurement values. Then make two measurements and send them to the instrument’s output buffer.

```
CONF:VOLT:DC
FORM:ELEM:TIME:STAT 1
TRIG:DEL 0.2
SAMP:COUN 2
INIT
FETC?
```

Typical Response:

```
+1.04530000E+00,2.354986E-01,+1.04570000E+00,4.489065E-01
```

INPut Subsystem

:INPut:IMPedance:AUTO

`INPut:IMPedance:AUTO` *`mode`* enables or disables the automatic input impedance mode for DC voltage measurements. When disabled (AUTO OFF), the multimeter maintains its input impedance of 10 MΩ for all DC voltage ranges. This is useful to prevent a change in input impedance, caused by changing ranges, from affecting the measurements.

Syntax

:INPut:IMPedance:AUTO *mode*

:INPut:IMPedance:AUTO?

Parameters

<table>
<tr><th>Parameter</th><th>Type</th><th>Unit</th><th>Range of Value</th></tr>
<tr><td>mode</td><td>boolean</td><td></td><td>1 | ON | 0 | OFF (default)</td></tr>
</table>

<table>
<tr><th>Mode</th><th>Impedance</th><th>Range</th></tr>
<tr><td>AUTO OFF</td><td>10 MΩ</td><td>All ranges</td></tr>
<tr><td rowspan="2">AUTO ON</td><td>10 MΩ</td><td>100 V and 300V</td></tr>
<tr><td>>10 GΩ</td><td>100 mV, 1 V, and 10 V</td></tr>
</table>

Query Response

mode

mode returns the state of the automatic input impedance mode. Returns “0” (OFF) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF ("0") and ON ("1") parameters.
- `*RST` Conditions: `INP:IMP:AUTO OFF`

Example

Enable automatic input impedance (use >10 GΩ for 100 mV, 1 V, and 10 V ranges).

`INP:IMP:AUTO ON`	*Enable automatic input impedance.*

Query the input impedance mode.

`INP:IMP:AUTO?`	*Query multimeter to return input impedance mode ("1").*

MEASure Subsystem

The `MEASure` command subsystem configures the multimeter to perform the specified measurement with the given range and resolution. When the multimeter is triggered, `MEASure` makes the measurement and sends the readings to the output buffer. Executing `MEASure` is equivalent to configuring the multimeter with the low-level commands shown in the following table:

Command	Setting
RANGe	As specified (or AUTO).
RESolution	As specified, as a function of range, integration time, or NPLCs.
AC filter ([:SENSe]:DET:BAND)	20 Hz - 300 kHz (medium filter)
Autozero ([:SENSe]:ZERO:AUTO)	OFF if resolution setting results in NPLC < 1; ON if resolution setting results in NPLC ≥ 1
Input resistance (:INPut:IMPedance:AUTO?)	Applies to DC voltage and is disabled for all other functions. 10 MΩ for all DC voltage ranges.
Samples per trigger (SAMP:COUN)	1 sample
Trigger count (TRIG:COUN)	1 trigger
Trigger delay (TRIG:DEL)	AUTO (Automatic delay)
Trigger source (TRIG:SOUR)	IMM (trigger signal is always true)
Math function (CALCulate:STATe)	OFF

:MEASure:CURRent:AC?

`MEASure:CURRent:AC? [range[,resolution]]` selects the AC current function and allows you to specify the measurement range and resolution.

Syntax :MEASure:CURRent:AC? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	A	value | MINimum (1) | MAXimum (3) | DEFault (auto range) | AUTO
resolution	NRf+	A	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault

See Table 4-6 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange.
- The MIN and MAX parameters select the minimum or maximum values for range and resolution:

  For range: MIN = 1; MAX = 3

  For resolution: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.
- To select an autorange, specify DEF for range or do not specify a value for the range and resolution parameters (see the next bullet point). In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify the AUTO or DEFault parameter for range as `MEAS:CURR:AC? AUTO` or `MEAS:CURR:AC? DEF` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting, and the resulting command becomes `MEAS:CURR:AC? DEF,MIN` or `MEAS:CURR:AC? DEF,MAX` (or use AUTO in place of DEF).

- Related Commands: `FETCh?`, `INITiate`, `READ?`
- This command does not support the “Amp” unit but can use “A”.

Example Make AC current measurements.

`MEAS:CURR:AC? 1,MAX`	*Function: AC Current; range selected: 1 A; MAX resolution: 1.0E-04 A.*

:MEASure:CURRent[:DC]?

`MEASure:CURRent[:DC]? [range[,resolution]]` selects the DC current function and allows you to specify the measurement range and resolution.

Syntax :MEASure:CURRent[:DC]? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	A	value | MINimum (0.01 for E1412A mode, 1E-6 for M1412A mode) | MAXimum (3) | DEFault (auto range) | AUTO
resolution	NRf+	A	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-3 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal’s maximum expected current. The multimeter then selects the correct range to accept that input.
- The AUTO option for the range parameter enables an autorange and will not accept a resolution parameter but will default to 10 PLCs for the integration time.
- The DEF option for the range parameter will also enable an autorange. The DEF option for the resolution parameter defaults to 10 PLCs for the integration time.

- To select an autorange, specify AUTO or DEF for range, or do not specify a value for the range and resolution parameters (see the next bullet point). In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify the AUTO or DEFault parameter for range as `MEAS:CURR:DC? AUTO` or `MEAS:CURR:DC? DEF` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting, and the resulting command becomes `MEAS:CURR:DC? DEF,MIN` or `MEAS:CURR:DC? DEF,MAX` (or use AUTO in place of DEF).
- Related Commands: `FETCh?`, `INITiate`, `READ?`

Example Make DC current measurements.

`MEAS:CURR:DC? .1,MAX`	*Function: DC current; range selected: 0.1 A MAX resolution: 1.0E-05A.*

:MEASure:FREQuency?

`MEASure:FREQuency? [range[,resolution]]` selects the frequency function.

Syntax :MEASure:FREQuency? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	Hz	value | MINimum (3) | MAXimum (3) | DEFault (3) | AUTO (3)
resolution	NRf+	Hz	value | MINimum (3E-06 for E1412A mode, 3E-07 for M1412A mode) | MAXimum (3E-04) | DEFault (3E-05)

Comments

- The range of the frequency function is between 3 Hz and 300 kHz.
- The aperture time is calculated by range and resolution (e.g., in the M1412A mode, `MEAS:FREQ 100, 0.001` sets the aperture as 10 ms because resolution / range equals 10 ppm).
- A frequency measurement returns “0” if no input is applied.

- Range and resolution settings are listed above for the MIN, MAX, DEF, and AUTO parameters.
- The range and resolution will be set to default after the module is reset (`*RST`).

:MEASure:FRESistance?

`MEASure:FRESistance? [range[,resolution]]` selects the 4-wire resistance function and allows you to specify the measurement range and resolution.

Syntax :MEASure:FRESistance? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	OHM	value | MINimum (100 for E1412A mode, 10 for M1412A mode) | MAXimum (100E6 for E1412A mode, 1E9 for M1412A mode) | DEFault (auto range) | AUTO
resolution	NRf+	OHM	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-4 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected resistance. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.
- To select an autorange, specify DEF for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify `MEAS:FRES? DEF` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting, and the resulting command becomes `MEAS:FRES? DEF,MIN` or `MEAS:FRES? DEF,MAX`.
- Related Commands: `FETCh?`, `INITiate`, `READ?`

Example Make 4-wire resistance measurements.

`MEAS:FRES? 1500,MAX`	*Function: 4-wire resistance; range selected: 10 kΩ; MAX resolution: 1 Ω.*

:MEASure:PERiod?

`MEASure:PERiod? [range[,resolution]]` selects the period function.

Syntax :MEASure:PERiod? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	s	value | MINimum (3.33E-01) | MAXimum (3.33E-01) | DEFault (3.33E-01) | AUTO (5E-02)
resolution	NRf+	s	value | MINimum (3.33E-07 for E1412A mode, 3.33E-08 for M1412A mode) | MAXimum (3.33E-05) | DEFault (3.33E-06)

Comments

- The range of the period function is between 0.33 s and 3.3 µs.
- The aperture time is calculated by range and resolution (e.g., in the M1412A mode, `MEAS:PER 0.2, 0.0000002` sets the aperture as 10 ms because resolution / range equals 10 ppm).
- A period measurement returns "0" if no input is applied.
- The range and resolution settings are listed above for the MIN, MAX, DEF, and AUTO parameters.
- The range and resolution will be set to default after the module is reset (`*RST`).

:MEASure:RESistance?

`MEASure:RESistance? [range[,resolution]]` selects the 2-wire resistance function and allows you to specify the measurement range and resolution.

Syntax :MEASure:RESistance? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	OHM	value | MINimum (100 for E1412A mode, 10 for M1412A mode) | MAXimum (100E6 for E1412A mode, 1E9 for M1412A mode) | DEFault (auto range) | AUTO
resolution	NRf+	OHM	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-4 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected resistance. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.
- To select an autorange, specify DEF for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify AUTO or DEF for the range parameter as in `MEAS:RES? DEF` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting, and the resulting command becomes `MEAS:RES? DEF,MIN` or `MEAS:RES? DEF,MAX`.
- Related Commands: `FETCh?`, `INITiate`, `READ?`

Example Make 2-wire resistance measurements.

`MEAS:RES? 1320,MAX`	*Function: 2-wire resistance; range selected: 10 kΩ; MAX resolution: 1 Ω*

:MEASure:VOLTage:AC?

`MEASure:VOLTage:AC? [range[,resolution]]` selects the AC-coupled RMS voltage function and allows you to specify the measurement range and resolution.

Syntax :MEASure:VOLTage:AC? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (auto range) | AUTO
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault

See Table 4-5 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected voltage. The multimeter then selects the correct range that will accept the input.
- The AUTO or DEF option for the range parameter enables an autorange.
- The MIN and MAX parameters select the minimum or maximum values for range:

  For range: MIN = 0.1 V; MAX = 300 V

  For resolution: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.
- To select an autorange, specify AUTO or DEF for range, or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify `MEAS:VOLT:AC? DEF` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting, and the resulting command becomes `MEAS:VOLT:AC? DEF,MIN` or `MEAS:VOLT:AC? DEF,MAX`.

- Related Commands: `FETCh?`, `INITiate`, `READ?`
- This command does not support the “Volt” unit but can use “V”.

Example Make AC voltage measurements.

`MEAS:VOLT:AC? 0.54,MAX`	*Function: AC voltage; range selected: 1 V; MAX resolution: 100 µV.*

:MEASure[:VOLTage[:DC]]?

`MEASure[:VOLTage[:DC]]? [`*`range`*`[,`*`resolution`*`]]` selects the DC voltage function and allows you to specify the range and resolution.

Syntax :MEASure[:VOLTage[:DC]]? [*range*[,*resolution*]]

Parameters

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (auto range) | AUTO
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-2 for resolution choices.

Comments

- To select a standard measurement range, specify range as the input signal’s maximum expected voltage. The multimeter then selects the correct range to accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.
- The MIN and MAX parameters select the minimum or maximum value for range and resolution:

  For range: MIN = 100 mV; MAX = 300 V.

  For resolution: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.

- To select an autorange, specify DEFault for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify `MEAS:VOLT:DC? DEF` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting, and the resulting command becomes `MEAS:VOLT:DC? DEF,MIN` or `MEAS:VOLT:DC? DEF,MAX`.
- Related Commands: `FETCh?`, `INITiate`, `READ?`
- This command does not support the “Volt” unit but can use “V”.

Example Make DC voltage measurements.

`MEAS:VOLT:DC? 0.825,MAX`	*Function: DC voltage; range selected: 1 V; MAX resolution: 100 μV.*

:MEASure[:VOLTage[:DC]]:RATio?

`MEASure[:VOLTage[:DC]]:RATio? [range[,resolution]]` configures the multimeter for DC voltage ratio measurements with the specified range and resolution.

$$\text{DC:DC RATio} = \frac{\text{DC signal voltage}}{\text{DC reference voltage}} = \frac{\text{Hi and Lo input}}{\text{Sense Hi and Lo input}}$$

The ratio is calculated from the voltage applied to the Hi and Lo input terminals divided by the reference voltage applied to the “Sense” Hi and Lo terminals. The autorange is automatically selected for the reference voltage measurement on the “Sense” Hi and Lo terminals. The specified range in the command applies to the signal connected to the Hi and Lo input terminals.

Syntax :MEASure[:VOLTage[:DC]]:RATio? [*range*[,*resolution*]]

Parameter

Parameter	Type	Unit	Range of Value
range (Hi-Lo input)	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (auto range) | AUTO
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault (10 PLCs)

See Table 4-2 for resolution choices.

NOTE

An autorange on the "Sense" terminals is in the 100 mV to 10 V range only. The maximum voltage you can apply to the "Sense" terminals is 10 V.

Comments

- To select a standard measurement range, specify range as the input signal's maximum expected voltage. The multimeter then selects the correct range to accept the input.
- The AUTO or DEF option for the range parameter enables an autorange. The DEF option for resolution defaults to 10 PLCs for the integration time.
- The MIN and MAX parameters select the minimum or maximum values for range and resolution:

  For range: MIN = 100 m; MAX = 300.

  For resolution: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.
- To select an autorange, specify DEFault for range or do not specify a value for the range and resolution parameters. In the autorange mode, the multimeter samples the input signal before each measurement and selects the appropriate range.
- To specify a MIN or MAX resolution while autoranging, you must specify `MEAS:VOLT:DC:RAT? DEF` (you cannot omit the range parameter). This prevents the MIN or MAX resolution from being interpreted as a range setting and the resulting command becomes `MEAS:VOLT:DC:RAT? DEF,MIN` or `MEAS:VOLT:DC:RAT? DEF,MAX`.
- Related Commands: `FETCh?`, `INITiate`, `READ?`
- This command does not support the "Volt" unit but can use "V".

Example Make DC voltage ratio measurements.

`MEAS:VOLT:DC:RAT? 0.825,MAX`	*Function: DC voltage; range selected: 1 V; MAX resolution: 100 μV.*

OUTPut Subsystem

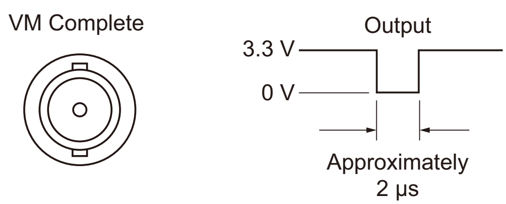
The `OUTPut` command subsystem enables you to route the multimeter's voltmeter complete signal to the PXIe bus TTL trigger lines.

:OUTPut:TRIGger:SLOPe

Selects the slope of the voltmeter complete output signal on the front-panel VM Complete SMB connector.

VM Complete Output (SMB)

The front-panel VM Complete (voltmeter complete) output provides a 3.3 V pulse after completion of each measurement to implement a standard hardware handshake sequence between measurement and switching devices.



The signal shown is for a negative pulse.

Syntax OUTPut:TRIGger:SLOPe *slope*

OUTPut:TRIGger:SLOPe?

Parameter

Parameter	Type	Unit	Range of Value
slope	CPD		POSitive | NEGative (default)

Query Response *slope*

slope returns the slope of the voltmeter. Returns POS, or NEG. The response data type is CRD.

Comment

- This parameter is set to its default value after a Reset (`*RST`).
- This parameter also affects the VM Complete signals issued on processing `*TST?` and `*CAL?` commands.

Example

Configure DC voltage measurements and make two measurements. The signal on the front-panel VM Complete connector outputs a positive pulse as each measurement is completed.

```
CONF:VOLT:DC 10
SAMP:COUN 2
OUTP:TRIG:SLOP POS
INIT
```

:OUTPut:TTLTrg<n>[:STATe]

`OUTPut:TTLTrg<n>[:STATe]` *`state`* enables or disables routing of the voltmeter complete signal to the specified PXIe bus trigger line (TTLTrg0 - TTLTrg7 are aliases for PXI0 - PXI7).

Syntax

:OUTPut:TTLTrg<n>[:STATe] *state*

:OUTPut:TTLTrg<n>[:STATe]?

Parameters

Parameter	Type	Unit	Range of Value
<*n*>	NR1		0 | 1 | 2 | 3 | 4 | 5 | 6 | 7
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state returns a number to show whether PXI trigger line routing of the voltmeter complete signal is enabled or disabled: “0” (OFF) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- The voltmeter complete signal is always routed to the multimeter’s front panel “VM Complete” SMB connector. When enabled (ON), the `OUTPut` command also routes the voltmeter complete signal to the specified trigger line on connector P2. When disabled (OFF), the voltmeter complete signal is routed only to the multimeter’s front panel connector.

- The multimeter generates the voltmeter complete signal after it has sampled the input for each reading. The length of time this low-going TTL signal is true (low) is 10 μs.
- `*RST` Condition: `OUTP:TTLT<n> OFF`

Example Query the voltmeter complete destination.

```
OUTP:TTLT7        ON Route signal to trigger line 7.
OUTP:TTLT7?       Query multimeter to return trigger line mode.
```

READ Subsystem

:READ?

The READ? command is most commonly used with CONFigure to:

- Place the multimeter into the wait-for-trigger state (executes the INITiate command).
- Transfer the readings directly to the output buffer when the trigger is received (the same action as FETCh? but the readings are not stored in internal memory as with the FETCh? command).

Syntax :READ?

Comments

- This command causes the multimeter to start taking readings as soon as its trigger requirements are met (the same as the INIT command).
- Related Commands: CONFigure, FETCh?, INITiate

Example Transfer readings directly to the output buffer.

CONF:VOLT:DC	*Function: DC voltage.*
SAMP:COUN 100	*Specify 100 readings per trigger.*
READ?	*Place multimeter in wait-for-trigger state and make measurements; send readings to output buffer; trigger source is IMMediate by default.*

SAMPle Subsystem

The `SAMPle` command subsystem operates with the `TRIGger` command subsystem. The `SAMPle` subsystem designates the number of readings (count) made for each trigger signal received.

:SAMPle:COUNt

`SAMPle:COUNt` ***number*** sets the number of measurement counts per trigger.

Syntax

SAMPle:COUNt *number*

SAMPle:COUNT? [*number*]

Parameter

Parameter	Type	Unit	Range of Value
number	NRf+		value | MINimum (1) | MAXimum (50,000 for E1412A mode, 2,000,000 for M1412A mode) | DEFault (1) Query does not support *number*=value.

- The E1412A does not support the “DEFault” parameter.
- The E1412A’s maximum count is 50,000.

Query Response

number

number returns one of the following numbers to the output buffer:

- The present sample count (1 through 2,000,000) if a parameter is not specified.
- If a parameter is specified, *number* returns the value assigned to DEF, MIN, or MAX. The response data type is NR1.

Comments

- MINimum sets 1 reading per trigger. MAXimum sets 2,000,000 readings per trigger.
- If MAX or 2,000,000 is specified for number, the command executes without error.

- A number > 2,000,000 returns Error -222, “Data out of range”.
- `CONFigure` and `MEASure` set the sample count to 1.
- `*RST` Condition: `SAMP:COUN 1`

Example Set the sample count.

`CONF:VOLT:DC`	*Function: DC voltage.*
`TRIG:SOUR EXT`	*Trigger source is external SMB on multimeter front panel.*
`SAMP:COUN 10`	*Specify 10 readings per trigger.*
`READ?`	*Place multimeter in wait-for-trigger state; make measurement when external trigger is received; send readings to output buffer.*

Query the sample count.

`SAMP:COUN?`	*Query multimeter to return sample count.*

:SAMPle:SOURce

Determines sample timing together with `TRIGger:DELay` and `SAMPle:TIMer` when the sample count is greater than one.

NOTE It is recommended that all triggered measurements be made using an appropriate fixed manual range. That is, turn the autorange off (`SENSe::RANGe:AUTO OFF`), or set a fixed range using the `SENSe::RANGe`, `CONFigure` or `MEASure` command.

Syntax :SAMPle:SOURce *source*

:SAMPle:SOURce?

Parameter

Parameter	Type	Unit	Range of Value
source	CPD		TIMer | IMMediate (default)

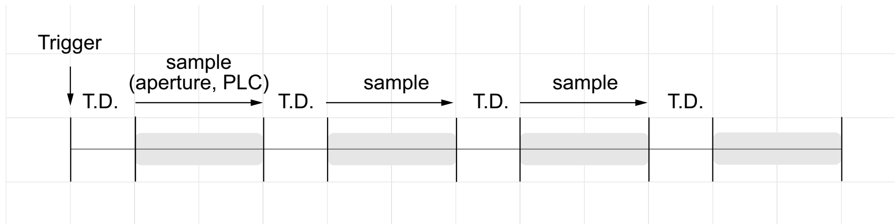
Query Response *source*

source returns “IMM” or “TIM” to show the current trigger source. The response data type is CRD.

Operation

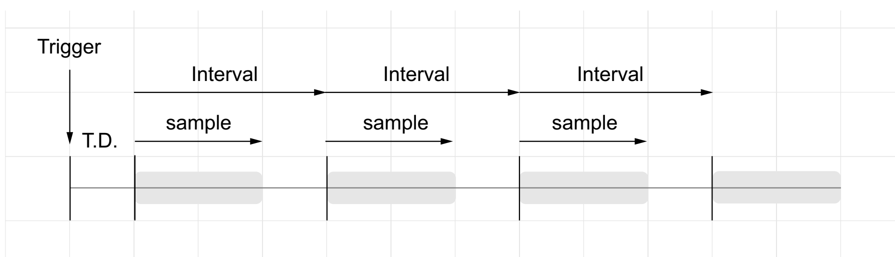
In all cases, the first sample is taken one trigger-delay (T.D.) time after the trigger (the delay being set with the `TRIGger:DELay` command). Beyond that, the timing mechanism depends on whether you select `IMMediate` (default) or `TIMer` as the source:

- `IMMediate` - The first sample starts one trigger-delay time after the trigger, and then the trigger-delay time is inserted between the first and second samples, the second and third, and so on:



The sample timing is not deterministic because the delay time (set with `TRIGger:DELay`) is inserted after each sample completes. The actual time required to take each sample depends on the integration time and autoranging time. In this case, the `SAMPle:TIMer` command has no effect.

- `TIMer` - The first sample starts one trigger-delay time after the trigger. However, the second sample starts one sample interval after the start of the first sample, and so on:



The sample timing is deterministic because the start of each sample is determined by the sample interval, set with the `SAMPle:TiMer` command (`TRIGger:DELay` affects only the start of the first sample). Integration and autoranging affect the sampling time for each sample but not the sample interval as long as the sample interval is longer than the sampling time.

Comments

- The E1412A does not support this command.
- This command has no effect if the sample count is 1 (see ":SAMPle:COUNt").
- After setting the sample count, sample source, and the sample interval or trigger-delay time, you must place the instrument in the "wait-for-trigger" state using the `INITiate` or `READ?` command. A trigger is not accepted from the selected trigger source (see ":TRIGger:SOURce" command) until the instrument is in the "wait-for-trigger" state.
- The instrument sets the sample source to "IMM" after a Reset (`*RST`).

Example

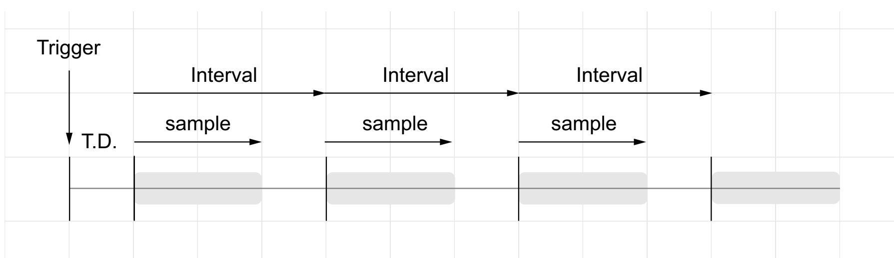
Set sample source to timer. The `INIT` command sets the meter to the "wait-for-trigger" state. When a trigger is received from the selected trigger source, the instrument starts taking periodic samples after the trigger delay.

```
SAMP:SOUR TIM
SAMP:TIM 0.1
INIT
```

:SAMPle:TIMer

Sets a sample interval for timed sampling (`SAMPle:SOURce TIMer`) when the sample count is greater than one.

The first sample is taken one trigger-delay (T.D.) time after the trigger (delay set by `TRIGger:DELay`). The second sample starts one sample interval after the start of the first sample, and so forth, as shown below:



Note that the sample timing is deterministic because the start of each sample is determined by the sample interval. Integration and autoranging affect the sampling time for each sample but not the sample interval as long as the sample interval is longer than the sampling time.

If the sampling time exceeds the sample interval, the next sample starts after it consumes the sampling time, so the interval become longer. Periodic sampling continues until the sample count (set with the `SAMPle:COUN`t command) is reached.

NOTE

It is recommended that all triggered measurements be made using an appropriate fixed manual range. That is, turn the autorange off (`SENSe::RANGe:AUTO OFF`), or set a fixed range using the `SENSe::RANGe`, `CONFigure`, or `MEASure` command. When an autorange is left on, the starting time of a sample becomes uncertain (when a range change occurs) and when ranging exceeds the interval between samples; then all subsequent samples become offset from their desired start points.

Syntax

:SAMPle:TIMer *interval*

:SAMPle:TIMer? [*interval*]

Parameter

Parameter	Type	Unit	Range of Value
interval	NRf+	s	value | MINimum (1E-6) | MAXimum (3600) | DEFault (1) Query does not support *interval*=value.

Query Response

interval

interval returns one of the following numbers to the output buffer:

- The current timer interval if a parameter is not specified.
- The value assigned to DEF, MIN, or MAX, if a parameter is specified.

The response data type is NR3.

Comments

- The E1412A does not support this command.
- The sample time resolution depends on the following table.

Interval [s]	Resolution [s]
~1.0	1 μ
~10	10 μ
~100	100 μ
~1000	1 m
~3600.0	10 m

- After setting the sample count, source, and delay time, you must place the meter in the “wait-for-trigger” state using the `INITiate` or `READ?` command. A trigger is not accepted from the selected trigger source (see the “:TRIGger:SOURce” command) until the instrument is in the “wait-for-trigger” state.
- The interval may be set to any value from 0 to 3600 seconds. However, the value is truncated to the nearest step based on the above resolution table.
- The instrument sets the sample timer to 1 second after a Reset (`*RST` command).

Example

Set the sample interval to 0.1 seconds. `INIT` sets the meter to the “wait-for-trigger” state. When a trigger is received from the selected trigger source, the instrument waits the trigger-delay time and then takes readings every 0.10 seconds until the sample count is reached.

```
SAMP:SOUR TIM
SAMP:TIM 0.1
INIT
```

SENSe Subsystem

The `[:SENSe]:` command subsystem is most commonly used with `CONFigure` to change specific “low-level” measurement parameters. `[:SENSe]:` enables you to change the following measurement parameters, predefined by the `CONFigure` command, without completely reconfiguring the multimeter.

`Function, Range and Resolution`

`Aperture Time and Number of Power Line Cycles`

`Bandwidth`

`Autozero`

[:SENSe]:CURRent:AC:BANDwidth

Sets the bandwidth for AC current measurements. The instrument uses three different AC filters that enable you either to optimize low frequency accuracy or to achieve faster AC settling times following a change in input signal amplitude.

Syntax

[:SENSe]:CURRent:AC:BANDwidth *bandwidth*

[:SENSe]:CURRent:AC:BANDwidth? [*bandwidth*]

Parameter

Parameter	Type	Unit	Range of Value
bandwidth	NRf+	Hz	value | MINimum (3) | MAXimum (200) | DEFault (20) Query does not support *bandwidth*=value.

Query Response

bandwidth

bandwidth returns a bandwidth value to the output buffer. The currently selected bandwidth is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *bandwidth* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- If you enter the lowest frequency that you expect to encounter, the command will select the appropriate bandwidth. For example, if you enter 15 Hz, the slow filter (3 Hz) is selected. If you enter 190 Hz, the medium filter (20 Hz) is selected to provide the appropriate low cutoff.
- Set the lowest frequency that you expect to encounter.

Input Frequency	Default Settling Delay	
	M1412A mode	E1412A mode
3 Hz - 300 kHz (Slow)	5 s/measurement	7 s/measurement
20 Hz - 300 kHz (Medium)	1 s/measurement	1 s/measurement
200 Hz - 300 kHz (Fast)	0.1 s/measurement	0.6 s/measurement

- This parameter is set to its default value after a Reset (*RST).
- The E1412A does not support this command.

Example Make and read an AC current measurement. Use the 3 Hz filter bandwidth.

```
CONF:CURR:AC 1
CURR:AC:BAND 3
READ?
```

Typical Response:
`+5.23918293E-01`

[:SENSe]:CURRent:AC:NULL[:STATe]

`[:SENSe]:CURRent:AC:NULL[:STATe]` *`state`* enables or disables the null function for AC current measurements.

Syntax [:SENSe]:CURRent:AC:NULL[:STATe] *state*

[:SENSe]:CURRent:AC:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean	1 | ON | 0 | OFF (default)	

Query Response *state*

state returns the null state of the AC current function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use: `[:SENSe]:CURRent:AC:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`).
- The E1412A does not support this command.

Example Configure AC current measurements, using the null function to subtract 100 mA from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:CURR:AC
CURR:AC:NULL:STAT ON;VAL 100 mA
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:CURRent:AC:NULL:VALue

`[:SENSe]:CURRent:AC:NULL:VALue` *`offset`* sets the null value for AC current measurements.

Syntax [:SENSe]:CURRent:AC:NULL:VALue *offset*

[:SENSe]:CURRent:AC:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	A	value | MINimum (–3.6) | MAXimum (+3.6) | DEFault (0) Query does not support *offset*=value.

- The E1412A does not support the "DEFault" parameter.

Query Response *offset*

offset returns a null offset value to the output buffer. The currently selected null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:CURRent:AC:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:CURRent:AC:NULL:STATe ON`).

- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- The E1412A does not support this command.

Example Configure AC current measurements, using the null function to subtract 100 mA from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:CURR:AC
CURR:AC:NULL:STAT ON;VAL 100 mA
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:CURRent:AC:NULL:VALue:AUTO

`[:SENSe]:CURRent:AC:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for AC current measurements.

Syntax [:SENSe]:CURRent:AC:NULL:VALue:AUTO *state*

[:SENSe]:CURRent:AC:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response *state*

state returns the state of automatic null of the AC current function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:CURRent:AC:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (OFF), the null value is specified by: `[:SENSe]:CURRent:AC:NULL:VALue`.

- When the null function is enabled (`[:SENSe]:CURRent:AC:NULL:STATe ON`), the instrument enables the automatic null value selection.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.

Example Configure AC current measurements, using the null function to subtract 100 mA from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:CURR:AC
CURR:AC:NULL:STAT ON;VAL 100 mA
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

Make a second set of measurements using the automatic null value selection.

```
CURR:AC:NULL:VAL:AUTO ON
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+00`

[:SENSe]:CURRent:AC:RANGe[:UPPer]

`[:SENSe]:CURRent:AC:RANGe[:UPPer]` *range* selects the range for AC current measurements.

Syntax [:SENSe]:CURRent:AC:RANGe[:UPPer] *range*

[:SENSe]:CURRent:AC:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	A	value | MINimum (1) | MAXimum (3) | DEFault (1) Query does not support *range*=value.

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 1 or 3.
- The E1412A does not support the "DEFault" parameter.
- Both M1412A and E1412A modes accept up to ±3.03 A as a valid input value. (Values over/under 3.0/–3.0 are rounded to 3.0.)

Query Response *range*

range returns a range value to the output buffer. The currently selected range is returned if MIN or MAX is not specified. Only the ranges available with the `RANGe` command are returned. For example, if `CONFigure` sets the 3A range, 3A is the range returned. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- You must select a range using `CURRent:AC:RANGe` before specifying resolution.
- Specifying a fixed range disables the autorange mode set by the `CURR:AC:RANG:AUTO OFF` command.
- The `CURR:AC:RANG` command overrides the range setting from a previous `CONFigure` command on the same function. With the new range, a new resolution is also selected.
- `*RST` Condition: `CURR:AC:RANG 1`
- This command does not support the "Amp" unit but can use "A".
- The user's manual always omits the UPPer header.

Example Query the AC current measurement range.

`CURR:AC:RANG`	*Select 3 A range.*
`3CURR:AC:RANG?`	*Query multimeter to return the present range.*

[:SENSe]:CURRent:AC:RANGe:AUTO

`[:SENSe]:CURRent:AC:RANGe:AUTO` *`state`* enables or disables the autorange function for AC current measurements.

Syntax

[:SENSe]:CURRent:AC:RANGe:AUTO *state*

[:SENSe]:CURRent:AC:RANGe:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response

state

state returns the autorange state of the AC current function. Returns “0” (OFF or ONCE) or “1” (ON). The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `CURRent:AC:RANGe`, autoranging is turned OFF.
- Related Command: `CONFigure`
- `*RST` Condition: `CURR:AC:RANG:AUTO ON`

Example

Disable the AC current autoranging.

`CURR:AC:RANG:AUTO OFF`	*Disable autorange.*

Query the AC current autorange mode.

`CURR:AC:RANG:AUTO?`	*Query multimeter to return autorange mode.*

[:SENSe]:CURRent:AC:RESolution

`[:SENSe]:CURRent:AC:RESolution` *`resolution`* selects the resolution for AC current measurements.

Syntax

[:SENSe]:CURRent:AC:RESolution *resolution*

[:SENSe]:CURRent:AC:RESolution? [*resolution*]

Parameter

Parameter	Type	Unit	Range of Value
resolution	NRf+	A	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault Query does not support *resolution*=value.

- See Table 4-6 for resolution choices.
- When the specified value is not in the table, the input value is rounded down to the next smallest resolution. (E.g., 3.0005E-7 * *range* input is rounded to 3.0000E-7 * *range* resolution, but 2.9995E-7 * *range* input is rounded to 1.0000E-7 * *range* resolution.)
- The E1412A does not support the "DEFault" parameter.

Query Response

resolution

resolution returns a resolution value to the output buffer. The currently selected resolution is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *resolution* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- MINimum selects the best resolution (the smallest value) for the selected range. MAXimum selects the worst resolution (the largest value) for the selected range.
- You must select a range using the `CURRent:AC:RANGe` before specifying resolution. Also, only specify a resolution when making measurements on a fixed range. Otherwise, the resolution will change to correspond with the range selected during autoranging.
- Specify resolution in the same units used for the measurement function.

- If autoranging is required, set the resolution using the DEF, MIN, or MAX parameter.
- Related Command: `CONFigure`
- This command does not support the “Amp” unit but can use “A”.
- When a value smaller than MINimum is specified, the set value is rounded up to the MINimum value with no error notification.
- When a value larger than MAXimum is specified, the set value is rounded down to the MAXimum value with no error notification.
- When `AutoRange` is on, you can specify a resolution value only via DEF, MIN, or MAX inputs. If you input any values, it returns error -221.

Example Query the AC current measurement range.

```
CURR:AC:RES 1E-4        Select 100 µA resolution.
CURR:AC:RES?            Query multimeter to return the present resolution.
```

[:SENSe]:CURRent[:DC]:APERture

Sets the integration time for one point measurement.

Syntax [:SENSe]:CURRent[:DC]:APERture *time*

[:SENSe]:CURRent[:DC]:APERture? [*time*]

Parameter

Parameter	Type	Unit	Range of Value
time	NRf+	s	value | MINimum | MAXimum | DEFault Query does not support *time*=value.

- The aperture time can be set in the range between the MINimum and MAXimum values. The resolution of the setting value is shown in Table 3-10.
- The DEFault, MINimum, and MAXimum values are determined by *power line frequency* and its driver mode. Please see the following table for the specific values.

Line Frequency (M1412A mode)		
	50 Hz	**60 Hz**
MINimum	500E-9	500E-9
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

Line Frequency (E1412A mode)		
	50 Hz	**60 Hz**
MINimum	0.4E-3	0.4E-3
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

- When `[:SENSe]:CURRent[:DC]:APERture:ENABle` is disabled, the value is calculated from `[:SENSe]:CURRent[:DC]:NPLCycles`.
- The E1412A does not support the "DEFault" parameter.

Query Response *time*

time is the current setting of the aperture time. If a parameter is specified, *time* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the aperture time also sets the integration time in PLCs and the resolution.
- The `CURR[:DC]:APER` command overrides the results of previously executed `CURR[:DC]:NPLC` and `CURR[:DC]:RES` commands. The last command executed has priority.
- When `CURR[:DC]:APER` is specified, `[:SENSe]:CURRent[:DC]:APERture:ENABle` is set to ON automatically.
- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- Related Commands: `CALibration:LFRrequency` and `SYSTem:LFRequency`

- *RST Condition: When the power line frequency is 50 Hz, the aperture is 0.2000, and when the power line frequency is 60 Hz, the aperture is 0.2004.

Example Set and query the aperture time.

```
CURR:APER 167E-03     Aperture time is 167 ms.
CURR:APER?            Query multimeter to return aperture time.
```

[:SENSe]:CURRent[:DC]:APERture:ENABled

Enables the integration time to be set in seconds (called aperture time) for DC current measurements. If the aperture time mode is disabled (default), the integration time is set in PLCs.

Syntax [:SENSe]:CURRent[:DC]:APERture:ENABled *state*

[:SENSe]:CURRent[:DC]:APERture:ENABled?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the state of the aperture time. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The CONFigure:CURRent[:DC], MEASure:CURRent[:DC]?, [:SENSe]:CURRent[:DC]:NPLC, and [:SENSe]:CURRent[:DC]:RESolution commands disable the aperture time mode and select an integration time in PLCs.
- This parameter is set to its default value after a Reset (*RST).
- The E1412A does not support this command.

Example Enable the aperture time mode, and set the aperture time to 300 ms.

```
CURR:APER:ENAB ON
CURR:DC:APER 300E-03
```

[:SENSe]:CURRent[:DC]:NPLCycles

`[:SENSe]:CURRent[:DC]:NPLCycles nplc` sets the integration time in PLCs.

Syntax

[:SENSe]:CURRent[:DC]:NPLCycles *nplc*

[:SENSe]:CURRent[:DC]:NPLCycles? [*nplc*]

Parameter

Parameter	Type	Unit	Range of Value
nplc	NRf+		value | MINimum (0.02 for E1412A mode, 25E-6 for M1412A mode) | MAXimum (100) | DEFault (10) Query does not support *nplc*=value.

- The resolution of the setting value is shown in Table 3-9.
- The integration time can be expressed by the following formula.

  integration time = *nplc / power line frequency*
- The E1412A does not support the “DEFault” parameter.
- When *power line frequency* is set as 60 Hz, values between MINimum and 30E-6 are rounded up to 30E-6.

Query Response

nplc

nplc returns the current setting of the integration time in PLCs. If a parameter is specified, *nplc* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the integration time in PLCs also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 166.667 ms (60 Hz line frequency) or 200 ms (50 Hz). The corresponding resolution depends on the function and range you select.
- The `CURR:DC:NPLC` command overrides the results of a previously executed `CURRent:APERture` or `CURRent:RESolution` command (the last command executed has priority).
- The greater the number of PLCs, the greater the normal mode rejection (and the lower the reading rate).

- Only whole-number PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line-related noise.
  Fractional PLC settings do not provide normal mode rejection of power line noise.
- When `CURR[:DC]:NPLC` is specified, `[:SENSe]:CURRent[:DC]:APERture:ENABle` is set to OFF automatically.
- `*RST` Condition: 10 PLCs

Example Set and query the DC current integration time in PLCs.

`CURR:DC:NPLC 100`	*Integration time is 100 PLCs.*
`CURR:DC:NPLC?`	*Query multimeter to return integration time.*

[:SENSe]:CURRent[:DC]:NULL[:STATe]

`[:SENSe]:CURRent[:DC]:NULL[:STATe]` ***`state`*** enables or disables the null function for DC current measurements.

Syntax [:SENSe]:CURRent[:DC]:NULL[:STATe] *state*

[:SENSe]:CURRent[:DC]:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the null state of the DC current function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use: `[:SENSe]:CURRent[:DC]:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.

Example

Configure DC current measurements, using the null function to subtract 100 mA from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:CURR:DC
CURR:DC:NULL:STAT ON;VAL 100 mA
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:CURRent[:DC]:NULL:VALue

`[:SENSe]:CURRent[:DC]:NULL:VALue` ***offset*** sets the null value for DC current measurements.

Syntax

[:SENSe]:CURRent[:DC]:NULL:VALue *offset*

[:SENSe]:CURRent[:DC]:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	A	value | MINimum (–3.6) | MAXimum (+3.6) | DEFault (0) Query does not support *offset*=value.

- The E1412A does not support the "DEFault" parameter.

Query Response

offset

offset returns a null offset value to the output buffer. The currently selected null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:CURRent[:DC]:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:CURRent[:DC]:NULL:STATe ON`).

- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.
- The E1412A does not support this command.

Example Configure DC current measurements, using the null function to subtract 100 mA from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:CURR:DC.
CURR:DC:NULL:STAT ON;VAL 100 mA
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:CURRent[:DC]:NULL:VALue:AUTO

`[:SENSe]:CURRent[:DC]:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for DC current measurements.

Syntax [:SENSe]:CURRent[:DC]:NULL:VALue:AUTO *state*

[:SENSe]:CURRent[:DC]:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean	0 | OFF (default) | 1 | ON	

Query Response *state*

state returns the state of automatic null of the DC current function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:CURRent[:DC]:NULL:VALue` is set to this value. The automatic null value selection will be disabled.

- When the automatic null value selection is disabled (OFF), the null value is specified by `[:SENSe]:CURRent[:DC]:NULL:VALue`.
- When the null function is enabled (`[:SENSe]:CURRent[:DC]:NULL:STATe ON`), the instrument enables automatic null value selection.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- The E1412A does not support this command.

Example Configure DC current measurements, using the null function to subtract 100 mA from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:CURR:DC
CURR:DC:NULL:STAT ON;VAL 100 mA
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

Make a second set of measurements using the automatic null value selection.

```
CURR:DC:NULL:VAL:AUTO ON.
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+00`

[:SENSe]:CURRent[:DC]:RANGe[:UPPer]

`[:SENSe]:CURRent[:DC]:RANGe[:UPPer]` *range* selects the range for DC current measurements.

Syntax [:SENSe]:CURRent[:DC]:RANGe[:UPPer] *range*

[:SENSe]:CURRent[:DC]:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	A	value | MINimum (0.01 for E1412A mode, 1E-6 for M1412A mode) | MAXimum (3) | DEFault (1) Query does not support *range*=value.

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 1E-6, 1E-5, 1E-4, 0.001, 0.01, 0.1, 1, or 3.
- The E1412A does not support the "DEFault" parameter.
- Both M1412A and E1412A modes accept up to ±3.03 A as a valid input value. (Values over/under 3.0/-3.0 are rounded to 3.0.)

Query Response

range

range returns a range value to the output buffer. The currently selected range is returned if DEF, MIN, or MAX is not specified. Only the ranges available with the `RANGe` command are returned. For example, if `CONFigure` sets the 3 A range, 3 A is the range returned. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- You must select a range using `CURRent[:DC]:RANGe` before specifying the resolution.
- Specifying a fixed range disables the autorange mode set by the `CURR[:DC]:RANG:AUTO` command.
- The `CURR[:DC]:RANG` command overrides the range setting from a previous `CONFigure` command on the same function.
- `*RST` Condition: `CURR[:DC]:RANG 1`
- This command does not support the "Amp" unit but can use "A".
- The user's manual always omits the UPPer header.

Example

Set and query the DC current measurement range.

```
CURR:DC:RANG 3      Select 3 A range.
CURR:DC:RANG?       Query multimeter to return the present range.
```

[:SENSe]:CURRent[:DC]:RANGe:AUTO

`[:SENSe]:CURRent[:DC]:RANGe:AUTO` *`state`* enables or disables the autorange function for DC current measurements.

Syntax

[:SENSe]:CURRent[:DC]:RANGe:AUTO *state*

[:SENSe]:CURRent[:DC]:RANGe:AUTO? [*state*]

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response

state

state is a number to show whether the DC current autorange mode is enabled or disabled: “0” (OFF or ONCE) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `CURRent[:DC]:RANGe`, autoranging is turned OFF.
- In order to specify an aperture time of 10 μs, you must select a fixed range (e.g., `CURR:DC:RANG:AUTO OFF`).
- Related Command: `CONFigure`
- `*RST` Condition: `CURR[:DC]:RANG:AUTO ON`

Example

Disable and query the DC current autorange mode.

```
CURR:DC:RANG:AUTO OFF        Disable autorange.
CURR:DC:RANG:AUTO?           Query multimeter to return autorange mode.
```

[:SENSe]:CURRent[:DC]:RESolution

`[:SENSe]:CURRent[:DC]:RESolution` ***resolution*** selects the resolution for DC current measurements.

Syntax

[:SENSe]:CURRent[:DC]:RESolution *resolution*

[:SENSe]:CURRent[:DC]:RESolution? [*resolution*]

Parameter

Parameter	Type	Unit	Range of Value
resolution	NRf+	A	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault Query does not support *resolution*=value.

- See Table 4-3 for resolution choices.
- When the specified value is not in the table, the input value is rounded down to the next smallest resolution. (E.g., 3.0005E-7 * range input is rounded to 3.0000E-7 * range resolution, but 2.9995E-7 * range input is rounded to 1.0000E-7 * *range* resolution.)
- The E1412A does not support the “DEFault” parameter.

Query Response

resolution

resolution returns a resolution value to the output buffer. The currently selected resolution is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *resolution* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- MINimum selects the best resolution (the smallest value) for the selected range. MAXimum selects the worst resolution (the largest value) for the selected range.
- You must select a range using `CURRent[:DC]:RANGe` before specifying the resolution. Also, only specify a resolution when making measurements on a fixed range. Otherwise, the resolution will change to correspond with the range selected during autoranging.
- Specify the resolution in the same units used for the measurement function.

- If autoranging is required, set the resolution using the DEF, MIN, or MAX parameter, or select a specific integration time using `CURRent[:DC]:NPLC`.
- Changing the resolution also changes the NPLC setting to the values that correspond to the specified resolution.
- When `CURR[:DC]:NPLC` is specified, `[:SENSe]:CURRent[:DC]:APERture:ENABle` is set to OFF automatically.
- The `CURR:DC:RES` command overrides the resolution setting from a previous `CONFigure:CURR:DC:RES` command.
- Related Commands: `CONFigure`, `CURRent:[:DC]:NPLC`
- `*RST` Condition: Based on the `*RST` values for the `CURRent:NPLC` command.
- This command does not support the “Amp” unit but can use “A”.
- When a specified value is smaller than the MINimum value, the value is rounded up to the MINimum value with no error notification.
- When a specified value is larger than the MAXimum value, the value is rounded down to the MAXimum value with no error notification.
- When `AutoRange` is on, you can specify a resolution value only via DEF, MIN, or MAX inputs. If you input any values, it returns error -221.

Example Query the DC current measurement range.

`CURR:DC:RES 1E-4`	*Select 100 µA resolution.*
`CURR:DC:RES?`	*Query multimeter to return the present resolution.*

[:SENSe]:CURRent[:DC]:ZERO:AUTO

Enables or disables the autozero mode for DC current measurements.

Syntax [:SENSe]:CURRent[:DC]:ZERO:AUTO *state*

[:SENSe]:CURRent[:DC]:ZERO:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response *state*

state returns the state of the autozero mode for DC current measurements. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- ON (default): the DMM internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the DMM’s input circuitry from affecting measurement accuracy.
- OFF: the instrument uses the last measured zero measurement and subtracts it from each measurement. It takes a new zero measurement each time you change the function, range or integration time.
- ONCE: the instrument takes one zero measurement and sets the autozero to OFF. The zero measurement taken is used for all subsequent measurements until the function, range or integration time is changed. If the specified integration time is less than 1 PLC, the zero measurement is taken at 1 PLC to optimize noise rejection. Subsequent measurements are taken at the specified fast (< 1 PLC) integration time.
- The autozero mode is set indirectly when you set the resolution and integration time with the `CONFigure:CURRent[:DC]` or `MEASure:CURRent[:DC]?` command. Autozero is automatically turned OFF when you select an integration time less than 1 PLC with these commands.
- This parameter is set to its default value after a Reset (`*RST`).
- The E1412A does not support this command.

Example Configure DC current measurements and perform an immediate autozero. Make and read two measurements.

```
CONF:CURR:DC 1
CURR:DC:ZERO:AUTO ONCE
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E-01,+1.04570000E-01`

[:SENSe]:DETector:BANDwidth

[:SENSe]:DETector:BANDwidth *bandwidth* selects the slow, medium or fast filter based on the bandwidth you specify. The multimeter uses these three different filters which enable you to either optimize low frequency accuracy or achieve faster AC settling times on AC voltage or AC current measurements.

Syntax

[:SENSe]:DETector:BANDwidth *bandwidth*

[:SENSe]:DETector:BANDwidth? [*bandwidth*]

Parameter

Parameter	Type	Unit	Range of Value
bandwidth	NRf+	Hz	value | MINimum (3) | MAXimum (200) | DEFault (20) Query does not support *bandwidth*=value.

- The E1412A does not support the “DEFault” parameter.
- Specifying a parameter less than 200 but greater than 20 selects the 20 Hz filter.
- Specifying a parameter less than 20 but greater than 3 selects the 3 Hz filter.
- Specifying a parameter greater than 200 but not greater than 300E+03 (300 kHz) selects the 200 Hz filter.
- Any value greater than 300 kHz will cause a “Data out of range” error. The maximum range for all three filters is 300 Hz. Specify the lowest frequency expected in the input signal. The multimeter selects the appropriate filter based on the table below.

Query Response

bandwidth

bandwidth returns a bandwidth value to the output buffer. The currently selected bandwidth is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *bandwidth* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The following table lists the filter frequency range and the settling time for making measurements.

AC Voltage or Current Input Frequency	AC Filter Selected	Max Reading Rate for Adequate Settling
3 Hz - 300 kHz	Slow filter	1 reading/5 seconds
20 Hz - 300 kHz	Medium filter (default)	1 reading/second
200 Hz - 300 kHz	Fast filter	10 readings/second

- The AC filter selection is stored in volatile memory and returns to the 20 Hz filter (medium) when the power is turned off or after a module reset. The upper limit on all three filters is 300 kHz.
- The `CONFigure` and `MEASure` commands select the 20 Hz filter.
- `*RST` Condition: `DET:BAND 20` (medium filter)

Example Set the AC signal filter for fast measurements from 200 Hz to 300 kHz. Then query the detector bandwidth.

`DET:BAND 200`	*Selects the fast filter.*
`DET:BAND?`	*Query multimeter to return the detector bandwidth setting.*

[:SENSe]:FREQuency:APERture

`[:SENSe]:FREQuency:APERture` *`time`* selects the aperture time (or gate time) for frequency measurements.

Syntax [:SENSe]:FREQuency:APERture *time*

[:SENSe]:FREQuency:APERture? [*time*]

Parameter

Parameter	Type	Unit	Range of Value
time	NRf+	s	value | MINimum (0.01 for E1412A mode, 0.001 for M1412A mode) | MAXimum (1) | DEFault (0.1) Query does not support *time*=value.

- The E1412A does not support the “DEFault” parameter.

Query Response *time*

time is the aperture time for frequency measurements. If a parameter is specified, *time* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The aperture for frequency measurements does not support the autorange mode.
- For the E1412A mode, specify 0.01 (10 ms) for 4.5 digits, 0.1 (default, 100 ms) for 5.5 digits or 1 second for 6.5 digits.
- For the M1412A mode, specify 0.001 (1 ms) or 0.01 (10 ms) for 4.5 digits, 0.1 (default, 100 ms) for 5.5 digits or 1 second for 6.5 digits.
- This parameter is set to its default value after a Reset (`*RST`).

Example Set a frequency aperture time of 1 second.

`FREQ:APER 1` *Sets the aperture time to 1 second.*

[:SENSe]:FREQuency:NULL[:STATe]

`[:SENSe]:FREQuency:NULL[:STATe]` *state* enables or disables the null function for frequency measurements.

Syntax [:SENSe]:FREQuency:NULL[:STATe] *state*

[:SENSe]:FREQuency:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response *state*

state returns the null state of the frequency function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use: `[:SENSe]:FREQuency:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.
- Unlike the `SENSe:FREQuency` and `SENSe:PERiod` range and the aperture commands, this parameter is not shared between frequency and period measurements. The null parameters are independent for frequency and period measurements.
- The E1412A does not support this command.

Example

Configure frequency measurements, using the null function to subtract 1 kHz from the measurements. Make and read two measurements.

```
CONF:FREQ
FREQ:NULL:STAT ON;VAL 1 kHz
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+03,+1.04570000E+03`

[:SENSe]:FREQuency:NULL:VALue

`[:SENSe]:FREQuency:NULL:VALue` *`offset`* sets the null value for frequency measurements.

Syntax

[:SENSe]:FREQuency:NULL:VALue *offset*

[:SENSe]:FREQuency:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	Hz	value | MINimum (–1.2E6) | MAXimum (+1.2E6) | DEFault (0) Query does not support *offset*=value.

Query Response *offset*

offset returns a null offset value to the output buffer. The currently selected frequency null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:FREQuency:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:FREQuency:NULL:STATe ON`).
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- Unlike the `SENSe:FREQuency` and `SENSe:PERiod` range and the aperture commands, this parameter is not shared between frequency and period measurements. The null parameters are independent for frequency and period measurements.
- The E1412A does not support this command.

Example Configure frequency measurements, using the null function to subtract 1 kHz from the measurements. Make and read two measurements.

```
CONF:FREQ
FREQ:NULL:STAT ON;VAL 1 kHz
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+03,+1.04570000E+03`

[:SENSe]:FREQuency:NULL:VALue:AUTO

`[:SENSe]:FREQuency:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for frequency measurements.

Syntax

[:SENSe]:FREQuency:NULL:VALue:AUTO *state*

[:SENSe]:FREQuency:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state returns the state of automatic null of the frequency function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:FREQuency:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (OFF), the null value is specified by: `[:SENSe]:FREQuency:NULL:VALue`.
- When the null function is enabled (`[:SENSe]:FREQuency:NULL:STATe ON`), the instrument enables the automatic null value selection.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- Unlike the `SENSe:FREQuency` and `SENSe:PERiod` range and the aperture commands, this parameter is not shared between frequency and period measurements. The null parameters are independent for frequency and period measurements.
- The E1412A does not support this command.

Example Configure frequency measurements, using the null function to subtract 1 kHz from the measurements. Make and read two measurements.

```
CONF:FREQ
FREQ:NULL:STAT ON;VAL 1 kHz
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+03,+1.04570000E+03`

Make a second set of measurements using the automatic null value selection.

```
FREQ:NULL:VAL:AUTO ON
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+03`

[:SENSe]:FREQuency:RANGe:LOWer

Sets the input frequency range of frequency and period measurements.
This parameter is shared between frequency and period measurements. Setting or querying the parameter with the `FREQuency` version of this command is identical to setting or querying it with the `PERiod` version.

Syntax [:SENSe]:FREQuency:RANGe:LOWer *range*

[:SENSe]:FREQuency:RANGe:LOWer? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
bandwidth	NRf+	Hz	value | MINimum (3) | MAXimum (200) | DEFault (20) Query does not support *bandwidth*=value.

Query Response *bandwidth*

bandwidth returns a bandwidth value to the output buffer. The currently selected bandwidth is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *bandwidth* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The E1412A does not support this command.
- If you enter the lowest frequency that you expect to encounter, the command will select the appropriate bandwidth. For example, if you enter 15 Hz, the slow filter (3 Hz) is selected. If you enter 190 Hz, the medium filter (20 Hz) is selected to provide the appropriate low cutoff.
- Set the lowest frequency that you expect to encounter.

Input Frequency	Default Settling Delay
3 Hz - 300 kHz (Slow)	5 s/measurement
20 Hz - 300 kHz (Medium)	1 s/measurement
200 Hz - 300 kHz (Fast)	0.1 s/measurement

- This parameter is set to its default value after a Reset (`*RST`).

Example

Make and read a frequency measurement. Use the 3 Hz filter bandwidth:

```
CONF:FREQ
FREQ:RANG:LOW 3
READ?
```

Typical Response:
`+6.27530000E+03`

[:SENSe]:FREQuency:TIMeout:AUTO

Controls how long the instrument waits before timing out on a frequency or period measurement when no signal is present.

Syntax

[:SENSe]:FREQuency:TIMeout:AUTO *state*

[:SENSe]:FREQuency:TIMeout:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response

state

state returns a number to show whether the auto timeout mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer. The response data type is NR1.

Comments

- The E1412A does not support this command.
- When set to OFF, the instrument waits 1 second before timing out. When set to ON, the wait time varies with the AC filter bandwidth; for the faster bandwidths, the instrument waits a shorter length of time before timing out and returning 0.0. This is advantageous in manufacturing test systems where a DUT failure may result in no signal; in this case, the failure can be detected sooner, speeding up test throughput.
- This setting is non-volatile; it will not be changed by power cycling or `*RST`.

Example

Configure frequency measurements, using the null function to subtract 1 kHz from the measurements. Enable the automatic timeout. Make and read two measurements.

```
CONF:FREQ
FREQ:NULL:STAT ON;VAL 1 kHz
FREQ:TIM:AUTO ON
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+03,+1.04570000E+03`

[:SENSe]:FREQuency:VOLTage:RANGe[:UPPer]

`[:SENSe]:FREQuency:VOLTage:RANGe[:UPPer]` *range* selects the voltage range for the signal level of frequency measurements.

Syntax

[:SENSe]:FREQuency:VOLTage:RANGe[:UPPer] *range*

[:SENSe]:FREQuency:VOLTage:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (10)

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 0.1, 1, 10, 100, or 300.
- The E1412A does not support the "DEFault" parameter.
- Both M1412A and E1412A modes accept up to ±303.0 V as a valid input value. (Values over/under 300.0/–300.0 are rounded to 300.0.)

Query Response

range

range returns a range value to the output buffer. The currently selected voltage range is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a fixed range disables the autorange mode set by the `FREQ:VOLT:RANG:AUTO` command
- Related Commands: `PERiod:VOLTage:RANGe`, `PERiod:VOLTage:RANGe:AUTO`
- `*RST` Condition: `FREQ:VOLT:RANG 10`
- This command does not support the "Volt" unit but can use "V".
- The user's manual always omits the UPPer header.

Example Set and query the voltage range for frequency measurements.

`FREQ:VOLT:RANG 100`	*Voltage range for frequency measurements is 100 V.*
`FREQ:VOLT:RANG?`	*Query the present range.*

[:SENSe]:FREQuency:VOLTage:RANGe:AUTO

`[:SENSe]:FREQuency:VOLTage:RANGe:AUTO` *`state`* enables or disables the autorange function for the signal level of frequency measurements.

Syntax [:SENSe]:FREQuency:VOLTage:RANGe:AUTO *state*

[:SENSe]:FREQuency:VOLTage:RANGe:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
range	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response *range*

range returns a number to show whether the autorange mode is enabled or disabled: “0” (OFF or ONCE) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `FREQuency:VOLTage:RANGe`, autoranging is turned OFF.
- Related Commands: `CONFigure`, `MEASure`, `PERiod:VOLTage:RANGe`, `PERiod:VOLTage:RANGe:AUTO`
- `*RST` Condition: `FREQ:VOLT:RANG:AUTO ON`

Example Disable autoranging.

`FREQ:VOLT:RANG:AUTO OFF`	*Disable autorange.*

Query the autorange mode.

`FREQ:VOLT:RANG:AUTO?`	*Query multimeter to return autorange mode.*

[:SENSe]:FRESistance:APERture

`[:SENSe]:FRESistance:APERture` *`time`* sets the integration time in seconds for 4-wire resistance measurements.

Syntax

[:SENSe]:FRESistance:APERture *time*

[:SENSe]:FRESistance:APERture? [*time*]

Parameter

Parameter	Type	Unit	Range of Value
time	NRf+	s	MINimum | MAXimum | DEFault Query does not support *time*=value.

- The aperture time can be set in the range between the MINimum and MAXimum values. The resolution of the setting value is shown in Table 3-10.
- DEFault, MINimum and MAXimum values are determined by *power line frequency* and its driver mode. Please see the following table for the specific values.

Line Frequency (M1412A mode)		
	50 Hz	**60 Hz**
MINimum	500E-9	500E-9
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

Line Frequency (E1412A mode)		
	50 Hz	60 Hz
MINimum	0.4E-3	0.4E-3
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

- When `[:SENSe]:FRESistance:APERture:ENABle` is disabled, the value is calculated from `[:SENSe]:<FRESistance|RESistance>:NPLCycles`.
- The E1412A does not support the “DEFault” parameter.

Query Response

time

time is the current setting of the aperture time. If a parameter is specified, *time* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the aperture time also sets the integration time in PLCs and the resolution.
- When `FRESistance:APER` is specified, `[:SENSe]:FRESistance:APERture:ENABle` is set to ON automatically.
- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- Related Commands: `[:SENSe]:RESistance`, `CALibration:LFRrequency` and `SYSTem:LFRequency`
- `*RST` Condition: When the power line frequency is 50 Hz, the aperture is 0.2000, and when the power line frequency is 60 Hz, the aperture is 0.2004.
- `[:SENSe]:FRESistance:APERture` and `[:SENSe]:RESistance:APERture` use the same parameter, and a change to one affects the other.

Example

Set and query the aperture time.

`FRES:APER 167E-03`	*Aperture time is 167 ms.*
`FRES:APER?`	*Query multimeter to return aperture time.*

[:SENSe]:FRESistance:APERture:ENABled

Enables the integration time to be set in seconds (called aperture time) for all resistance measurements. If the aperture time mode is disabled (default), the integration time is set in PLCs.

Syntax

[:SENSe]:FRESistance:APERture:ENABled *state*

[:SENSe]:FRESistance:APERture:ENABled?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean	1 | ON | 0 | OFF (default)	

Query Response

state

state returns the state of the aperture time. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The `CONFigure:FRESistance, MEASure:FRESistance?`, `[:SENSe]:FRESistance:NPLC`, and `[:SENSe]:FRESistance:RESolution` commands disable the aperture time mode and select an integration time in number of PLCs.
- This parameter is set to its default value after a Reset (`*RST`).
- `[:SENSe]:FRESistance:APERture` and `[:SENSe]:RESistance:APERture` use the same parameter, and a change in one affects the other.
- The E1412A does not support this command.

Example

Enable the aperture time mode, and set the aperture time to 300 ms.

```
FRES:APER:ENAB ON
FRES:APER 300E-03
```

[:SENSe]:FRESistance:NPLCycles

`[:SENSe]:FRESistance:NPLCycles` *`nplc`* sets the integration time in PLCs.

Syntax

[:SENSe]:FRESistance:NPLCycles *nplc*

[:SENSe]:FRESistance:NPLCycles? [*nplc*]

Parameter

Parameter	Type	Unit	Range of Value
nplc	NRf+		value | MINimum (0.02 for E1412A mode, 25E-6 for M1412A mode) | MAXimum (100) | DEFault (10) Query does not support *nplc*=value.

- The resolution of the setting value is shown in Table 3-9.
- The integration time can be expressed by the following formula.

  integration time = *nplc / power line frequency*
- The E1412A does not support the “DEFault” parameter.
- When *power line frequency* is set as 60 Hz, set values between MINimum and 30E-6 are rounded up to 30E-6.

Query Response

nplc

nplc returns the current setting of the integration time in PLCs. If a parameter is specified, *nplc* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the integration time in PLCs also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 166.667 ms (60 Hz line frequency) or 200 ms (50 Hz). The corresponding resolution depends on the function and range you select.
- The `FRES:NPLC` command overrides the results of a previously executed `FRESistance:APERture` or `FRESistance:RESolution` command (the last command executed has priority).
- The greater the number of PLCs, the greater the normal mode rejection (and the lower the reading rate).

- Only whole-number PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line-related noise.
  Fractional PLC settings do not provide normal mode rejection of power line noise.
- When `FRESistance:NPLC` is specified, `[:SENSe:]FRESistance:APERture:ENABle` is set to OFF automatically.
- `*RST` Condition: 10 PLCs
- `[:SENSe]:FRESistance:NPLCycles` and `[:SENSe]:RESistance:NPLCycles` use the same parameter, and a change in one affects the other.

Example Set and query the DC current integration time in PLCs.

`CURR:DC:NPLC 100`	*Integration time is 100 PLCs.*
`CURR:DC:NPLC?`	*Query multimeter to return integration time.*

[:SENSe]:FRESistance:NULL[:STATe]

`[:SENSe]:FRESistance:NULL[:STATe]` *`state`* enables or disables the null function for all resistance measurements.

Syntax [:SENSe]:FRESistance:NULL[:STATe] *state*

[:SENSe]:FRESistance:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean	1 | ON | 0 | OFF (default)	

Query Response *state*

state returns the null state of the DC current function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use `[:SENSe]:FRESistance:AC:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.

- `[:SENSe]:FRESistance:NULL[:STATe]` and `[:SENSe]:RESistance:NULL[:STATe]` use the same parameter, and a change in one affects the other.
- The E1412A does not support this command.

Example Configure 4-wire resistance measurements, using the null function to subtract 0.1 Ω from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:FRES
FRES:NULL:STAT ON;VAL 0.1
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+02,+1.04570000E+02`

[:SENSe]:FRESistance:NULL:VALue

`[:SENSe]:FRESistance:NULL:VALue` *`offset`* sets the null value for all resistance measurements.

Syntax [:SENSe]:FRESistance:NULL:VALue *offset*

[:SENSe]:FRESistance:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	OHM	value | MINimum (–120E6 for E1412A mode, –1.2E9 for M1412A mode) | MAXimum (+120E6 for the E1412A the mode, +1.2E9 for M1412A mode) | DEFault (0) Query does not support *offset*=value.

Query Response *offset*

offset returns a null offset value to the output buffer. The currently selected resistance null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:FRESistance:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:FRESistance:NULL:STATe ON`).
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- `[:SENSe]:FRESistance:NULL:VALue` and `[:SENSe]:RESistance:NULL:VALue` use the same parameter, and a change in one affects the other.
- The E1412A does not support this command.

Example

Configure 4-wire resistance measurements, using the null function to subtract 0.1 Ω from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:FRES
FRES:NULL:STAT ON;VAL 0.1
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+02,+1.04570000E+02`

[:SENSe]:FRESistance:NULL:VALue:AUTO

`[:SENSe]:FRESistance:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for all resistance measurements.

Syntax

[:SENSe]:FRESistance:NULL:VALue:AUTO *state*

[:SENSe]:FRESistance:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean	1 | ON | 0 | OFF (default)	

Query Response *state*

state returns the state of automatic null of the 4-wire resistance function. Returns "0" (OFF) or "1" (ON). The response data type is NR1.

Comments

- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:FRESistance:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (OFF), the null value is specified by: `[:SENSe]:FRESistance:NULL:VALue`.
- When the null function is enabled (`[:SENSe]:FRESistance:NULL:STATe ON`), the instrument enables the automatic null value selection.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- `[:SENSe]:FRESistance:NULL:VALue:AUTO` and `[:SENSe]:RESistance:NULL:VALue:AUTO` use the same parameter, and a change in one affects the other.
- The E1412A does not support this command.

Example Configure 4-wire resistance measurements, using the null function to subtract 0.1 Ω from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:FRES
FRES:NULL:STAT ON;VAL 0.1
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+02,+1.04570000E+02`

Make a second set of measurements using the automatic null value selection.

```
FRES:NULL:VAL:AUTO ON
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+00`

[:SENSe]:FRESistance:OCOMpensated

Enables or disables offset compensation. Offset compensation removes the effects of small DC voltages in the circuit being measured. The technique involves taking the difference between two resistance measurements, one with the current source set to the normal value, and one with the current source set to a lower value. Enabling Offset Compensation approximately doubles the reading time.

Syntax [:SENSe]:FRESistance:OCOMpensated *state*

[:SENSe]:FRESistance:OCOMpensated?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the state of offset compensation. Returns “0” (OFF) or “1” (ON). The response data type is NR1

Comments

- Applies only to resistance measurements in the 10 Ω, 100 Ω, 1 kΩ, and 10 kΩ ranges.
- This parameter is set to its default value after a Reset (`*RST`).
- The offset compensation function is only effective for Sample Count = 1. Otherwise, the function is automatically disabled.
- Affects both 2-wire and 4-wire resistance measurements.
- The E1412A does not support this command.

Example Configure low-power 4-wire resistance measurements. Enable offset compensation. Make and read two measurements.

```
FRES:POW:LIM ON
FRES:OCOM ON
SAMP:COUN 1
READ?
```

Typical Response:
`+4.05451008E-03,+4.97391062E-03`

[:SENSe]:FRESistance:RANGe[:UPPer]

`[:SENSe]:FRESistance:RANGe[:UPPer]` *range* selects the range for 4-wire resistance measurements.

Syntax

[:SENSe]:FRESistance:RANGe[:UPPer] *range*

[:SENSe]:FRESistance:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	OHM	value | MINimum (100 for E1412A mode, 10 for M1412A mode) | MAXimum (100E6 for E1412A mode, 1E9 for M1412A mode) | DEFault (1E3) Query does not support *range*=value.

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 10, 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, or 1E9.
- The E1412A does not support the "DEFault" parameter.
- The E1412A mode accepts up to ±120E6 Ω as a valid input value. (Values over/under 100E6/–100E6 are rounded to 100E6.)
- The M1412A mode accepts up to ±1.2E9 Ω as a valid input value. (Values over/under 1.0E9/–1.0E9 are rounded to 1.0E9.)

Query Response

range

range returns a range value to the output buffer. The currently selected range is returned if DEF, MIN, or MAX is not specified. Only the ranges available with the RANGe command are returned. For example, if `CONFigure` sets the 100 Ω range, 100 Ω is the range returned. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- You must select a range using `FRESistance:RANGe` before specifying the resolution.
- Specifying a fixed range disables the autorange mode set by the `FRES:RANG:AUTO` command.

- The `FRES:RANG` command overrides the range setting from a previous `CONFigure` command on the same function. The multimeter uses the same aperture time to set the resolution on the new range as was selected by `CONFigure`.
- `*RST` Condition: `FRES:RANG 1k`
- Affects both 2-wire and 4-wire resistance measurements.

Example Set and query the 4-wire resistance measurement range.

`FRES:RANG`	*Select 100 Ω range.*
`FRES:RANG?`	*Query multimeter to return the present range.*

[:SENSe]:FRESistance:RANGe:AUTO

`[:SENSe]:FRESistance:RANGe:AUTO` *`state`* enables or disables the autorange function for 4-wire resistance measurements.

Syntax [:SENSe]:FRESistance:RANGe:AUTO *range*

[:SENSe]:FRESistance:RANGe:AUTO? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ON | 1 | ON (default)

Query Response *state*

state is a number to show whether the 4-wire resistance autorange mode is enabled or disabled: “0” (OFF or ONCE) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `FRESistance:RANGe`, autoranging is turned OFF.

- In order to specify an aperture time of 10 μs, you must select a fixed range (e.g., `FRES:RANG:AUTO OFF`).
- Related Commands: `CONFigure`, `CURR:AC:RANGe`, `CURR[:DC]:RANGe`
- `*RST` Condition: `FRES:RANG:AUTO ON`
- Affects both 2-wire and 4-wire resistance measurements.

Example Disable and query 4-wire resistance autorange mode.

`FRES:RANG:AUTO OFF`	*Disable autorange.*
`FRES:RANG:AUTO?`	*Query multimeter to return autorange mode.*

[:SENSe]:FRESistance:RESolution

`[:SENSe]:FRESistance:RESolution` ***`resolution`*** selects the resolution for 4-wire resistance measurements.

Syntax [:SENSe]:FRESistance:RESolution *resolution*

[:SENSe]:FRESistance:RESolution? [*resolution*]

Parameter

Parameter	Type	Unit	Range of Value
resolution	NRf+	OHM	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault Query does not support *resolution*=value.

- See Table 4-4 for resolution choices.
- When the specified value is not in the table, the input value is rounded down to the next smallest resolution. (E.g., 3.0005E-7 * *range* input is rounded to 3.0000E-7 * *range* resolution, but 2.9995E-7 * *range* input is rounded to 1.0000E-7 * *range* resolution.)
- The E1412A does not support the “DEFault” parameter.

Query Response *resolution*

resolution returns a resolution value to the output buffer. The currently selected resolution is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *resolution* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- MINimum selects the best resolution (the smallest value) for the selected range. MAXimum selects the worst resolution (the largest value) for the selected range.
- You must select a range using `FRESistance:RANGe` before specifying the resolution. Also, only specify a resolution when making measurements on a fixed range. Otherwise, the resolution will change to correspond with the range selected during autoranging.
- Specify the resolution in the same units used for the measurement function.
- If autoranging is required, set the resolution using the DEF, MIN, or MAX parameter.
- Changing the resolution also changes the NPLC setting to the values that correspond to the specified resolution.
- When `CURR[:DC]:NPLC` is specified, `[:SENSe]:CURRent[:DC]:APERture:ENABle` is set to OFF automatically.
- `*RST` Condition: `FRES:RES 1E-3`
- Affects both 2-wire and 4-wire resistance measurements.
- When a specified value is smaller than the MINimum value, the set value is rounded up to the MINimum value with no error notification.
- When a specified value is larger than the MAXimum value, the set value is rounded down to the MAXimum value with no error notification.
- When `AutoRange` is on, you can specify a resolution value only via DEF, MIN, or MAX inputs. If you input any values, it returns error -221.

Example Query the DC current measurement range.

`FRES:RES 0.3E-3`	*Select 0.3 mΩ resolution.*
`FRES:RES?`	*Query multimeter to return the present resolution.*

[:SENSe]:FUNCtion[:ON]

`[:SENSe]:FUNCtion[:ON]` *function* selects the measurement function. You can select the functions shown in the following table.

Syntax

[:SENSe]:FUNCtion[:ON] *function*

[:SENSe]:FUNCtion[:ON]?

Parameter

Parameter	Type	Unit	Range of Value
function	CPD		"CURRent:AC" | "CURRent[:DC]" | "FREQuency" | "FRESistance" | "PERiod" | "RESistance" | "VOLTage:AC" | "VOLTage[:DC]:RATio" | "VOLTage[:DC]" (default) | "VOLTage[:DC]","VOLTage:DC2" | "CURRent[:DC]","VOLTage:DC2"

Query Response

function

function returns one of the following quoted strings to the output buffer: "CURR:AC", "CURR", "FREQ", "FRES", "PER", "RES", "VOLT:AC", "VOLT", "VOLT:RAT", '"VOLT","VOLT:DC2"', '"CURR","VOLT:DC2"'. The response data type is CRD.

Comments

- `*RST` Condition: `FUNC "VOLT[:DC]"`

Example

Change the measurement function.

```
CONF:VOLT         Function: DC voltage.
FUNC "FRES"       Set function to 4-wire resistance.
FUNC?             Query multimeter to return selected function.
READ?             Place multimeter in wait-for-trigger state and
                  make measurement; send reading to output buffer.
```

[:SENSe]:PERiod:APERture

`[:SENSe]:PERiod:APERture` *`time`* selects the aperture time (or gate time) for period measurements.

Syntax

[:SENSe]:PERiod:APERture *time*

[:SENSe]:PERiod:APERture? [*time*]

Parameter

Parameter	Type	Unit	Range of Value
time	NRf+	s	value | MINimum (0.01 for E1412A mode, 0.001 for M1412A mode) | MAXimum (1) | DEFault (0.1) Query does not support *time*=value.

- The E1412A does not support the “DEFault” parameter.

Query Response

time

time is the aperture time for period measurements. If a parameter is specified, *time* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The aperture for period measurements does not autorange.
- For the E1412A mode, specify 0.01 (10 ms) for 4.5 digits, 0.1 (default, 100 ms) for 5.5 digits or 1 second for 6.5 digits.
- For the M1412A mode, specify 0.001 (1 ms) or 0.01 (10 ms) for 4.5 digits, 0.1 (default, 100 ms) for 5.5 digits or 1 second for 6.5 digits.
- This parameter is set to its default value after a Reset (`*RST`).

Example

Set a period aperture time of 1 second.

`PER:APER 1`	*Set aperture time to 1 second.*

[:SENSe]:PERiod:NULL[:STATe]

`[:SENSe]:PERiod:NULL[:STATe]` *`state`* enables or disables the null function for period measurements.

Syntax

[:SENSe]:PERiod:NULL[:STATe] *state*

[:SENSe]:PERiod:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state returns the null state of the period function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- To set a fixed null value, use `[:SENSe]:PERiod:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.
- Unlike the `SENSe:FREQuency` and `SENSe:PERiod` range and the aperture commands, this parameter is not shared between frequency and period measurements. The null parameters are independent for frequency and period measurements.

[:SENSe]:PERiod:NULL:VALue

`[:SENSe]:PERiod:NULL:VALue` *`offset`* sets the null value for period measurements.

Syntax

[:SENSe]:PERiod:NULL:VALue *offset*

[:SENSe]:PERiod:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	s	value | MINimum (–1.2) | MAXimum (+1.2) | DEFault (0) Query does not support *offset*=value.

Query Response

offset

offset returns a null offset value to the output buffer. The currently selected period null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The E1412A does not support this command.
- Specifying a null value disables the automatic null value selection (`[:SENSe]:PERiod:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:PERiod:NULL:STATe ON`).
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- Unlike the `SENSe:FREQuency` and `SENSe:PERiod` range and the aperture commands, this parameter is not shared between frequency and period measurements. The null parameters are independent for frequency and period measurements.

[:SENSe]:PERiod:NULL:VALue:AUTO

`[:SENSe]:PERiod:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for period measurements.

Syntax

[:SENSe]:PERiod:NULL:VALue:AUTO *state*

[:SENSe]:PERiod:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state returns the state of automatic null of the period function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:PERiod:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (OFF), the null value is specified by `[:SENSe]:PERiod:NULL:VALue`.
- When the null function is enabled (`[:SENSe]:PERiod:NULL:STATe ON`), the instrument enables the automatic null value selection.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- Unlike the `SENSe:FREQuency` and `SENSe:PERiod` range and the aperture commands, this parameter is not shared between frequency and period measurements. The null parameters are independent for frequency and period measurements.

[:SENSe]:PERiod:RANGe:LOWer

Sets the input frequency range of frequency and period measurements.
This parameter is shared between frequency and period measurements. Setting or querying the parameter with the `PERiod` version of this command is identical to setting or querying it with the `FREQuency` version.

Syntax

[:SENSe]:PERiod:RANGe:LOWer *bandwidth*

[:SENSe]:PERiod:RANGe:LOWer? [*bandwidth*]

Parameter

Parameter	Type	Unit	Range of Value
bandwidth	NRf+	Hz	value | MINimum (3) | MAXimum (200) | DEFault (20) Query does not support *bandwidth*=value.

Query Response

bandwidth

bandwidth returns a bandwidth value to the output buffer. The currently selected bandwidth is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *bandwidth* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The E1412A does not support this command.
- If you enter the lowest frequency that you expect to encounter, the command will select the appropriate bandwidth. For example, if you enter 15 Hz, the slow filter (3 Hz) is selected. If you enter 190 Hz, the medium filter (20 Hz) is selected to provide the appropriate low cutoff.

- Set the lowest frequency that you expect to encounter. Lower bandwidths result in longer settling delays, as shown below:

Input Frequency	Default Settling Delay
3 Hz - 300 kHz (Slow)	5 s/measurement
20 Hz - 300 kHz (Medium)	1 s/measurement
200 Hz - 300 kHz (Fast)	0.1 s/measurement

- This parameter is set to its default value after a Reset (*RST).

Example Make and read a period measurement. Use the 3 Hz filter bandwidth:

```
CONF:PER
PER:RANG:LOW 3
READ?
```

Typical Response:
`+1.27530000E-04`

[:SENSe]:PERiod:TIMeout:AUTO

Controls how long the instrument waits before timing out on a frequency or period measurement when no signal is present.

Syntax [:SENSe]:PERiod:TIMeout:AUTO *state*

[:SENSe]:PERiod:TIMeout:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response *state*

state returns a number to show whether the auto timeout mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer. The response data type is NR1.

Comments

- The E1412A does not support this command.
- When set to OFF, the instrument waits 1 second before timing out. When set to ON, the wait time varies with the AC filter bandwidth; for the faster bandwidths, the instrument waits a shorter length of time before timing out and returning 0.0. This is advantageous in manufacturing test systems where a DUT failure may result in no signal; in this case, the failure can be detected sooner, speeding up test throughput.
- This setting is non-volatile; it will not be changed by power cycling or `*RST`.

Example

Configure period measurements, using the null function to subtract 1 kHz from the measurements. Enable the automatic timeout. Make and read two measurements:

```
CONF:PER
PER:NULL:STAT ON;VAL 1 kHz
PER:TIM:AUTO ON
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E-03,+1.04570000E-03`

[:SENSe]:PERiod:VOLTage:RANGe[:UPPer]

`[:SENSe]:PERiod:VOLTage:RANGe[:UPPer]` *range* selects the voltage range for the signal level of period measurements.

Syntax

[:SENSe]:PERiod:VOLTage:RANGe[:UPPer] *range*

[:SENSe]:PERiod:VOLTage:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (10)

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 0.1, 1, 10, 100, or 300.
- The E1412A does not support the "DEFault" parameter.

- Both M1412A and E1412A modes accept up to ±303.0 V as a valid input value. (Values over/under 300.0/–300.0 are rounded to 300.0.)

Query Response

range

range is a range value to the output buffer. The currently selected voltage range is returned if DEF, MIN or MAX is not specified. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a fixed range disables the autorange mode set by the `PER:VOLT:RANG:AUTO` command.
- Related Commands: `FREQuency:VOLTage:RANGe`, `FREQuency:VOLTage:RANGe:AUTO`
- `*RST` Condition: `PER:VOLT:RANG 10`
- This command does not support the “Volt” unit but can use “V”.
- The user’s manual always omits the UPPer header.

Example

Set and query the voltage range for period measurements.

`PER:VOLT:RANG 100`	*Voltage range for period measurements is 100 V.*
`PER:VOLT:RANG?`	*Query the present range.*

[:SENSe]:PERiod:VOLTage:RANGe:AUTO

`[:SENSe]:PERiod:VOLTage:RANGe:AUTO` *`state`* enables or disables the autorange function for the signal level of period measurements.

Syntax

[:SENSe]:PERiod:VOLTage:RANGe:AUTO *state*

[:SENSe]:PERiod:VOLTage:RANGe:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response *state*

state returns a number to show whether the autorange mode is enabled or disabled: “0” (OFF or ONCE) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `PERiod:VOLTage:RANGe`, autoranging is turned OFF.
- Related Commands: `CONFigure`, `MEASure`, `FREQuency:VOLTage:RANGe`, `FREQuency:VOLTage:RANGe:AUTO`
- `*RST` Condition: `PER:VOLT:RANG:AUTO ON`

Example Disable autoranging.

`PER:VOLT:RANG:AUTO OFF`	*Disable autorange.*

Query the autorange mode.

`PER:VOLT:RANG:AUTO?`	*Query multimeter to return autorange mode.*

[:SENSe]:RESistance:APERture

`[:SENSe]:RESistance:APERture` *`time`* sets the integration time in seconds for 2-wire resistance measurements.

Syntax [:SENSe]:RESistance:APERture *time*

[:SENSe]:RESistance:APERture? [*time*]

Parameter

Parameter	Type	Unit	Range of Value
time	NRf+	s	value | MINimum | MAXimum | DEFault Query does not support *time*=value.

- The aperture time can be set in the range between the MINimum and MAXimum values. The resolution of the setting value is shown in Table 3-10.

- DEFault, MINimum and MAXimum values are determined by *power line frequency* and its driver mode. Please see the following table for the specific values.

Line Frequency (M1412A mode)		
	50 Hz	**60 Hz**
MINimum	500E-9	500E-9
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

Line Frequency (E1412A mode)		
	50 Hz	**60 Hz**
MINimum	0.4E-3	0.4E-3
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

- When `[:SENSe]:RESistance:APERture:ENABle` is disabled, the value is calculated from `[:SENSe]:<FRESistance|RESistance>:NPLCycles`.
- The E1412A does not support the “DEFault” parameter.

Query Response *time*

time is the current setting of the aperture time. If a parameter is specified, *time* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the aperture time also sets the integration time in PLCs and the resolution.
- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- When `RESistance:APER` is specified, `[:SENSe]:RESistance:APERture:ENABle` is set to ON automatically.

- Related Commands: [:SENSe]:FRESistance, CALibration:LFRrequency, SYSTem:LFRequency.
- *RST Condition: When the power line frequency is 50 Hz, the aperture is 0.2000, and when the power line frequency is 60 Hz, the aperture is 0.2004.
- [:SENSe]:FRESistance:APERture and [:SENSe]:RESistance:APERture use the same parameter, and a change in one affects the other.

Example Set and query the aperture time.

`RES:APER 167E-03`	*Aperture time is 167 ms.*
`RES:APER?`	*Query multimeter to return aperture time.*

[:SENSe]:RESistance:APERture:ENABled

Enables the integration time to be set in seconds (called aperture time) for all resistance measurements. If the aperture time mode is disabled (default), the integration time is set in PLCs.

Syntax [:SENSe]:RESistance:APERture:ENABled *state*

[:SENSe]:RESistance:APERture:ENABled?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the state of the aperture time. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The CONFigure:RESistance, MEASure:RESistance?, [:SENSe]:RESistance:NPLC and [:SENSe]:RESistance:RESolution commands disable the aperture time mode and select an integration time in NPLC.
- This parameter is set to its default value after a Reset (*RST).

- `[:SENSe]:FRESistance:APERture` and `[:SENSe]:RESistance:APERture` use the same parameter, and a change in one affects the other.
- The E1412A does not support this command.

Example Enable the aperture time mode, and set the aperture time to 300 ms.

```
RES:APER:ENAB ON
RES:APER 300E-03
```

[:SENSe]:RESistance:NPLCycles

`[:SENSe]:RESistance:NPLCycles` *`nplc`* sets the integration time in PLCs.

Syntax [:SENSe]:RESistance:NPLCycles *nplc*

[:SENSe]:RESistance:NPLCycles? [*nplc*]

Parameter

Parameter	Type	Unit	Range of Value
nplc	NRf+		value | MINimum (0.02 for E1412A mode, 25E-6 for M1412A mode) | MAXimum (100) | DEFault (10) Query does not support *nplc*=value.

- The resolution of the setting value is shown in Table 3-9.
- The integration time can be expressed by the following formula.

  integration time = *nplc / power line frequency*
- The E1412A does not support the “DEFault” parameter.
- When *power line frequency* is set as 60 Hz, set values between MINimum and 30E-6 are rounded up to 30E-6.

Query Response *nplc*

nplc returns the current setting of the integration time in PLCs. If a parameter is specified, *nplc* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the integration time in PLCs also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 166.667 ms (60 Hz line frequency) or 200 ms (50 Hz). The corresponding resolution depends on the function and range you select.
- The `RES:NPLC` command overrides the results of a previously executed `RESistance:APERture` or `RESistance:RESolution` command (the last command executed has priority).
- The greater the number of PLCs, the greater the normal mode rejection (and the lower the reading rate).
- Only whole-number PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line-related noise.
  Fractional PLC settings do not provide normal mode rejection of power line noise.
- When `RESistance:NPLC` is specified, `[:SENSe]:RESistance:APERture:ENABle` is set to OFF automatically.
- `*RST` Condition: 10 PLCs
- `[:SENSe]:FRESistance:NPLCycles` and `[:SENSe]:RESistance:NPLCycles` use the same parameter, and a change in one affects the other.

Example Set and query the integration time in PLCs.

`RES:NPLC 100`	*Integration time is 100 PLCs.*
`RES:NPLC?`	*Query multimeter to return integration time.*

[:SENSe]:RESistance:NULL[:STATe]

`[:SENSe]:RESistance:NULL[:STATe]` *`state`* enables or disables the null function for all resistance measurements.

Syntax [:SENSe]:RESistance:NULL[:STATe] *state*

[:SENSe]:RESistance:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state returns the null state of the DC current function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use: `[:SENSe]:RESistance:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.
- `[:SENSe]:FRESistance:NULL[:STATe]` and `[:SENSe]:RESistance:NULL[:STATe]` use the same parameter, and a change in one affects the other.
- The E1412A does not support this command.

Example

Configure 2-wire resistance measurements, using the null function to subtract 100 mΩ from the measurements. Then make two measurements and send them to the instrument’s output buffer:

```
CONF:RES
RES:NULL:STAT ON;VAL 0.1
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+02,+1.04570000E+02`

[:SENSe]:RESistance:NULL:VALue

`[:SENSe]:RESistance:NULL:VALue` ***`offset`*** sets the null value for all resistance measurements.

Syntax

[:SENSe]:RESistance:NULL:VALue *offset*

[:SENSe]:RESistance:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	OHM	value | MINimum (–120E6 for E1412A mode, –1.2E9 for M1412A mode) | MAXimum (+120E6 for E1412A mode, +1.2E9 for M1412A mode) | DEFault (0) Query does not support *offset*=value.

Query Response

offset

offset returns a null offset value to the output buffer. The currently selected null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:RESistance:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:RESistance:NULL:STATe ON`).
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- `[:SENSe]:FRESistance:NULL:VALue` and `[:SENSe]:RESistance:NULL:VALue` use the same parameter, and a change to one affects the other.
- The E1412A does not support this command.

Example

Configure 2-wire resistance measurements, using the null function to subtract 100 mΩ from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:RES
RES:NULL:STAT ON;VAL 0.1
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+02,+1.04570000E+02`

[:SENSe]:RESistance:NULL:VALue:AUTO

`[:SENSe]:RESistance:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for all resistance measurements.

Syntax

[:SENSe]:RESistance:NULL:VALue:AUTO *state*

[:SENSe]:RESistance:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state returns the state of automatic null of the 2-wire resistance function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:RESistance:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (`[:SENSe]:RESistance:NULL:VALue:AUTO OFF`), the null value is specified by: `[:SENSe]:RESistance:NULL:VALue`.
- When the null function is enabled (`[:SENSe]:RESistance:NULL:STATe ON`), the instrument enables automatic null value selection.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- `[:SENSe]:FRESistance:NULL:VALue:AUTO` and `[:SENSe]:RESistance:NULL:VALue:AUTO` use the same parameter, and a change to one affects the other.
- The E1412A does not support this command.

Example Configure 2-wire resistance measurements, using the null function to subtract 0.1 Ω from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:RES
RES:NULL:STAT ON;VAL 0.1
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+02,+1.04570000E+02`

Make a second set of measurements using the automatic null value selection.

```
RES:NULL:VAL:AUTO ON
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+00`

[:SENSe]:RESistance:OCOMpensated

Enables or disables offset compensation. Offset compensation removes the effects of small DC voltages in the circuit being measured. The technique involves taking the difference between two resistance measurements, one with the current source set to the normal value and one with the current source set to a lower value. Enabling offset compensation approximately doubles the reading time.

Syntax [:SENSe]:RESistance:OCOMpensated *state*

[:SENSe]:RESistance:OCOMpensated?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the state of offset compensation. Returns "0" (OFF) or "1" (ON). The response data type is NR1.

Comments

- Applies only to resistance measurements in the 10 Ω, 100 Ω, 1 kΩ, and 10 kΩ ranges.
- This parameter is set to its default value after a Reset (`*RST`).
- The offset compensation function is only effective for Sample Count = 1. Otherwise, the function is automatically disabled.
- Affects both 2-wire and 4-wire resistance measurements.
- The E1412A does not support this command.

Example

Configure low-power 2-wire resistance measurements. Enable offset compensation. Make and read two measurements.

```
RES:POW:LIM ON
RES:OCOM ON
SAMP:COUN 1
READ?
```

Typical Response:
`+4.05451008E-03,+4.97391062E-03`

[:SENSe]:RESistance:RANGe[:UPPer]

`[:SENSe]:RESistance:RANGe[:UPPer]` *range* selects the range for 2-wire resistance measurements.

Syntax

[:SENSe]:RESistance:RANGe[:UPPer] *range*

[:SENSe]:RESistance:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	OHM	value | MINimum (100 for E1412A mode, 10 for M1412A mode) | MAXimum (100E6 for E1412A mode, 1E9 for M1412A mode) | DEFault (1E3) Query does not support *range*=value.

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 10, 100, 1E3, 10E3, 100E3, 1E6, 10E6, 100E6, or 1E9.

- The E1412A does not support the “DEFault” parameter.
- The E1412A mode accepts up to ±120E6 Ω as a valid input value. (Values over/under 100E6/–100E6 are rounded to 100E6.)
- The M1412A mode accepts up to ±1.2E9 Ω as a valid input value. (Values over/under 1.0E9/–1.0E9 are rounded to 1.0E9.)

Quer Response *range*

range returns a range value to the output buffer. The currently selected range is returned if DEF, MIN or MAX is not specified. Only the ranges available with the `RANGe` command are returned. For example, if `CONFigure` sets the 100 Ω range, 100 Ω is the range returned. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- You must select a range using `RESistance:RANGe` before specifying the resolution.
- Specifying a fixed range disables the autorange mode set by the `RES:RANG:AUTO` command.
- The `RES:RANG` command overrides the range setting from a previous `CONFigure` command on the same function. The multimeter uses the same aperture time to set the resolution on the new range as was selected by `CONFigure`.
- `*RST` Condition: `FRES:RANG 1E3`
- Affects both 2-wire and 4-wire resistance measurements.
- The user’s manual always omits the UPPer header.

Example Set and query the 2-wire resistance measurement range.

`RES:RANG 100`	*Select 100 Ω range.*
`RES:RANG?`	*Query multimeter to return the present range.*

[:SENSe]:RESistance:RANGe:AUTO

`[:SENSe]:RESistance:RANGe:AUTO` *`state`* enables or disables the autorange function for 2-wire resistance measurements.

Syntax

[:SENSe]:RESistance:RANGe:AUTO *state*

[:SENSe]:RESistance:RANGe:AUTO? [*state*]

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response

state

state is a number to show whether the 2-wire resistance autorange mode is enabled or disabled: “0” (OFF or ONCE) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `RESistance:RANGe`, autoranging is turned OFF.
- In order to specify an aperture time of 10 μs, you must select a fixed range (e.g., `RES:RANG:AUTO OFF`).
- Related Commands: `CONFigure`, `MEASure`, `RESistance:RANGe`, `FRESistance:RANGe`
- `*RST` Condition: `RES:RANG:AUTO ON`
- Affects both 2-wire and 4-wire resistance measurements.

Example

Disable and query 2-wire resistance autorange mode.

```
RES:RANG:AUTO OFF        Disable autorange.
RES:RANG:AUTO?           Query multimeter to return autorange mode.
```

[:SENSe]:RESistance:RESolution

`[:SENSe]:RESistance:RESolution` *`resolution`* selects the resolution for 2-wire resistance measurements.

Syntax

[:SENSe]:RESistance:RESolution *resolution*

[:SENSe]:RESistance:RESolution? [*resolution*]

Parameter

Parameter	Type	Unit	Range of Value
resolution	NRf+	OHM	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault Query does not support *resolution*=value.

- See Table 4-4 for resolution choices.
- When the specified value is not in the table, the input value is rounded down to the next smallest resolution. (E.g., 3.0005E-7 * *range* input is rounded to 3.0000E-7 * *range* resolution, but 2.9995E-7 * *range* input is rounded to 1.0000E-7 * *range* resolution.)
- The E1412A does not support the “DEFault” parameter.

Query Response

resolution

resolution returns a resolution value to the output buffer. The currently selected resolution is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *resolution* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- MINimum selects the best resolution (the smallest value) for the selected range. MAXimum selects the worst resolution (the largest value) for the selected range.
- You must select a range using `RESistance:RANGe` before specifying a resolution. Also, only specify a resolution when making measurements on a fixed range. Otherwise, the resolution will change to correspond with the range selected during autoranging.
- Specify the resolution in the same units used for the measurement function.

- If autoranging is required, set the resolution using the DEF, MIN, or MAX parameter.
- Changing the resolution also changes the NPLC setting to the values that correspond with the resolution specified.
- When `CURR[:DC]:NPLC` is specified, `[:SENSe]:CURRent[:DC]:APERture:ENABle` is set to OFF automatically.
- `*RST` Condition: `RES:RES 1E-3`
- Affects both 2-wire and 4-wire resistance measurements.
- When a specified value is smaller than the MINimum value, the set value is rounded up to the MINimum value with no error notification.
- When a specified value is larger than the MAXimum value, the set value is rounded down to the MAXimum value with no error notification.
- When `AutoRange` is on, you can specify a resolution value only via DEF, MIN, or MAX inputs. If you input any values, it returns error -221.

Example Query the DC current measurement range.

`FRES:RES 0.3E-3`	*Selects 0.3 mΩ resolution.*
`FRES:RES?`	*Query multimeter to return the present resolution.*

[:SENSe]:RESistance:ZERO:AUTO

Disables or enables the autozero mode for 2-wire resistance measurements.

Syntax [:SENSe]:RESistance:ZERO:AUTO *state*

[:SENSe]:RESistance:ZERO:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		ONCE | 0 | OFF | 1 | ON (default)

Query Response *state*

state returns the state of automatic zero of the 2-wire resistance function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- ON: The DMM internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the DMM's input circuitry from affecting measurement accuracy.
- OFF: The instrument uses the last measured zero measurement and subtracts it from each measurement. It takes a new zero measurement each time you change the function, range or integration time.
- ONCE: The instrument takes one zero measurement and sets autozero to OFF. The zero measurement taken is used for all subsequent measurements until the function, range or integration time is changed. If the specified integration time is less than 1 PLC, the zero measurement is taken at 1 PLC to optimize noise rejection. Subsequent measurements are taken at the specified fast (< 1 PLC) integration time.
- Does not affect 4-wire resistance measurements, which are always made with autozero ON.
- The autozero mode is set indirectly when you set the resolution and integration time using `CONFigure:{RESistance|FRESistance}` or `MEASure:{RESistance|FRESistance}?`. Autozero is automatically turned OFF when you select an integration time less than 1 PLC with these commands.
- This parameter is set to its default value after a Reset (`*RST`).

Example Configure 2-wire resistance measurements and perform an immediate autozero. Make and read two measurements:

```
CONF:RES 1E4
RES:ZERO:AUTO ONCE
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+03,+1.04570000E+03`

[:SENSe]:VOLTage:AC:BANDwidth

Sets the bandwidth for AC voltage measurements. The instrument uses three different AC filters that enable you either to optimize low frequency accuracy or to achieve faster AC settling times following a change in input signal amplitude.

Syntax

[:SENSe]:VOLTage:AC:BANDwidth *bandwidth*

[:SENSe]:VOLTage:AC:BANDwidth? [*bandwidth*]

Parameter

Parameter	Type	Unit	Range of Value
bandwidth	NRf+	Hz	value | MINimum (3) | MAXimum (200) | DEFault (20) Query does not support *bandwidth*=value.

Query Response

bandwidth

bandwidth returns a bandwidth value to the output buffer. The currently selected voltage bandwidth is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *bandwidth* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The E1412A does not support this command.
- If you enter the lowest frequency that you expect to encounter, the command will select the appropriate bandwidth. For example, if you enter 15 Hz, the slow filter (3 Hz) is selected. If you enter 190 Hz, the medium filter (20 Hz) is selected to provide the appropriate low cutoff.
- Set the lowest frequency that you expect to encounter. Lower bandwidths result in longer settling delays, as shown below:

Input Frequency	Default Settling Delay	
	M1412A mode	**E1412A mode**
3 Hz - 300 kHz (Slow)	5 s/measurement	7 s/measurement
20 Hz - 300 kHz (Medium)	1 s/measurement	1 s/measurement
200 Hz - 300 kHz (Fast)	0.1 s/measurement	0.6 s/measurement

- This parameter is set to its default value after a Reset (`*RST`).

Example Make and read an AC current measurement. Use the 3 Hz filter bandwidth.

```
CONF:VOLT:AC 1
VOLT:AC:BAND 3
READ?
```

Typical Response:
`+5.23918293E-01`

[:SENSe]:VOLTage:AC:NULL[:STATe]

`[:SENSe]:VOLTage:AC:NULL[:STATe]` *`state`* enables or disables the null function for AC voltage measurements.

Syntax [:SENSe]:VOLTage:AC:NULL[:STATe] *state*

[:SENSe]:VOLTage:AC:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the null state of the AC voltage function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use `[:SENSe]:VOLTage:AC:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.
- The E1412A does not support this command.

Example Configure AC voltage measurements, using the null function to subtract 100 mV from the measurements. Then make two measurements and send them to the instrument’s output buffer:

```
CONF:VOLT:AC
VOLT:AC:NULL:STAT ON;VAL 100
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:VOLTage:AC:NULL:VALue

`[:SENSe]:VOLTage:AC:NULL:VALue` ***`offset`*** sets the null value for AC voltage measurements.

Syntax

[:SENSe]:VOLTage:AC:NULL:VALue *offset*

[:SENSe]:VOLTage:AC:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	V	value | MINimum (-1200) | MAXimum (+1200) | DEFault (0) Query does not support *offset*=value.

Query Response

offset

offset returns a null offset value to the output buffer. The currently selected voltage null offset is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:VOLTage:AC:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:VOLTage:AC:NULL:STATe ON`).
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- The E1412A does not support this command.

Example Configure AC voltage measurements, using the null function to subtract 100 mV from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:VOLT:AC
VOLT:AC:NULL:STAT ON;VAL 100 mV
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:VOLTage:AC:NULL:VALue:AUTO

`[:SENSe]:VOLTage:AC:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for AC voltage measurements.

Syntax [:SENSe]:VOLTage:AC:NULL:VALue:AUTO *state*

[:SENSe]:VOLTage:AC:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response *state*

state returns the state of automatic null of the AC voltage function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:VOLTage:AC:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (OFF), the null value is specified by `[:SENSe]:VOLTage:AC:NULL:VALue`.
- When the null function is enabled (`[:SENSe]:VOLTage:AC:NULL:STATe ON)`, the instrument enables the automatic null value selection.

- This parameter is set to its default value after a Reset (*RST) or CONFigure function.

Example Configure AC voltage measurements, using the null function to subtract 100 mV from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:VOLT:AC
VOLT:AC:NULL:STAT ON;VAL 100 mV
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

Make a second set of measurements using the automatic null value selection.

```
VOLT:AC:NULL:VAL:AUTO ON
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+00`

[:SENSe]:VOLTage:AC:RANGe[:UPPer]

`[:SENSe]:VOLTage:AC:RANGe[:UPPer]` *range* selects the range for AC-coupled RMS voltage measurements.

Syntax [:SENSe]:VOLTage:AC:RANGe[:UPPer] *range*

[:SENSe]:VOLTage:AC:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (100 m) | MAXimum (300) | DEFault (10) Query does not support *range*=value.

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 0.1, 1, 10, 100, or 300.
- The E1412A does not support the "DEFault" parameter.

- Both M1412A and E1412A modes accept up to ±303.0 V as a valid input value. (Values over/under 300.0/–300.0 are rounded to 300.0.)

Query Response *range*

range returns a range value to the output buffer. The currently selected voltage range is returned if MIN or MAX is not specified. Only the ranges available with the `RANGe` command are returned. For example, if `CONFigure` sets the 10 V range, 10 V is the range returned. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- You must select a range using `VOLTage:AC:RANGe` before specifying the resolution.
- Specifying a fixed range disables the autorange mode set by the `VOLT:AC:RANG:AUTO OFF` command.
- The `VOLT:AC:RANG` command overrides the range setting from a previous `CONFigure` command on the same function. With the new range, a new resolution is also selected.
- `*RST` Condition: `VOLT:AC:RANG 10`
- This command does not support the “Volt” unit but can use “V”.
- The user’s manual always omits the UPPer header.

Example Query the AC voltage measurement range.

`VOLT:AC:RANG 10`	*Select 10 V range.*
`VOLT:AC:RANG?`	*Query multimeter to return the present range.*

[:SENSe]:VOLTage:AC:RANGe:AUTO

`[:SENSe]:VOLTage:AC:RANGe:AUTO` *`state`* enables or disables the autorange function for AC voltage measurements.

Syntax [:SENSe]:VOLTage:AC:RANGe:AUTO *state*

[:SENSe]:VOLTage:AC:RANGe:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response

state

state returns the autorange state of the AC voltage function. Returns “0” (OFF or ONCE) or “1” (ON). The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `VOLTage:AC:RANGe`, autoranging is turned OFF.
- Related Command: `CONFigure`
- `*RST` Condition: `VOLT:AC:RANG:AUTO ON`

Example

Disable AC voltage autoranging.

`VOLT:AC:RANG:AUTO OFF` *Disable autorange.*

Query the AC voltage autorange mode.

`VOLT:AC:RANG:AUTO?` *Query multimeter to return autorange mode.*

[:SENSe]:VOLTage:AC:RESolution

`[:SENSe]:VOLTage:AC:RESolution` ***resolution*** selects the resolution for AC voltage measurements.

Syntax

[:SENSe]:VOLTage:AC:RESolution *resolution*

[:SENSe]:VOLTage:AC:RESolution? [*resolution*]

Parameter

Parameter	Type	Unit	Range of Value
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault Query does not support *resolution*=value.

- See Table 4-5 for resolution choices.
- When the specified value is not in the table, the input value is rounded down to the next smallest resolution. (E.g., 3.0005E-7 * *range* input is rounded to 3.0000E-7 * *range* resolution, but 2.9995E-7 * *range* input is rounded to 1.0000E-7 * *range* resolution.)
- The E1412A does not support the “DEFault” parameter.

Query Response

resolution

resolution returns a resolution value to the output buffer. The currently selected voltage resolution is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *resolution* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- MINimum selects the best resolution (the smallest value) for the selected range. MAXimum selects the worst resolution (the largest value) for the selected range.
- You must select a range using `VOLTage:AC:RANGe` before specifying a resolution. Also, only specify a resolution when making measurements on a fixed range. Otherwise, the resolution will change to correspond with the range selected during autoranging.
- Specify resolution in the same units used for the measurement function.
- If autoranging is required, set the resolution using the DEF, MIN, or MAX parameter.
- The `VOLT:AC:RES` command overrides the resolution setting from a previous `CONFigure:VOLT:AC` command.
- Related Commands: `CONFigure`, `VOLTage[:DC]:RESolution`
- This command does not support the “Volt” unit but can use “V”.
- When a specified value is smaller than the MINimum value, the set value is rounded up to the MINimum value with no error notification.

- When a specified value is larger than the MAXimum value, the set value is rounded down to the MAXimum value with no error notification.

Example Change the resolution.

`CONF:VOLT:AC 6.25,MAX`	*Function: DC voltage; range selected: 10 V;. MAX resolution.*
`VOLT:AC:RANG 0.95`	*Range selected: 1.0 V; MAX resolution: 100 μV.*
`VOLT:AC:RES 10E-06`	*Set resolution to 10 μV.*
`VOLT:AC:RES?`	*Query multimeter to return the present resolution.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; send readings to output buffer.*

[:SENSe]:VOLTage[:DC]:APERture

Sets the integration time for one point measurement.

Syntax [:SENSe]:VOLTage[:DC]:APERture *time*

[:SENSe]:VOLTage[:DC]:APERture? [*time*]

Parameter

Parameter	Type	Unit	Range of Value
time	NRf+	s	value | MINimum | MAXimum | DEFault Query does not support *time*=value.

- Aperture time can be set in the range between the MINimum and MAXimum values. The resolution of the setting value is shown in Table 3-10.
- DEFault, MINimum and MAXimum values are determined by *power line frequency* and its driver mode. Please see the following table for the specific values.

Line Frequency (M1412A mode)		
	50 Hz	**60 Hz**
MINimum	500E-9	500E-9
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

Line Frequency (E1412A mode)		
	50 Hz	**60 Hz**
MINimum	0.4E-3	0.4E-3
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

- When `[:SENSe]:VOLTage[:DC]:APERture:ENABle` is disabled, the value is calculated from `[:SENSe]:VOLTage[:DC]:NPLCycles`.
- The E1412A does not support the "DEFault" parameter.

Query Response *time*

time is the current setting of the aperture time. If a parameter is specified, *time* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the aperture time also sets the integration time in PLCs and the resolution.
- The `VOLT[:DC]:APER` command overrides the results of previously executed `VOLT[:DC]:NPLC` and `VOLT[:DC]:RES` commands. The last command executed has priority.
- When `VOLT[:DC]:APER` is specified, `[:SENSe]:VOLTage[:DC]:APERture:ENABle` is set to ON automatically.
- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).

- Related Commands: `CALibration:LFRrequency` and `SYSTem:LFRequency`
- `*RST` Condition: When the power line frequency is 50 Hz, the aperture is 0.2000, and when the power line frequency is 60 Hz, the aperture is 0.2004.

Example Set and query the aperture time.

```
VOLT:APER 167E-03      Aperture time is 167 ms.
VOLT:APER?             Query multimeter to return aperture time.
```

[:SENSe]:VOLTage[:DC]:APERture:ENABled

Enables the integration time to be set in seconds (called aperture time) for DC voltage measurements. If the aperture time mode is disabled (default), the integration time is set in PLCs.

Syntax [:SENSe]:VOLTage[:DC]:APERture:ENABled *state*

[:SENSe]:VOLTage[:DC]:APERture:ENABled?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the state of the aperture time. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The `CONFigure:VOLTage[:DC]`, `MEASure:VOLTage[:DC]?`, `[:SENSe]:VOLTage[:DC]:NPLC`, and `[:SENSe]:VOLTage[:DC]:RESolution` commands disable the aperture time mode, and select an integration time in NPLC.
- This parameter is set to its default value after a Reset (`*RST`).
- The E1412A does not support this command.

Example Enable the aperture time mode, and set the aperture time to 300 ms.

```
VOLT:APER:ENAB ON
VOLT:DC:APER 300E-03
```

[:SENSe]:VOLTage[:DC]:IMPedance:AUTO

`[:SENSe]:VOLTage[:DC]:IMPedance:AUTO` *`state`* enables or disables automatic input impedance mode for DC voltage and ratio measurements.

Syntax

[:SENSe]:VOLTage[:DC]:IMPedance:AUTO *state*

[:SENSe]:VOLTage[:DC]:IMPedance:AUTO? [*state*]

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response

state

state is a number to show whether the DC voltage autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer. The response data type is NR1.

Comments

- OFF: The input impedance for DC voltage measurements is fixed at 10 MΩ for all ranges to minimize noise pickup.
- ON: The input impedance for DC voltage measurements varies by range. It is set to “HI-Z” (>10 GΩ) for the 100 mV, 1 V, and 10 V ranges to reduce the effects of measurement loading errors on these lower ranges. The 100 V and 300 V ranges remain at a 10 MΩ input impedance.
- The `CONFigure` and `MEASure?` commands automatically select “AUTO OFF”.
- This parameter is set to its default value after a Reset (`*RST`).
- Related Command: `INPut:IMPedance:AUTO`
- The E1412A does not support this command.

Example

Make all DC voltage measurements with a 10 MΩ input impedance.

```
VOLT:IMP:AUTO OFF
```

[:SENSe]:VOLTage[:DC]:NPLCycles

`[:SENSe]:VOLTage[:DC]:NPLCycles` *`nplc`* sets the integration time in PLCs.

Syntax

[:SENSe]:VOLTage[:DC]:NPLCycles *nplc*

[:SENSe]:VOLTage[:DC]:NPLCycles? [*nplc*]

Parameter

Parameter	Type	Unit	Range of Value
nplc	NRf+		value | MINimum (0.02 for E1412A mode, 25E-6 for M1412A mode) | MAXimum (100) | DEFault (10) Query does not support *nplc*=value.

- The integration time can be expressed by the following formula.

  integration time = *nplc / power line frequency*

- The E1412A does not support the “DEFault” parameter.
- When *power line frequency* is set as 60 Hz, set values between MINimum and 30E-6 are rounded up to 30E-6.

Query Response

nplc

nplc returns the current setting of the integration time in PLCs. If a parameter is specified, *nplc* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the integration time in PLCs also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 166.667 ms (60 Hz line frequency) or 200 ms (50 Hz). The corresponding resolution depends on the function and range you select.
- The `VOLT:DC:NPLC` command overrides the results of previously executed `VOLTage:APERture` or `VOLTage:RESolution` commands (the last command executed has priority).
- The greater the number of PLCs, the greater the normal mode rejection (and the lower the reading rate).

- Only whole-number PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line-related noise.
  Fractional PLC settings do not provide normal mode rejection of power line noise.
- When `VOLT[:DC]:NPLC` is specified, `[:SENSe]:VOLTage[:DC]:APERture:ENABle` is set to OFF automatically.
- `*RST` Condition: 10 PLCs

Example Set and query the DC voltage integration time in PLCs.

```
VOLT:DC:NPLC 100        Integration time is 100 PLCs.
VOLT:DC:NPLC?           Query multimeter to return integration time.
```

[:SENSe]:VOLTage[:DC]:NULL[:STATe]

`[:SENSe]:VOLTage[:DC]:NULL[:STATe]` *`state`* enables or disables the null function for DC current measurements.

Syntax [:SENSe]:VOLTage[:DC]:NULL[:STATe] *state*

[:SENSe]:VOLTage[:DC]:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the null state of the DC voltage function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use `[:SENSe]:VOLTage[:DC]:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.
- The E1412A does not support this command.

Example Configure DC voltage measurements, using the null function to subtract 100 mV from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:VOLT:DC
VOLT:DC:NULL:STAT ON;VAL 100 mV
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:VOLTage[:DC]:NULL:VALue

`[:SENSe]:VOLTage[:DC]:NULL:VALue` ***`offset`*** sets the null value for DC voltage measurements.

Syntax [:SENSe]:VOLTage[:DC]:NULL:VALue *offset*

[:SENSe]:VOLTage[:DC]:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	V	value | MINimum (–1200) | MAXimum (+1200) | DEFault (0) Query does not support *offset*=value.

Query Response *offset*

offset returns a null offset value to the output buffer. The currently selected voltage null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:VOLTage[:DC]:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:VOLTage[:DC]:NULL:STATe ON`).
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.

- The E1412A does not support this command.

Example Configure DC voltage measurements, using the null function to subtract 100 mV from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
CONF:VOLT:DC
VOLT:DC:NULL:STAT ON;VAL 100 mV
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:VOLTage[:DC]:NULL:VALue:AUTO

`[:SENSe]:VOLTage[:DC]:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for DC voltage measurements.

Syntax [:SENSe]:VOLTage[:DC]:NULL:VALue:AUTO *state*

[:SENSe]:VOLTage[:DC]:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response *state*

state returns the state of automatic null of the DC voltage function. Returns "0" (OFF) or "1" (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:VOLTage[:DC]:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (OFF), the null value is specified by: `[:SENSe]:VOLTage[:DC]:NULL:VALue`.

- When the null function is enabled (`[:SENSe]:VOLTage[:DC]:NULL:STATe ON`), the instrument enables the automatic null value selection.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.

Example Configure DC voltage measurements, using the null function to subtract 100 mV from the measurements. Then make two measurements and send them to the instrument's output buffer:

```
VOLT:DC:NULL:STAT ON;VAL 100 mV
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

Make a second set of measurements using the automatic null value selection.

```
VOLT:DC:NULL:VAL:AUTO ON
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+00`

[:SENSe]:VOLTage[:DC]:RANGe[:UPPer]

`[:SENSe]:VOLTage[:DC]:RANGe[:UPPer]` *range* selects the range for DC voltage measurements.

Syntax [:SENSe]:VOLTage[:DC]:RANGe[:UPPer] *range*

[:SENSe]:VOLTage[:DC]:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (300) | DEFault (300) Query does not support *range*=value.

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 0.1, 1, 10, 100, or 300.
- The E1412A does not support the “DEFault” parameter.

- Both M1412A and E1412A modes accept up to ±303.0 V as a valid input value. (Values over/under 300.0/-300.0 are rounded to 300.0.)

Query Response *range*

range returns a range value to the output buffer. The currently selected voltage range is returned if DEF, MIN or MAX is not specified. Only the ranges available with the `RANGe` command are returned. For example, if `CONFigure` sets the 10 V range, 10 V is the range returned. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- You must select a range using `VOLTage[:DC]:RANGe` before specifying the resolution.
- Specifying a fixed range disables the autorange mode set by the `VOLT[:DC]:RANG:AUTO OFF` command.
- The `VOLT[:DC]:RANG` command overrides the range setting from a previous `CONFigure` command on the same function.
- `*RST` Condition: `VOLT[:DC]:RANG 300`
- This command does not support the “Volt” unit but can use “V”.
- The user’s manual always omits the UPPer header.

Example Set and query the DC voltage measurement range.

```
VOLT:DC:RANG 10        Select 10 V range.
VOLT:DC:RANG?          Query multimeter to return the present range.
```

[:SENSe]:VOLTage[:DC]:RANGe:AUTO

`[:SENSe]:VOLTage[:DC]:RANGe:AUTO` *`state`* enables or disables the autorange function for DC voltage measurements.

Syntax [:SENSe]:VOLTage[:DC]:RANGe:AUTO *state*

[:SENSe]:VOLTage[:DC]:RANGe:AUTO? [*state*]

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response *state*

state is a number to show whether the DC voltage autorange mode is enabled or disabled: “0” (OFF or ONCE) or “1” (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `VOLTage[:DC]:RANGe`, autoranging is turned OFF.
- In order to specify an aperture time of 10 μs, you must select a fixed range (e.g., `VOLT:DC:RANG:AUTO OFF`).
- Related Commands: `CONFigure`, `VOLTage:AC:RANGe`, `RESistance:RANGe`
- `*RST` Condition: `VOLT[:DC]:RANG:AUTO ON`

Example Disable and query the DC voltage autorange mode.

```
VOLT:DC:RANG:AUTO OFF       Disable autorange.
VOLT:DC:RANG:AUTO?          Query multimeter to return autorange mode.
```

[:SENSe]:VOLTage[:DC]:RESolution

`[:SENSe]:VOLTage[:DC]:RESolution` *`resolution`* selects the resolution for DC voltage measurements.

Syntax

[:SENSe]:VOLTage[:DC]:RESolution *resolution*

[:SENSe]:VOLTage[:DC]:RESolution? [*resolution*]

Parameter

Parameter	Type	Unit	Range of Value
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault Query does not support *resolution*=value.

- See Table 4-2 for resolution choices.

- When the specified value is not in the table, the input value is rounded down to the next smallest resolution. (E.g., 3.0005E-7 * *range* input is rounded to 3.0000E-7 * *range* resolution, but 2.9995E-7 * *range* input is rounded to 1.0000E-7 * *range* resolution.)
- The E1412A does not support the “DEFault” parameter.

Query Response *resolution*

resolution returns a resolution value to the output buffer. The currently selected voltage resolution is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *resolution* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- MINimum selects the best resolution (the smallest value) for the selected range. MAXimum selects the worst resolution (the largest value) for the selected range.
- You must select a range using `VOLTage[:DC]:RANGe` before specifying a resolution. Also, only specify a resolution when making measurements on a fixed range. Otherwise, the resolution will change to correspond with the range selected during autoranging.
- Specify resolution in the same units used for the measurement function.
- If autoranging is required, set the resolution using the DEF, MIN, or MAX parameter, or select a specific integration time using `VOLTage[:DC]:NPLC`.
- Changing the resolution also changes the NPLC setting to the values that correspond to the specified resolution.
- When `CURR[:DC]:NPLC` is specified, `[:SENSe]:CURRent[:DC]:APERture:ENABle` is set to OFF automatically.
- The `VOLT:DC:RES` command overrides the resolution setting from a previous `CONFigure:VOLT:DC:RES` command.
- Related Commands: `CONFigure`, `VOLTage:AC:NPLC`
- `*RST` Condition: Based on the `*RST` values for the `VOLTage:NPLC` command.
- This command does not support the “Volt” unit but can use “V”.
- When a specified value is smaller than the MINimum value, the set value is rounded up to the MINimum value with no error notification.
- When a specified value is larger than the MAXimum value, the set value is rounded down to the MAXimum value with no error notification.

- When `AutoRange` is on, you can specify a resolution value only via DEF, MIN, or MAX inputs. If you input any values, it returns error -221.

Example Change and query the resolution.

`CONF:VOLT:DC 6.25,MAX`	*Function: DC voltage; range selected: 10 V; MAX resolution.*
`VOLT:DC:RANG 0.95`	*Range selected: 1 V; MAX resolution.*
`VOLT:DC:RES 3E-07`	*Set resolution to 0.3 μV.*
`VOLT:DC:RES?`	*Query multimeter to return the present resolution.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; send readings to output buffer.*

[:SENSe]:VOLTage[:DC]:ZERO:AUTO

Disables or enables the autozero mode for DC voltage measurements.

Syntax [:SENSe]:VOLTage[:DC]:ZERO:AUTO *state*

[:SENSe]:VOLTage[:DC]:ZERO:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response *state*

state returns the state of the autozero mode for DC voltage measurements. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- ON (default): The DMM internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the DMM’s input circuitry from affecting measurement accuracy.
- OFF: The instrument uses the last measured zero measurement and subtracts it from each measurement. It takes a new zero measurement each time you change the function, range or integration time.

- ONCE: The instrument takes one zero measurement and sets autozero to OFF. The zero measurement taken is used for all subsequent measurements until the function, range or integration time is changed. If the specified integration time is less than 1 PLC, the zero measurement is taken at 1 PLC to optimize noise rejection. Subsequent measurements are taken at the specified fast (< 1 PLC) integration time.
- The autozero mode is set indirectly when you set the resolution and integration time with `CONFigure:VOLTage[:DC]` or `MEASure:VOLTage[:DC]?`. Autozero is automatically turned OFF when you select an integration time less than 1 PLC with these commands.
- This parameter is set to its default value after a Reset (`*RST`).

Example Configure DC voltage measurements and perform an immediate autozero. Make and read two measurements.

```
CONF:VOLT:DC 1
VOLT:DC:ZERO:AUTO ONCE
SAMP:COUN 2
READ?
```

Typical Response:
`+1.04530000E-01,+1.04570000E-01`

[:SENSe]:VOLTage:DC2:APERture

Sets the integration time for one point measurement.

Syntax [:SENSe]:VOLTage:DC2:APERture *time*

[:SENSe]:VOLTage:DC2:APERture? [*time*]

Parameter

Parameter	Type	Unit	Range of Value
time	NRf+	s	value | MINimum | MAXimum | DEFault Query does not support *time*=value.

- The aperture time can be set in the range between the MINimum and MAXimum values. The resolution of the setting value is shown in Table 3-10.

- DEFault, MINimum and MAXimum values are determined by *power line frequency* and its driver mode. Please see the following table for the specific values.

Line Frequency (M1412A mode)		
	50 Hz	**60 Hz**
MINimum	500E-9	500E-9
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

Line Frequency (E1412A mode)		
	50 Hz	**60 Hz**
MINimum	0.4E-3	0.4E-3
DEFault	200E-3	200E-3
MAXimum	2.0	2.0

- When `[:SENSe]:VOLTage:DC2:APERture:ENABle` is disabled, the value is calculated from [`:SENSe]:VOLTage:DC2:NPLCycles`.
- The E1412A does not support the "DEFault" parameter.

Query Response *time*

time is the current setting of the aperture time. If a parameter is specified, *time* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Setting the aperture time also sets the integration time in PLCs and the resolution.
- The `VOLT:DC2:APER` command overrides the results of previously executed `VOLT:DC2:NPLC` and `VOLT:DC2:RES` commands. The last command executed has priority.
- When `VOLT:DC2:APER` is specified, `[:SENSe]:VOLTage:DC2:APERture:ENABle` is set to ON automatically.

- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- Related Commands: `CALibration:LFRrequency` and `SYSTem:LFRequency`
- When the `FUNC "VOLT:RAT"` is specified, no DC2 settings can be changed.
- `*RST` Condition: When the power line frequency is 50 Hz, the aperture is 0.2000, and when the power line frequency is 60 Hz, the aperture is 0.2004.

Example Set and query the aperture time.

`VOLT:DC2:APER 167E-03`	*Aperture time is 167 ms.*
`VOLT:DC2:APER?`	*Query multimeter to return aperture time.*

[:SENSe]:VOLTage:DC2:APERture:ENABled

Enables the integration time to be set in seconds (called aperture time) for DC2 voltage measurements. If the aperture time mode is disabled (default), the integration time is set in PLCs.

Syntax [:SENSe]:VOLTage:DC2:APERture:ENABled *state*

[:SENSe]:VOLTage:DC2:APERture:ENABled?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		1 | ON | 0 | OFF (default)

Query Response *state*

state returns the state of the aperture time. Returns "0" (OFF) or "1" (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- The `CONFigure[:VOLTage[:DC]]:RATio`, `[:SENSe]:VOLTage"[:DC2]:NPLC`, and `[:SENSe]:VOLTage[:DC2]:RESolution` commands disable the aperture time mode and select an integration time in PLCs.
- When `FUNC "VOLT:RAT"` is specified, no DC2 settings can be changed.

- This parameter is set to its default value after a Reset (*RST).

Example Enable the aperture time mode, and set the aperture time to 300 ms.

```
VOLT:DC2:APER:ENAB ON
VOLT:DC2:APER 300E-03
```

[:SENSe]:VOLTage:DC2:NPLCycles

`[:SENSe]:VOLTage:DC2:NPLCycles` *`nplc`* sets the integration time in PLCs.

Syntax [:SENSe]:VOLTage:DC2:NPLCycles *nplc*

[:SENSe]:VOLTage:DC2:NPLCycles? [*nplc*]

Parameter

Parameter	Type	Unit	Range of Value
nplc	NRf+		value | MINimum (0.02 for E1412A mode, 25E-6 for M1412A mode) | MAXimum (100) | DEFault (10) Query does not support *nplc*=value.

- The integration time can be expressed by the following formula.

  integration time = *nplc / power line frequency*

- When the power line frequency is set as 60 Hz, set values between MINimum and 30E-6 are rounded up to 30E-6.

Query Response *nplc*

nplc returns the current setting of the integration time in PLCs. If a parameter is specified, *nplc* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The E1412A does not support this command.
- Setting the integration time in PLCs also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 166.667 ms (60 Hz line frequency) or 200 ms (50 Hz). The corresponding resolution depends on the function and range you select

- The `VOLT:DC2:NPLC` command overrides the results of previously executed `VOLTage:DC2:APERture` or `VOLTage:DC2:RESolution` commands (the last command executed has priority).
- The greater the number of PLCs, the greater the normal mode rejection (and the lower the reading rate).
- Only whole-number PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line-related noise.
  Fractional PLC settings do not provide normal mode rejection of power line noise.
- When `FUNC “VOLT:RAT”` is specified, no DC2 settings can be changed.
- When `VOLT:DC2:NPLC` is specified, `[:SENSe]:VOLTage:DC2:APERture:ENABle` is set to OFF automatically.
- `*RST` Condition: 10 PLCs

Example Set and query the DC2 voltage integration time in PLCs.

`VOLT:DC2:NPLC 100`	*Integration time is 100 PLCs.*
`VOLT:DC2:NPLC?`	*Query multimeter to return integration time.*

[:SENSe]:VOLTage:DC2:NULL[:STATe]

`[:SENSe]:VOLTage:DC2:NULL[:STATe]` *`state`* enables or disables the null function for DC2 voltage measurements.

Syntax [:SENSe]:VOLTage:DC2:NULL[:STATe] *state*

[:SENSe]:VOLTage:DC2:NULL[:STATe]?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean	1 | ON | 0 | OFF (default)	

Query Response *state*

state returns the null state of the DC2 voltage function. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- To set a fixed null value, use `[:SENSe]:VOLTage:DC2:NULL:VALue`.
- The instrument disables the null function after a Reset (`*RST`) or `CONFigure` function.
- When `FUNC "VOLT:RAT"` is specified, no DC2 settings can be changed.
- The E1412A does not support this command.

Example

Configure ratio measurements, using the null function to subtract 100 mV from the DC2 measurements. Then make two measurements and send them to the instrument's output buffer:

```
SENS:FUNC "VOLT","VOLT:DC2"
VOLT:DC2:NULL:STAT ON;VAL 100 mV
SAMP:COUN 1
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:VOLTage:DC2:NULL:VALue

`[:SENSe]:VOLTage:DC2:NULL:VALue` *`offset`* sets the null value for DC2 voltage measurements.

Syntax

[:SENSe]:VOLTage:DC2:NULL:VALue *offset*

[:SENSe]:VOLTage:DC2:NULL:VALue? [*offset*]

Parameter

Parameter	Type	Unit	Range of Value
offset	NRf+	V	value | MINimum (-12) | MAXimum (+12) | DEFault (0) Query does not support *offset*=value.

Query Response

offset

offset returns a null offset value to the output buffer. The currently selected voltage null offset value is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *offset* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- Specifying a null value disables the automatic null value selection (`[:SENSe]:VOLTage:DC2:NULL:VALue:AUTO OFF`).
- To use the null value, the null state must be on (`[:SENSe]:VOLTage:DC2:NULL:STATe ON`).
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.
- When `FUNC "VOLT:RAT"` is specified, no DC2 settings can be changed.
- The E1412A does not support this command.

Example

Configure ratio measurements, using the null function to subtract 100 mV from the DC2 measurements. Then make two measurements and send them to the instrument's output buffer:

```
SENS:FUNC "VOLT","VOLT:DC2"
VOLT:DC2:NULL:STAT ON;VAL 100 mV
SAMP:COUN 1
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

[:SENSe]:VOLTage:DC2:NULL:VALue:AUTO

`[:SENSe]:VOLTage:DC2:NULL:VALue:AUTO` *`state`* enables or disables the automatic null value selection for DC2 voltage measurements.

Syntax

[:SENSe]:VOLTage:DC2:NULL:VALue:AUTO *state*

[:SENSe]:VOLTage:DC2:NULL:VALue:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF (default) | 1 | ON

Query Response

state

state returns the state of automatic null of the DC2 voltage function. Returns "0" (OFF) or "1" (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- When the automatic reference selection is ON, the first measurement made is used as the null value for all subsequent measurements. `[:SENSe]:VOLTage:DC2:NULL:VALue` is set to this value. The automatic null value selection will be disabled.
- When the automatic null value selection is disabled (OFF), the null value is specified by `[:SENSe]:VOLTage:DC2:NULL:VALue`.
- When the null function is enabled (`[:SENSe]:VOLTage:DC2:NULL:STATe ON`), the instrument enables the automatic null value selection.
- When `FUNC “VOLT:RAT”` is specified, no DC2 settings can be changed.
- This parameter is set to its default value after a Reset (`*RST`) or `CONFigure` function.

Example

Configure ratio measurements, using the null function to subtract 100 mV from the DC2 measurements. Then make two measurements and send them to the instrument’s output buffer:

```
SENS:FUNC “VOLT”,“VOLT:DC2”
VOLT:DC2:NULL:STAT ON;VAL 100 mV
SAMP:COUN 1
READ?
```

Typical Response:
`+1.04530000E+00,+1.04570000E+00`

Make a second set of measurements using the automatic null value selection.

```
VOLT:DC2:NULL:VAL:AUTO ON.
READ?
```

Typical Response:
`+0.00000000E+00,+0.01420000E+00`

[:SENSe]:VOLTage:DC2:RANGe[:UPPer]

`[:SENSe]:VOLTage:DC2:RANGe[:UPPer]` *range* selects the range for DC2 voltage measurements.

Syntax

[:SENSe]:VOLTage:DC2:RANGe[:UPPer] *range*

[:SENSe]:VOLTage:DC2:RANGe[:UPPer]? [*range*]

Parameter

Parameter	Type	Unit	Range of Value
range	NRf+	V	value | MINimum (0.1) | MAXimum (10) | DEFault (10) Query does not support *range*=value.

- To select a standard measurement range, specify range as the input signal's maximum expected current. The multimeter then selects the correct range from the following: 0.1, 1, or 10.
- Both M1412A and E1412A modes accept up to ±12.0 V as a valid input value. (Values over/under 10.0/-10.0 are rounded to 10.0.)

Query Response

range

range returns a range value to the output buffer. The currently selected voltage range is returned if DEF, MIN, or MAX is not specified. Only the ranges available with the `RANGe` command are returned. For example, if `CONFigure` sets the 10 V range, 10 V is the range returned. If a parameter is specified, *range* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- You must select a range using `VOLTage:DC2:RANGe` before specifying the resolution.
- Specifying a fixed range disables the autorange mode set by the `VOLT:DC2:RANG:AUTO OFF` command.
- The `VOLT:DC2:RANG` command overrides the range setting from a previous `CONFigure` command on the same function.
- `*RST` Condition: `VOLT:DC2:RANG 10`
- When `FUNC "VOLT:RAT"` is specified, no DC2 settings can be changed.
- The E1412A does not support this command.

- The user's manual always omits the UPPer header.

Example Set and query the DC2 voltage measurement range.

```
VOLT:DC2:RANG        Select 10 V range.
VOLT:DC2:RANG?       Query multimeter to return the present range.
```

[:SENSe]:VOLTage:DC2:RANGe:AUTO

`[:SENSe]:VOLTage:DC2:RANGe:AUTO` *`state`* enables or disables the autorange function for DC2 voltage measurements.

Syntax [:SENSe]:VOLTage:DC2:RANGe:AUTO *state*

[:SENSe]:VOLTage:DC2:RANGe:AUTO? [*state*]

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response *state*

state is a number to show whether the DC2 voltage autorange mode is enabled or disabled: "0" (OFF or ONCE) or "1" (ON). The number is sent to the output buffer. The response data type is NR1.

Comments

- You can substitute decimal values for the OFF ("0") and ON ("1") parameters.
- When autoranging is ON, the multimeter samples the input before each measurement and selects the appropriate range.
- If you explicitly select a range using `VOLTage:DC2:RANGe`, autoranging is turned OFF.
- In order to specify an aperture time of 10 μs, you must select a fixed range (e.g., `VOLT:DC2:RANG:AUTO OFF`).
- Related Commands: `CONFigure`, `VOLTage:AC:RANGe`, `VOLTage[:DC]:RANGe`, `RESistance:RANGe`
- `*RST` Condition: `VOLT:DC2:RANG:AUTO ON`
- When `FUNC "VOLT:RAT"` is specified, no DC2 settings can be changed.

- The E1412A does not support this command.

Example Disable and query the DC2 voltage autorange mode.

```
VOLT:DC2:RANG:AUTO OFF      Disable autorange.
VOLT:DC2:RANG:AUTO?         Query multimeter to return autorange mode.
```

[:SENSe]:VOLTage:DC2:RESolution

`[:SENSe]:VOLTage:DC2:RESolution` ***resolution*** selects the resolution for DC2 voltage measurements.

Syntax [:SENSe]:VOLTage:DC2:RESolution *resolution*

[:SENSe]:VOLTage:DC2:RESolution? [*resolution*]

Parameter

Parameter	Type	Unit	Range of Value
resolution	NRf+	V	value | MINimum (the best resolution) | MAXimum (the worst resolution) | DEFault Query does not support *resolution*=value.

- See Table 4-2 for resolution choices.
- When the specified value is not in the table, the input value is rounded down to the next smallest resolution. (E.g., 3.0005E-7 * *range* input is rounded to 3.0000E-7 * *range* resolution, but 2.9995E-7 * *range* input is rounded to 1.0000E-7 * *range* resolution.)

Query Response *resolution*

resolution returns a resolution value to the output buffer. The currently selected voltage resolution is returned if DEF, MIN, or MAX is not specified. If a parameter is specified, *resolution* returns the value assigned to DEF, MIN, or MAX. The response data type is NR3.

Comments

- The E1412A does not support this command.
- MINimum selects the best resolution (the smallest value) for the selected range. MAXimum selects the worst resolution (the largest value) for the selected range.

- You must select a range using VOLTage:DC2:RANGe before specifying a resolution. Also, only specify a resolution when making measurements on a fixed range. Otherwise, the resolution will change to correspond to the range selected during autoranging.
- Specify the resolution in the same units used for the measurement function.
- If autoranging is required, set the resolution using the DEF, MIN, or MAX parameter, or select a specific integration time using VOLTage[:DC2]:NPLC.
- Changing the resolution also changes the NPLC setting to the values that correspond to the specified resolution.
- When CURR[:DC]:NPLC is specified, [:SENSe]:CURRent[:DC]:APERture:ENABle is set to OFF automatically.
- Related Commands: CONFigure, VOLTage:DC2:NPLC
- When FUNC “VOLT:RAT” is specified, no DC2 settings can be changed.
- *RST Condition: Based on the *RST values for the VOLTage:DC2:NPLC command
- This command does not support the “Volt” unit but can use “V”.
- When a specified value is smaller than the MINimum value, the set value is rounded up to the MINimum value with no error notification.
- When a specified value is larger than the MAXimum value, the set value is rounded down to the MAXimum value with no error notification.
- When AutoRange is on, you can specify a resolution value only via DEF, MIN, or MAX inputs. If you input any values, it returns error -221.

Example Change and query the resolution.

`SENS:FUNC “VOLT”,“VOLT:DC2”`	*Function: DCV + DC2;*
`VOLT:DC:RANG 0.95`	*Range selected: 1 V;*
`VOLT:DC2:RANG 0.95`	*Range selected: 1 V;*
`VOLT:DC:RES 3E-07`	*Set resolution to 0.3 μV.*
`VOLT:DC2:RES 3E-07`	*Set resolution to 0.3 μV.*
`VOLT:DC2:RES?`	*Query multimeter to return the present resolution.*
`READ?`	*Place multimeter in wait-for-trigger state and make measurements; send readings to output buffer.*

[:SENSe]:VOLTage:DC2:ZERO:AUTO

Disables or enables the autozero mode for DC2 voltage measurements.

Syntax

[:SENSe]:VOLTage:DC2:ZERO:AUTO *state*

[:SENSe]:VOLTage:DC2:ZERO:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response

state

state returns the state of the autozero mode for DC2 voltage measurements. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- The E1412A does not support this command.
- ON (default): The DMM internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the DMM’s input circuitry from affecting measurement accuracy.
- OFF: The instrument uses the last measured zero measurement and subtracts it from each measurement. It takes a new zero measurement each time you change the function, range or integration time.
- ONCE: The instrument takes one zero measurement and sets autozero to OFF. The zero measurement taken is used for all subsequent measurements until the function, range or integration time is changed. If the specified integration time is less than 1 PLC, the zero measurement is taken at 1 PLC to optimize noise rejection. Subsequent measurements are taken at the specified fast (< 1 PLC) integration time.
- When `FUNC “VOLT:RAT”` is specified, no DC2 settings can be changed.
- This parameter is set to its default value after a Reset (`*RST`).

Example

Configure DC voltage ratio measurements and perform an immediate autozero. Make and read two measurements.

```
SENS:FUNC “VOLT”,“VOLT:DC2”
VOLT:DC2:ZERO:AUTO ONCE
SAMP:COUN 1
READ?
```

Typical Response:
`+1.04530000E-01,+1.04570000E-01`

[:SENSe]:ZERO:AUTO

`[:SENSe]:ZERO:AUTO` *`state`* enables or disables the autozero mode. Autozero applies to DC voltage, DC current, and 2-wire resistance measurements only. 4-wire resistance and DC voltage ratio measurements automatically enable the autozero mode.

Syntax

[:SENSe]:ZERO:AUTO *state*

[:SENSe]:ZERO:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
state	boolean		0 | OFF | ONCE | 1 | ON (default)

Query Response

state

state returns the state of the autozero mode. Returns “0” (OFF) or “1” (ON). The response data type is NR1

Comments

- The ON parameter enables autozero. This is the default parameter, which causes the multimeter to internally disconnect the input signal following each measurement and make a zero measurement. The zero reading is subtracted from the input signal reading to prevent offset voltages present on the multimeter’s input circuitry from affecting measurement accuracy.
- The OFF parameter disables autozero. In this mode the multimeter takes one zero measurement and subtracts it from all subsequent input signal measurements prior to a change in function, range or integration time. A new zero measurement is made following a change in function, range or integration time. This mode increases measurement speed because a zero measurement is not made for each input signal measurement.

- Autozero ONCE issues an immediate zero measurement and can be used to get an update on the zero measurement for a specific input signal measurement. This helps to increase measurement time since you update the zero reading without making zero measurements for every measurement.
- `*RST` Condition: `ZERO:AUTO ON` (enables autozero mode)

Example Disable autozero and query the autozero mode.

`ZERO:AUTO OFF`	*Autozero disabled.*
`ZERO:AUTO?`	*Query the autozero mode.*

STATus Subsystem

Comment The STATus system contains seven registers, four of which are under IEEE 488.2 control: the standard event status register (*ESR?), the standard event enable register (*ESE and *ESE?), the status byte register (*STB?), and the status byte enable register (*SRE and *SRE?). The operational status bit (OPR), request service bit (RQS), standard event summary bit (ESB), message available bit (MAV) and questionable data bit (QUE) in the status byte register (bits 7, 6, 5, 4, and 3 respectively) can be queried with the *STB? command. Use the *ESE? command to query the “unmask” value for the standard event status register (the bits you want logically OR’d into the summary bit). Query using decimal weighted bit values.

:STATus:PRESet

Sets all defined bits in the channel summary’s enable registers and clears all the bits in the system’s enable registers (STAT:<QUES>:ENAB). The registers are returned to their default states.

Syntax :STATus:PRESet

Comments

- The STATus:PRESet command affects only the enable register by setting all enable register bits to 0. It does not affect the “status byte” or the “standard event status”.
- PRESet does not clear any of the event registers.

:STATus:OPERation:CONDition?

Returns the value of the operational status condition register. See "Status System Register Diagram of the M1412A" for the bit definitions. The register setting is not changed by this command.

NOTE The E1412A does not have the operation data condition register.

Syntax :STATus:OPERation:CONDition?

Query Response *value*

value returns the value of the target register. It is the sum of the binary-weighted values for the set bits. The response data type is NR1 (decimal).

:STATus:OPERation:ENABle

Sets the operational status enable register. The enable register is a mask that allows true conditions in the event register to be reported in the summary bit.

NOTE The E1412A does not have the Operation Data condition register.

Syntax :STATus:OPERation:ENABle *mask*

:STATus:OPERation:ENABle?

Parameter

Parameter	Type	Unit	Range of Value
mask	NR1 or NDN		Mask. 0 to 65535 (decimal). Default is 0.

- *mask* is the sum of the binary-weighted values for the set bits.

Query Response *mask*

mask returns the current setting of the target enable register. The response data type is NR1 (decimal).

Comments

- The E1412A does not support this command.
- `STATus:OPERation:ENABle?` returns a decimal-weighted number representing the bits enabled in the operation data/signal register's enable register, signifying which bits will set OPE in the status byte.
- `STATus:OPERation:ENABle` enables (unmasks) bits in the `OPERation` data/signal register's enable register to be reported to the summary bit (setting status byte register bit 7 to true).
- The event register bits are not reported in the status bytes register unless specifically enabled.

:STATus:OPERation[:EVENt]?

Returns the value of the operational status event register. The register setting is changed by this command.

NOTE The E1412A does not have the operation data condition register.

Syntax :STATus:OPERation[:EVENt]?

Query Response *value*

value returns the current setting of the target event register. It is the sum of the binary-weighted values for the set bits. The response data type is NR1 (decimal).

Comment

- This command clears all bits in the event register when executed.

:STATus:QUEStionable:CONDition?

Returns the value of the questionable status condition register. See “Status System Register Diagram of the M1412A” for the bit definitions. The register setting is not changed by this command.

Syntax :STATus:QUEStionable:CONDition?

Query Response *value*

value returns the value of the target register. It is the sum of the binary-weighted values for the set bits. The response data type is NR1 (decimal).

:STATus:QUEStionable:ENABle

Sets the questionable status enable register. The enable register is a mask that allows true conditions in the event register to be reported in the summary bit.

Syntax :STATus:QUEStionable:ENABle *mask*

:STATus:QUEStionable:ENABle?

Parameter

Parameter	Type	Unit	Range of Value
mask	NR1 or NDN		Mask. 0 to 65535 (decimal). Default is 0.

mask is the sum of the binary-weighted values for the set bits.

Query Response *mask*

mask returns the current setting of the target enable register. The response data type is NR1 (decimal).

Comments

- `STATus:QUEStionable:ENABle` enables (unmasks) bits in the questionable data/signal register's enable register to be reported to the summary bit (setting status byte register bit 3 to true).
- The event register bits are not reported in the status bytes register unless specifically enabled.
- `STATus:QUEStionable:ENABle?` returns a decimal-weighted number representing the bits enabled in the questionable data/signal register's enable register, signifying which bits will set QUE in the status byte.

:STATus:QUEStionable[:EVENt]?

Returns the value of the questionable status event register. The register setting is changed by this command.

Syntax :STATus:QUEStionable[:EVENt]?

Query Response *value*

value returns the current setting of the target event register. It is the sum of the binary-weighted values for the set bits. The response data type is NR1 (decimal).

Comment

- This command clears all bits in the event register when executed.

SYSTem Subsystem

The `SYSTem` command subsystem includes general commands.

:SYSTem:DATE?

Gets the date of the internal clock.

Syntax :SYSTem:DATE?

Query Response *year, month, day*

Response data	Description
year	Year. 4-digit integer. Parameter data type is NR1.
month	Month. Integer from 1 to 12. Parameter data type is NR1.
day	Day. Integer from 1 to 31. Parameter data type is NR1.

:SYSTem:ERRor?

`SYSTem:ERRor?` returns the error numbers and corresponding error messages in the error queue. See “Error Messages” for details on the error numbers, messages and descriptions.

Syntax :SYSTem:ERRor?

Query Response *response*

response returns *code*, *message* which contains the error/event code and message, separated by a comma. The data type of code is NR1 and message is SRD.

Comments

- When an error is generated by the multimeter, it stores an error number and corresponding message in the error queue.

- One error is removed from the error queue each time the `SYSTem:ERRor?` command is executed. The errors are cleared in a first-in, first-out order. This means that if several errors are waiting in the queue, each `SYSTem:ERRor?` query returns the oldest (not the most recent) error. That error is then removed from the queue.
- When the error queue is empty, subsequent `SYSTem:ERRor?` queries return +0,“No error”. To clear all errors from the queue, execute the `*CLS` command.
- If the queue overflows, the last error is replaced with -350,“Queue overflow”. No additional errors are accepted by the queue until space becomes available.

Example Read the error queue.

`SYST:ERR?`	*Query the error queue.*

:SYSTem:LFRequency

Selects the line frequency.

Syntax :SYSTem:LFRequency *frequency*

:SYSTem:LFRequency? *frequency*

Parameter

Parameter	Type	Unit	Range of Value
frequency	NRf+		value | MINimum (50) | MAXimum (60) | DEFault (60) Query does not support *frequency*=value.

- The E1412A does not support the “DEFault” parameter.

Query Response *frequency*

frequency returns the present setting: 50 or 60. The response data type is NR1.

Comments

- The feature of the command is the same as `CALibration:LFRequency`.
- `*SAV`/`*RCL` does not save/recall this parameter (the same as Truevolt).
- The setting made with this command is not changed by a power off or the `*RST` command.

- At power on, the DMM sets the line frequency to the actual line frequency of either 50 Hz or 60 Hz (400 Hz is detected as 50 Hz).

:SYSTem:MODule[n]:MODel?

Returns the model number of the specified module.

Syntax :SYSTem:MODule[n]:MODel?

Query Response *number*

number returns the model number. The response data type is SRD. It returns “E1412A” when an instrument is running in the E1412A-compatible mode, otherwise it returns “M1412A”.

:SYSTem:MODule[n]:SERial?

Returns the serial number of the specified module.

Syntax :SYSTem:MODule[n]:SERial?

Query Response *serial*

serial returns a serial number. The response data type is SRD.

:SYSTem:MODule[n]:SLOT?

Returns the slot number of the specified module.

Syntax :SYSTem:MODule[n]:SLOT?

Query Response *slot*

slot returns a slot number. The response data type is NR1.

:SYSTem:MODule[n]:UPTime?

Returns the length of time that the instrument has been running since the last power-on.

Syntax :SYSTem:MODule[n]:UPTime?

Query Response *days, hours, minutes, seconds*

The response indicates the length of time for each unit respectively. Each response data type is NR1.

Comment

- This is typically used to verify that the instrument is warmed up sufficiently before calibration.

Example `SYST:MOD:UPT?` *Typical return +8,+2,+13,+50*

:SYSTem:SET

Sets the instrument state as defined by the data returned by the `SYSTem:SET?` query.

Syntax :SYSTem:SET *block*

:SYSTem:SET?

Parameter

Parameter	Type	Unit	Range of Value
block	Block		#nN<instrument state>

Query Response *block*

The block data begins with a leading # character. Given the format #nN<instrument state>, the first digit, n, after the # indicates the number of digits in N. The number N indicates the length of the data.

Comments

- The block data is set by the `SYSTem:SET` command.
- Refer to the section 8.7.9 of IEEE 488.2-1992.

:SYSTem:TIME?

Gets the time of the internal clock.

Syntax :SYSTem:TIME?

Query Response *hour, minute, second*

Response data	Description
hour	Hour. Integer from 0 to 23. Parameter type is NR1.
minute	Minute. Integer from 0 to 59. Parameter type is NR1.
second	Second. Integer from 0 to 59. Parameter type is NR1.

:SYSTem:VERSion?

Returns the version of the SCPI standard.

Syntax :SYSTem:VERSion?

Query Response *response*

response returns the version of the SCPI standard. For example, 1999.0. The response data type is NR2.

Comment

- The information returned is in the format “YYYY.R” where “YYYY” is the year and “R” is the revision number within that year.

TRIGger Subsystem

:ABORt

The ABORt command aborts a measurement in progress, returning the instrument to the trigger idle state.

Syntax :ABORt

Comments

- ABORt does not affect any other settings of the trigger system. When the INITiate command is sent, the trigger system will respond as it did before ABORt was executed.
- Related Commands: INITiate, TRIGger
- *RST Condition: After an *RST command, the multimeter acts as though an ABORt has occurred.

Example Abort a measurement.

```
CONF:VOLT:DC        Function: DC voltage.
TRIG:SOUR EXT       Trigger source is external trigger.
INIT                Place multimeter in wait-for-trigger state.
ABOR                Abort waiting for a trigger and place multimeter in idle state.
```

:INITiate[:IMMediate]

`INITiate[:IMMediate]` places the multimeter into the wait-for-trigger state. When a trigger is received, readings are placed in the multimeter internal memory.

Syntax :INITiate[:IMMediate]

Comments

- In the E1412A, commands sent after `INIT` are blocked when the initiated Trigger system returns to idle.
- The M1412A does not wait for the completion of initialization executed by `INIT` command. You can use `*OPC?` command to wait its completion before next command.
- After the trigger system is initiated using `INITiate`, use the `TRIGger` command subsystem to control the behavior of the trigger system.
- If `TRIGger:SOURce` is `IMMediate`, measurement starts and readings are stored in internal memory as soon as `INITiate` is executed. Readings stored in memory from previous commands are replaced by the new readings.
- To transfer readings from memory to the output buffer, use the `FETCh?` command.
- If `TRIGger:SOURce` is not `IMMediate`, measurement starts as soon as a trigger is received either from the external SMB connector, the PXIe bus backplane (TTL trigger lines), or a BUS trigger.
- The `READ?` command executes `INITiate` implicitly. The `MEASure` subsystem commands execute `READ?` implicitly. Executing `READ?` outputs data directly to the output buffer, bypassing the multimeter's internal memory.
- Related Commands: `CONFigure`, `FETCh?`, `READ?`
- `*RST` Condition: `*RST` places the multimeter in the idle state.

Example Place the multimeter in the wait-for-trigger state.

`CONF:VOLT:DC`	*Function: DC voltage.*
`TRIG:SOUR EXT`	*Trigger source is the external SMB on the multimeter.*
`INIT`	*Place multimeter in wait-for-trigger state; store readings in internal memory when external trigger is received.*
`FETC?`	*Place readings in output buffer.*
`INIT`	*You must re-initiate the wait-for-trigger state after each trigger cycle.*

TRIGger

The `TRIGger` command subsystem controls the behavior of the trigger system. The subsystem can control:

- The number of triggers that occur before the multimeter returns to the idle state (`TRIGger:COUNt`).
- The delay between a trigger and measurement (`TRIGger:DELay`).
- The source of the trigger (`TRIGger:SOURce`).

:TRIGger:COUNt

`TRIGger:COUNt` *`number`* sets the number of triggers to be issued.

Syntax :TRIGger:COUNt *number*

:TRIGger:COUNt? [*number]*

Parameter

Parameter	Type	Unit	Range of Value
number	NRf+		value | MINimum (1) | MAXimum (2,000,000) | DEFault (1) Query does not support *number*=value and INFinity.

- The E1412A does not support the “DEFault” parameter.
- The E1412A’s maximum count is 50,000.

Query Response *number*

number returns one of the following numbers to the output buffer:

- The present sample count (2,000,000) if a parameter is not specified.
- If a parameter is specified, *number* returns the value assigned to DEF, MIN, or MAX.
- When `INFinity` is specified, it returns 9.9E37 (Inf.).

The response data type is NR3.

Comments

- MINimum sets the trigger count to 1. MAXimum sets it to 2,000,000.
- If MAX or 2,000,000 is specified for number, the command executes without error.
- A number > 2,000,000 returns error -222, “Data out of range”.
- The `TRIGger:COUNt` value `* SAMPle:COUNt` value must be less than the value listed in Table 3-22. If the product does not satisfy this condition, it will return error on processing the `INITiate` command.
- `CONFigure` and `MEASure` set the trigger count to 1.
- `*RST` Condition: `TRIG:COUN 1`

Example Set the trigger count.

```
CONF:VOLT:DC        Function: DC voltage.
TRIG:SOUR EXT       Trigger source is “Trig” SMB on multimeter front panel.
TRIG:COUN 10        Multimeter will accept 10 external triggers
                     (one measurement is taken with each trigger).
READ?               Place multimeter in wait-for-trigger state;
                    make measurement when external trigger is received;
                    send readings to output buffer.
```

Query the trigger count.

```
TRIG:COUN?          Query multimeter to return trigger count.
```

:TRIGger:DELay

TRIGger:DELay *delay* sets the delay time between receipt of a trigger and the start of the measurement.

NOTE This delay also occurs between each sample when **SAMP:COUN** > 1. See the triggering process diagram.

Syntax

:TRIGger:DELay *delay*

:TRIGger:DELay? [*delay*]

Parameter

Parameter	Type	Unit	Range of Value
delay	NRf+	s	value | MINimum (0) | MAXimum (3600) | DEFault (auto) Query does not support *delay*=value.

- The E1412A does not support the “DEFault” parameter.

Query Response

delay

delay returns one of the following numbers to the output buffer:

- The current trigger delay (0 through 3600 seconds) if a parameter is not specified.
- If a parameter is specified, *delay* returns the value assigned to DEF, MIN, or MAX.

The response data type is NR3.

Comments

- The trigger delay is inserted between the trigger and each measurement.
- If a trigger delay is specified using the **TRIG:DEL *delay***, **TRIGger:DELay:AUTO** is turned OFF.
- The multimeter selects an automatic delay if you do not specify a trigger delay (see the “:TRIGger:DELay:AUTO” command).
- ***RST** Condition: **TRIGger:DELay:AUTO ON**

- The resolution for each input value is shown in the following table.

Input	Resolution
< 1 s	1 μs
1 - 10 s	10 μs
10 - 100 s	100 μs
100 - 1000 s	1 ms
1000 - 3600 s	10 ms

Example Set the trigger delay.

`TRIG:DEL .002` *Wait 2 ms between trigger and start of measurement.*

Query the trigger delay.

`TRIG:DEL?` *Query multimeter to return trigger delay.*

:TRIGger:DELay:AUTO

`TRIGger:DELay:AUTO` *`mode`* enables or disables a trigger delay automatically determined by the present function, range, NPLC setting, AC filter setting, and integration time (see Table 3-23 to Table 3-30). The trigger delay specifies the period between the trigger signal and the start of the measurement (and between each sample when `SAMPle:COUNt` > 1).

Syntax :TRIGger:DELay:AUTO *mode*

:TRIGger:DELay:AUTO?

Parameter

Parameter	Type	Unit	Range of Value
mode	boolean		0 | OFF | 1 | ON (default)

Query Response *mode*

mode returns the state of the trigger delay mode. Returns “0” (OFF) or “1” (ON). The response data type is NR1.

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- The trigger delay is inserted between the trigger and each measurement.
- When a trigger delay is specified using the `TRIGger:DELay` *`delay`* command, `TRIG:DEL:AUTO` is turned OFF.
- When a `CONFigure` or `MEASure` command is received, `TRIG:DEL:AUTO` is turned ON.
- `*RST` Condition: `TRIG:DEL:AUTO ON`
- When you set DC Voltage & DC2 Voltage or DC Current & DC2 Voltage as the sense function, the DC2 Voltage measurement delay value is set according to the DC Voltage or DC Current automatic delay value.

Example Disable the automatic trigger delay.

`TRIG:DEL:AUTO OFF`	*Disable automatic trigger delay.*

Query the trigger delay mode.

`TRIG:DEL:AUTO?`	*Query multimeter to return trigger delay mode.*

:TRIGger:SOURce

`TRIGger:SOURce` *`source`* configures the trigger system to respond to the specified source.

The following sources are available:

- BUS: `*TRG` common command.
- EXT: The multimeter’s External Trigger SMB connector (triggers on the negative or falling edge of the ±5 V TTL input signal).
- IMMediate: The trigger system is always true.
- TTLTrg0 - TTLTrg7: Trigger source is PXIe bus trigger line 0 through 7.

Syntax :TRIGger:SOURce *source*

:TRIGger:SOURce?

Parameter

Parameter	Type	Unit	Range of Value
source	CPD		BUS | EXTernal | TTLTrg0 - TTLTrg7 | PXI0 - PXI7 | IMMediate (default)

Query Response *source*

source returns “BUS”, “EXT”, “IMM”, “PXI0 - 7” or “TTLT0 - 7” to show the current trigger source. The response data type is CRD.

Comments

- The `TRIGger:SOURce` command only selects the trigger source. You must use the `INITiate` command to place the multimeter in the wait-for-trigger state. (The `MEASure` command automatically executes an `INITiate` command.)
- `TRIGger:SOURce EXT` uses the multimeter’s front panel “Trig” SMB connector as the trigger source. The multimeter is triggered on the falling (negative-slope) edge of a 5 V TTL input signal (maximum input is +5 V to the front panel SMB connector).
- `TRIGger:SOURce IMMediate` causes a trigger to occur immediately provided the multimeter is placed in the wait-for-trigger state using `INITiate`, `READ?` or `MEAS?`.
- When the `*TRG` common command is executed and the multimeter is not in the wait-for-trigger state, a “Trigger ignored” error is generated.
- The `CONFigure` and `MEASure` command subsystems automatically set the trigger source to `TRIG:SOUR IMM`.
- The `READ?` command cannot be used if the trigger source is `TRIG:SOUR BUS`.
- Related Commands: `INITiate`, `READ?`, `MEAS?`
- `*RST` Condition: `TRIG:SOUR IMM`

Example Set the sample source.

`CONF:VOLT:DC`	*Function: DC voltage.*
`TRIG:SOUR EXT`	*Trigger source is external SMB on multimeter front panel.*
`TRIG:COUN 10`	*Multimeter will accept 10 external triggers.*
`READ?`	*Place multimeter in wait-for-trigger state; make measurements when external trigger is received; send reading to output buffer.*

Query the trigger source.

`TRIG:SOUR?`	*Query multimeter to return trigger source setting.*

Default Values of Parameters

Table 6-2 Default Parameters List

Setting Parameter	Factory Default Value	*RST value (←: the same as on the left)
Sense Function SENS:FUNC?	“VOLT”	←
Auto Range SENS::RANG:AUTO?	1	←
Aperture Enabled SENS::APER:ENAB?	0	←
Aperture SENS::APER?	DC measurements: 0.2 Freq. and Per.: 0.1	←
NPLC SENS::NPLC?	10	←
Auto Zero Enabled SENS:ZERO:AUTO?	1	←
Frequency/Period Auto Timeout Enabled SENS:<FREQ|PER>:TIM:AUTO?	0	Not Changed
Input Impedance INP:IMP:AUTO?	0	←
AC Input Filter DET:BAND?	20	←
Null Function CALC:NULL OFFS? SENS::NULL:STAT? SENS::NULL:VAL? SENS::NULL:VAL:AUTO?	State: 0 Value: 0.0 Auto: 1	←

Setting Parameter	Factory Default Value	*RST value (←: the same as on the left)
Offset Compensation SENS:<RES|FRES>:OCOM?	0	←
Math Function CALC:STAT?	0	←
DB Reference CALC:DB:REF?	0.0	←
DBM Offset CALC:DBM:OFFS?	600	Not changed
Limit Values CALC:LIM:LOW? CALC:LIM:UPP?	0.0	←
Trigger Count TRIG:COUN?	1	←
Trigger Source TRIG:SOUR?	IMM	←
Auto Trigger Delay TRIG:DEL:AUTO?	1	←
Sample Count SAMP:COUN?	1	←
Trigger Slope OUTP:TRIG:SLOP?	NEG	←
Sample Source SAMP:SOUR?	IMM	←
Sample Timer SAMP:TIM?	1	←
Data Format FORM:DATA?	"ASC, 9" for M1412A mode. "ASC, 8" for E1412A mode.	←

Setting Parameter	Factory Default Value	*RST value (←: the same as on the left)
Byte Order FORM:BORD?	NORM	Not changed
Line Frequency CAL:LFR? SYST:LFR?	60	Not changed

7 Error Messages

This chapter lists the error messages for the M1412A. The error code is given (e.g., -101) followed by the associated error message and a description of what the error message means.

Execution Errors

-101 `Invalid character`

An invalid character was found in the command string. You may have inserted a character such as #, $, or % in the command header or within a parameter.

Example: `CONF:VOLT#DC`

-102 `Syntax error`

Invalid syntax was found in the command string. You may have inserted a blank space before or after a colon in the command header, or before a comma.

Example: `SAMP:COUN ,1`

-103 `Invalid separator`

An invalid separator was found in the command string. You may have used a comma instead of a colon, semicolon, or blank space, or you may have used a blank space instead of a comma.

Example: `TRIG:COUN,1` or `CONF:FREQ 1000 0.1`

-104 `Data type error`

An improper parameter type was found in the command string. You may have specified a number where a string was expected or vice versa. The error is a general message. It has been replaced by other errors in M1412A. For example, `TRIG:COUN A` generates a -224,"Illegal parameter value" error.

-105 `GET not allowed`

A Group Execute Trigger (GET) is not allowed within a command string.

-108 `Parameter not allowed`

More parameters were received than expected for the command. You may have entered an extra parameter, or you added a parameter to a command that does not accept a parameter.

Example: `READ? 10`

-109 `Missing parameter`

Fewer parameters were received than expected for the command. You omitted one or more parameters that are required for the command.

Example: `SAMP:COUN`

-112 `Program mnemonic too long`

A command header was received that contained more than the maximum 12 characters allowed.

Example: `CONFIGURATION:VOLT:DC`

A string contains more than the maximum 12 characters allowed in the `CALibration:SECure:CODE` command.

-113 `Undefined header`

A command was received that is not valid for this multimeter. You may have misspelled the command or it may not be a valid command. If you are using the short form of the command, remember that it may contain up to four letters.

Example: `TRIGG:COUN 3`

-121 `Invalid character in number`

An invalid character was found in the number specified for a parameter value.

Example: `STAT:QUES:ENAB #B01010102`

-123 `Exponent too large`

A numeric parameter was found whose exponent was larger than 32,759.

Example: `TRIG:COUN 1E34000`

-124 `Too many digits`

A numeric parameter was found whose mantissa contained more than 255 digits, excluding leading zeros.

In practice, no error is generated because the tail of the parameter number is cutoff.

-128 `Numeric data not allowed`

A numeric parameter was found where a character string was expected. Check the list of parameters to verify you have used a valid parameter type.

Example: `TRIG:SOUR 1`

-131 `Invalid suffix`

A suffix was incorrectly specified for a numeric parameter. You may have misspelled the suffix.

Example: `TRIG:DEL 0.5 SECS`

-138 `Suffix not allowed`

A suffix was received following a numeric parameter that does not accept a suffix.

Example: `SAMP:COUN 1 SEC` (SEC is not a valid suffix).

-148 `Character data not allowed`

A character string was received where a numeric parameter was expected. Check the list of parameters to verify that you have used a valid parameter type.

Example: `CAL:LFR XYZ`

-151 `Invalid string data`

An invalid character string was received. Check to see if you have enclosed the character string in single or double quotes.

Example: `CAL:STR ’NEXT CAL DUE 10/4/1996` (the ending quote is missing).

-158 `String data not allowed`

A character string was received but is not allowed for the command. Check the list of parameters to verify that you have used a valid parameter type.

Example: `CALC:STAT ‘ON’` or `TRIG:COUN ‘150’`

-160 to -168 `Block data errors`

The multimeter does not accept block data.

-170 to -178 `Expression errors`

The multimeter does not accept mathematical expressions.

-211 `Trigger ignored`

`*TRG` was received but the trigger was ignored. Make sure the multimeter is in the "wait-for-trigger" state before issuing a trigger, and make sure the correct trigger source is selected.

-213 `Init ignored`

An `INITiate` command was received but could not be executed because a measurement was already in progress. Send a Device Clear command to halt a measurement in progress and place the multimeter in the "idle" state.

-214 `Trigger deadlock`

A trigger deadlock occurs when the trigger source is BUS and a `READ?` command is received.

-221 `Settings conflict`

This error can be generated in one of the following situations:

You sent a `CONFigure` or `MEASure` command with autorange enabled and with a fixed resolution.

Example: `CONF:VOLT:DC DEF,0.1`

For example, dB measurements are not allowed with 2-wire resistance. The math state is turned off as a result of this condition.

-222 `Data out of range`

A numeric parameter value is outside the valid range for the command.

Example: `TRIG:COUN -3`

-223 `Too much data`

A character string was received but could not be executed because the string length was more than 12 characters. This error can be generated by the `CALibration:STRing` command.

In practice, no error is generated because redundant data is trimmed.

-224 `Illegal parameter value`

A discrete parameter was received that is not a valid choice for the command. You may have used an invalid parameter choice.

Examples: `CALC:FUNC SCALE` (SCALE is not a valid choice), `SAMP:COUN ON` (ON is not a valid choice), or `TRIG:COUN A.`

-230 `Data corrupt or stale`

A `FETCh?` command was received but the internal memory for readings was empty. The reading retrieved may be invalid or settings may have been changed since the data was taken.

-310 `System error`

The multimeter cannot execute the settings.

-330 `Self-test failed`

The multimeter's complete self-test failed from the remote interface (`*TST?` command). In addition to this error, more specific self-test errors are also reported.

-350 `Queue overflow`

The error queue is full because more than 20 errors have occurred. No additional errors are stored until you remove errors from the queue. The error queue is cleared when the power is turned off or after a `*CLS` (clear status) command has been executed.

-410 `Query INTERRUPTED`

A command was received that sends data to the output buffer, but the output buffer contained data from a previous command (the previous data is not overwritten). The output buffer is cleared when the power is turned off or after a `*RST` (reset) command has been executed.

-420 `Query UNTERMINATED`

The multimeter was addressed to talk (e.g., to send data over the interface), but a command has not been received that sends data to the output buffer.

For example, you may have executed a `CONFigure` command (which does not generate data) and then attempted an ENTER statement to read data from the remote interface.

E1412A returns -113 and -420 when you send an improper query command but M1412A returns only -113 (e.g., `CONF:PP?`).

-430 `Query DEADLOCKED`

A command was received that generates too much data to fit in the output buffer, and the input buffer is also full. Command execution continues, but all data is lost.

-440 `Query UNTERMINATED after indefinite response`

The `*IDN?` command must be the last query command within a command string.

Example: `*IDN?;:SYST:VERS?`

501 `Isolator UART framing error`

502 `Isolator UART overrun error`

511 `Unexpected reset occurred`

The outguard circuit recognized the inguard circuit reset (probably due to an abnormal input condition). This error causes the instrument to go to the power-on setting, and the previous setting is lost.

521 `Input buffer overflow`

522 `Output buffer overflow`

531 `Insufficient memory`

There is not enough memory to store the requested number of readings in internal memory using the `INITiate` command. The product of the sample count (`SAMPle:COUNt`) and the trigger count (`TRIGger:COUNt`) must not exceed 512 readings.

532 `Cannot achieve requested resolution`

The multimeter cannot achieve the requested measurement resolution. You may have specified an invalid resolution in the `CONFigure` or `MEASure` command.

540 `Cannot use overload as math reference`

The multimeter cannot store an overload reading (9.90000000E+37) as the math reference for null or dB measurements. The math state is turned off as a result of this condition.

Calibration Errors

The following errors indicate failures that may occur during a calibration. The most common errors have descriptions here.

701 `Cal security disabled by jumper`

The calibration security feature has been disabled with a jumper inside the multimeter. When applicable, this error will occur at power-on to warn you that the multimeter is unsecured.

702 `Cal secured`

The multimeter is secured against calibration.

703 `Invalid secure code`

An invalid calibration security code was received when attempting to unsecure or secure the multimeter. You must use the same security code to unsecure the multimeter as was used to secure it, and vice versa. The security code may contain up to 12 alphanumeric characters. The first character must be a letter.

704 `Secure code too long`

A security code was received that contained more than 12 characters.

705 `Cal aborted`

A calibration in progress is aborted when you send a Device Clear command to the multimeter.

706 `Cal value out of range`

The specified calibration value (`CAL:VALue`) is invalid for the current function and range.

707 `Cal signal measurement out of range`

The specified calibration value (`CAL:VALue`) does not match the signal applied to the multimeter.

708 `Cal signal frequency out of range`

The input signal frequency for an AC calibration does not match the required input frequency for calibration.

709 `No cal for this function or range`

You cannot perform calibrations for AC current, period, ratio, or on the 100 MΩ range.

710 `Full scale correction out of range`

720 `Cal DCV offset out of range`

721 `Cal DCI offset out of range`

722 `Cal RES offset out of range`

723 `Cal FRES offset out of range`

8 Special Functions and Range Commands

This chapter provides descriptions of the device special functions and range commands available for the M1412A.

The M1412A multimeter is designed so that the default mode of operation will deliver high accuracy readings with a minimum of programming effort. However, many applications require high-speed measurements.

This chapter discusses two topics:

- Special non-SCPI function (F1, F2, F3, and F4) and range (R1, R2, R3, R4, R5, R6, and R7) commands used to speed up measurement setup.
- How to increase measurement speed where reduced reading accuracy is acceptable.

:F1 to :F4 and :R1 to :R7

The M1412A multimeter has special function and range commands for DCV, DCI, 2-wire resistance (RES) and 4-wire resistance (FRES) shown in the following table. ACV, ACI, frequency, and period functions are not supported with these special commands.

Table 8-1 Range

Function	R1	R2	R3	R4	R5	R6	R7
F1 (DCV)	0.1 V	1 V	10 V	100 V	300 V	*1	*1
F2 (DCI)	0.01 A	0.1 A	1 A	3 A	*2	*2	*2
F3 (RES)	100 Ω	1 kΩ	10 kΩ	100 kΩ	1 MΩ	10 MΩ	100 MΩ
F4 (FRES)	100 Ω	1 kΩ	10 kΩ	100 kΩ	1 MΩ	10 MΩ	100 MΩ

*1 Invalid ranges

*2 Will return “Out of range” error

These special commands act like a `[:SENSe]:` command to change a function or range. The range command acts only on the current function. For example, if the current function is DCV and its range is 10 V, sending the range command `R2` changes the DCV range to 1 V but does not affect the DCI, RES, or FRES ranges. To also change the 2-wire resistance range to the `R2` setting, you must send the commands `F3` and `R2`. First, `F3` changes the current function from DCV to RES, and then `R2` sets the range to 1 kΩ. Sending `F1` returns the function to DCV and to the range and state to which it was last set prior to the `F3` command.

The following tables show equivalent `[:SENSe]:` commands for the special commands. You can save approximately three (3) milliseconds by using an `F1` - `F4` special function command instead of changing function with the equivalent SCPI `[:SENSe]:` function command.

Special Command	Equivalent [:SENSe]: SCPI Command
F1	[:SENSe]:FUNC “VOLT[:DC]”
F2	[:SENSe]:FUNC “CURR[:DC]”
F3	[:SENSe]:FUNC “RES”
F4	[:SENSe]:FUNC “FRES”

The special range commands affect the currently configured function. You can save approximately five (5) milliseconds by using an `R1` - `R7` special range command instead of changing the range with the equivalent SCPI `[:SENSe]:` range command.

Special Command	Equivalent [:SENSe]: SCPI Command
R1	[:SENSe]:VOLT[:DC]:RANG 0.1 [:SENSe]:CURR[:DC]:RANG 0.01 [:SENSe]:RES:RANG 100 [:SENSe]:FRES:RANG 100
R2	[:SENSe]:VOLT[:DC]:RANG 1 [:SENSe]:CURR[:DC]:RANG 0.1 [:SENSe]:RES:RANG 1E3 [:SENSe]:FRES:RANG 1E3
R3	[:SENSe]:VOLT[:DC]:RANG 10 [:SENSe]:CURR[:DC]:RANG 1 [:SENSe]:RES:RANG 10E3 [:SENSe]:FRES:RANG 10E3
R4	[:SENSe]:VOLT[:DC]:RANG 100 [:SENSe]:CURR[:DC]:RANG 3 [:SENSe]:RES:RANG 100E3 [:SENSe]:FRES:RANG 100E3
R5	[:SENSe]:VOLT[:DC]:RANG 300 CURR[:DC] DOES NOT APPLY [:SENSe]:RES:RANG 1E6 [:SENSe]:FRES:RANG 1E6
R6	VOLT[:DC] DOES NOT APPLY CURR[:DC] DOES NOT APPLY [:SENSe]:RES:RANG 10E6 [:SENSe]:FRES:RANG 10E6
R7	VOLT[:DC] DOES NOT APPLY CURR[:DC] DOES NOT APPLY [:SENSe]:RES:RANG 100E6 [:SENSe]:FRES:RANG 100E6

M1412A Resolution Using Special Functions and Ranges

Resolution remains a function of the NPLC parameter set at the time a special function or range is used. The NPLC setting is fixed throughout use of the special functions and ranges unless you change the setting with the `[:SENSe]::NPLC` command or configure the multimeter with the `CONFigure` command using a resolution that changes the NPLC setting. The resolution will track the NPLC setting as shown in Table 4-2, Table 4-3, and Table 4-4. The following table shows range and NPLC settings for power-on and after a module reset. Changing a range within one function does not place other functions at that range setting. Each function operates independently.

Special Function	Power-on State	*RST State
F1 (DCV)	10 V (R3), NPLC = 10	300 V (R5), NPLC = 10
F2 (DCI)	1 A (R3), NPLC = 10	1 A (R3), NPLC = 10
F3 (RES)	1 kΩ (R2), NPLC = 10	1 kΩ (R2), NPLC = 10
F4 (FRES)	1 kΩ (R2), NPLC = 10	1 kΩ (R2), NPLC = 10

NOTE

See Table 4-2, Table 4-3, and Table 4-4 in this chapter to determine what resolution will result following a special function or special range change. The NPLC setting remains fixed for each function during execution of the special function and range commands (e.g., may differ from function to function).

Example Assume the power-on state where the multimeter function is DC Voltage, 10 V range, with an NPLC setting of 10 PLCs providing 10 μV resolution (see Table 4-2). Use the special range command R5 to change the DC Voltage range to 300 V. The NPLC setting remains at 10 PLCs providing a resolution of 1 mV (see Table 4-2). Use the special function command F3 to change the function to 2-Wire Resistance. The range goes to the resistance power-on state (1 kΩ for 2-Wire Resistance, NPLC = 10); it does not change with the previous DCV R5 command. NPLC remains at 10 PLCs providing resolution of 1 mΩ. The special range commands do not affect other functions except in the F3 (RES) and F4 (FRES) function changes. Range changes on F3 cause the same range change on F4 and vice versa.

9 Differences Between the M1412A and E1412A

This chapter describes the differences between the M1412A and E1412A.

The SCPI Service Manager of the M1412A works with 2 modes. For the following functions, there are differences between the M1412A and E1412A.

Calculate Function

Null Function

The M1412A has `SENS::NULL` functions. The null value can be set for each sense function. When you use `CALC:NULL` as an E1412A style, each sense function's `SENS::NULL` setting are overwritten.

Sense Function

Ratio

When `SENS:FUNC VOLT:RAT` is specified, a parameter change by sending the `SENS:VOLT:DC` subsystem is regarded as a Ratio parameter change. This changes both DC and DC2 setting parameters as coupled in the E1412A. The M1412A adds `SENS:VOLT:DC2` subsystem commands as an original feature of M1412A. When you use the `SENS:VOLT:DC2` subsystem, only DC2 setting parameters are modified.

NPLC/Resolution

The E1412A only accepts some discrete representative points for NPLC (e.g., 0.002, 0.02, 0.2, 1 ...), but the M1412A accepts integer values and decimal values like 0.xxx (0.xxx has 100 ns resolution).

When you specify the instrument to the E1412A-compatible mode, the value set for NPLC will not be adjust to the E1412A representative points in the Range-Resolution table.

When you specify Resolution in the E1412A-compatible mode, NPLC is set to match the table. This behavior is asymmetric.

When you specify NPLC values that do not exist in the E1412A Range-Resolution table, Resolution will be set as the minimum value that exceeds the specified value. (E.g., when you specify 2 PLC for NPLC values with E1412A-compatible mode, Resolution will be set to the value corresponding to 10 PLCs.)

NPLC/Aperture Coupling

In the E1412A, the values of NPLC and Aperture are coupled, and a change in one value affects the other value.

The M1412A decouples them. These values are independent and can be switched with the `SENS::APERture:ENABle` command.

Aperture Value

The M1412A's Aperture range is:
500 ns to 16.7 ms (60 Hz) or 20 ms (50 Hz) with 500 ns resolution
16.7 ms (60 Hz) or 20 ms (50 Hz) to 2.0 s with 16.7 ms (60 Hz) or 20 ms (50 Hz) resolution.

MIN|MAX value of Aperture is changed whether the instrument is in the E1412A-compatible mode or not.

Resolution Input Value

The E1412A's `SENS::RESolution` command is defined with the following input specifications:

- It accepts Inf (9.9E37) value. When you specify a value smaller than the minimum input range, it is rounded up to the minimum acceptable value, and +532 error is returned.

  For the M1412A case, the specification is changed as the below:

- It refuses Inf (9.9E37) value. When you specify a value smaller than the minimum input range, it is rounded up to the minimum acceptable value, and no error is returned.

Supported Ranges

The M1412A supports lower ranges in DCI and RES than the E1412A. For the performance compatibility of AutoRange, the E1412A-compatible mode does not use these ranges.

DC2

The M1412A allows DCV measurement on the Sense terminal independently with DCV or DCI measurement on DCV and DCI terminals. (We call the DC2 function for this Sense terminal DCV measurement.)

The `SENS:VOLT:DC2` subsystem is supported in the M1412A SCPI. The DC2 measurement setting does not have any influence on conventional E1412A Sense terminal measurements unless the above subsystem commands are used explicitly. (For `FRES`, `RATio`)

Trigger System

Trigger Delay and Sampling

The M1412A adopts the `SAMPle:SOURce` command that is used in Truevolt.

When `SAMP:SOUR IMM` is specified, the sampling behavior is the same as the E1412A (the delay specified for Trigger Delay will be applied for each sampling measurement). When `SAMP:SOUR TIM` is specified, the delay specified for Trigger Delay is applied only once (at the start of sampling). Each measurement will be taken at the interval specified in `SAMP:TIM` or Aperture, whichever is longer.

TTLTrg

`TTLTrg` can be replaced with PXI. `TRIG:SOUR TTLTrg<n>` and `TRIG:SOUR PXI<n>` are treated as equivalent.

ABORt Subsystem

The E1412A only accepts the Abort command in the "wait-for-trigger" state when the trigger source is BUS. The M1412A can be aborted from the Trigger subsystem with any trigger source and in any phase, such as waiting for Trigger Delay.

Input Buffer

The E1412A has an input buffer and an output buffer, and the input buffer can contain 512 readings. The M1412A has a 1k point-block RAM buffer for storing internal memory, and the M1412A uses DMA when the amount of measurement data exceeds the size of the buffer. Users do not need to send `FETC?` periodically.

Value Format

The E1412A returns measurement result values in the format below:

<- MEAS?
-> 1.2345678E-03 (if the resolution is 6.5 digits or 5.5 digits)
-> 1.23460E-03 (if the resolution is 4.5 digits)

The M1412A supports E1412A mode and M1412A mode.

E1412A mode

<- MEAS?
-> 1.2345678E-03 (the length is always 8, regardless of the resolution)
<- FORM:DATA?
-> ASC,8

M1412A mode (same as 34470A, in this case)

<- MEAS?
-> 1.23456789E-03 (the length is always 9, regardless of the resolution)
<- FORM:DATA?
-> ASC,9

Users can change the length of ASCII-format data with the following command, whether or not the E1412A mode is used.

<- FORMat:DATA ASC,9

`FORMat:DATA` also supports REAL, 64. If this is specified, the returned value is formatted as a 64-bit floating point number. (An ASCII-based stream cannot parse the value correctly.)

INITiate Command

The E1412A's `INITiate` command is a sequential command: The processing of commands that follow `INITiate` will be blocked until the Trigger system returns to an idle state. The M1412A's `INITiate` command is an overlapped command: After the Trigger system is put into the "wait-for-trigger" state, subsequent commands are processed without waiting for the Trigger system to finish.

When you want to use the `INITiate` command like E1412A, "`INIT;*OPC?`" is useful.

Status Subsystem

Status Register

The E1412A only supports the questionable register as a status register.

The M1412A supports both the operation register and questionable register.

Status System Diagram

Status Byte

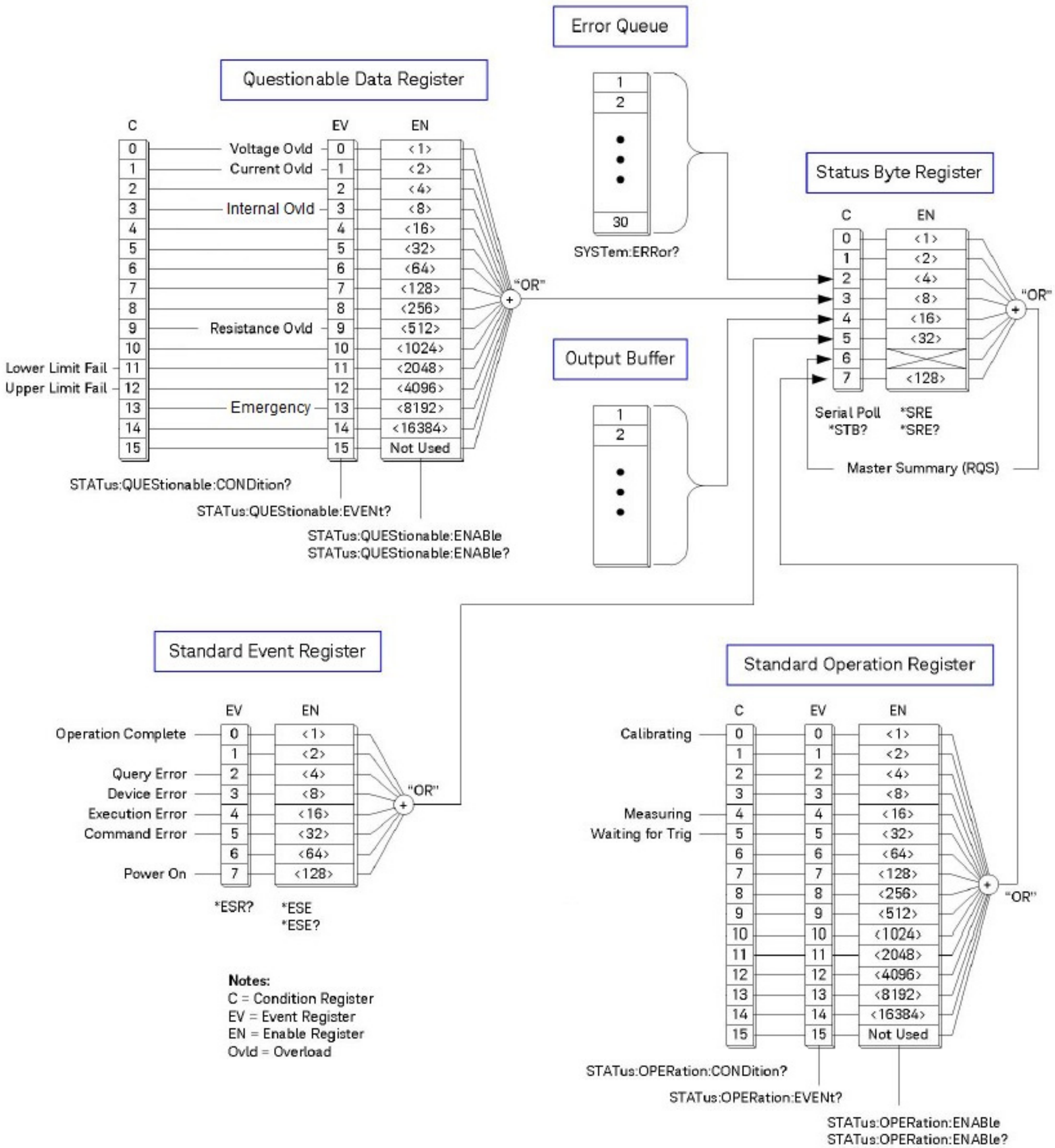
Status byte bits are turned off or on (0 or 1) to represent the instrument's operation status. When you execute a serial poll, an external computer (controller) reads the contents of the status byte and responds accordingly. When an unmasked status bit is set to "1", the instrument sends an SRQ to the controller, causing the controller to perform an interrupt service routine.

The status byte register can be read with either a serial poll or the `*STB?` query command. Serial poll is a low-level GPIB command.

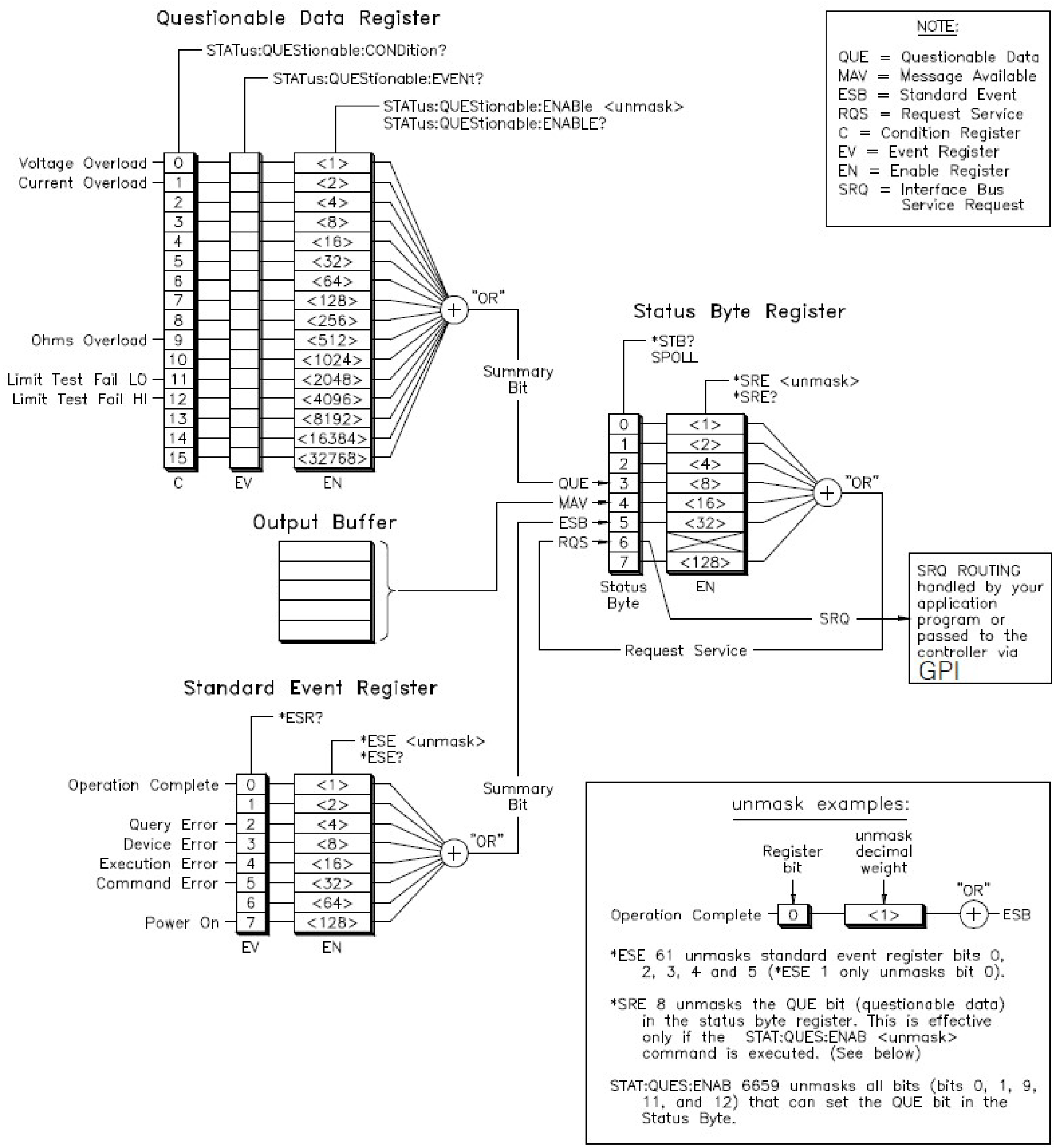
Bit	Decimal	Description
0	1	Measurement status summary
1	2	Not used
2	4	Error queue not empty
3	8	Questionable status summary
4	16	Output buffer
5	32	Event status byte summary
6	64	Master status summary (Request for service)
7	128	Operation status summary

In general, use serial polling (not `*STB?`) inside interrupt service routines. Use `*STB?` in other cases (not in interrupt service routines) when you want to know the value of the status byte.

Status System Register Diagram of the M1412A



Status System Register Diagram of the E1412A



10 Verification Tests

This chapter provides information for verification tests on the Keysight M1412A 7.5 Digit PXIe Digital Multimeter.

You can perform performance verification tests at different levels depending on your needs by programs using SCPI commands.

- Functional Test - A series of internal self-tests that give a high confidence that the multimeter is operational. The self-tests take less than 20 seconds to complete.
- Quick Verification Test - A combination of the internal self-tests and selected verification tests (specified by Q in the verification tables). These tests performed under computer control can be completed in less than ten minutes.
- Performance Verification - Must be performed at each calibration interval. These tests performed under computer control can be completed in less than 60 minutes. Allowing time for thermal offset voltages to settle, on ranges where thermal voltages impact the measurement, can add another 10 minutes to the testing.

Recommended Test Equipment

Table 10-1 lists the recommended test equipment for testing the M1412A. Essential requirements for each piece of test equipment are described in the Requirements column.

If the exact instrument is not available, you can substitute it with an instrument that has calibration standards of equivalent accuracy.

Special care must be taken to ensure that the calibration standards and test procedures used do not introduce additional errors. Ideally, the standards used to test and calibrate the multimeter should be an order of magnitude more accurate than each multimeter range full-scale error specification.

Table 10-1 Recommended Test Equipment

Instrument	Requirements	Recommended Model	Use [1]
PXIe Embedded Controller or Host PC	Windows 10 or 11 (for host PC) PCI Express Gen. 2 Card slot.	(Embedded controller) Keysight M9035A Keysight M9037A Keysight M9038A (with host PC) Keysight M9022A Keysight M9023A Keysight M9024A	F,Q,P
PXIe Mainframe		Keysight M9010A Keysight M9019A Keysight M9046A	F,Q,P
AC Standard [2]	Frequency Range: 10 Hz to 300 kHz Voltage Range: 10 mV rms to 200 V rms	Fluke 5720A Fluke 5730A	Q,P
Amplifier	Required to adjust and performance verify the 300 V, 50 kHz point. Max Frequency required: 50 kHz Max Voltage required: 300 V rms	Fluke 5725A (auxiliary amp to the 5720A, 5730A)	P

Instrument	Requirements	Recommended Model	Use [1]
DC Standard [3]	Voltage Range: -300 V to +300 V Current Range: 1 µA to 3 A Resistance Range: 10 Ω to 100 MΩ	Fluke 5720A Fluke 5730A Fluke 5725A or 5560A for High Current	Q,P
Resistance Standard [2]	Values: 10 Ω to 100 MΩ	Fluke 5720A Fluke 5730A	Q,P
Frequency Standard [2]	Frequency Range: 3 Hz to 300 kHz	Keysight 33500B series Function/Arbitrary Waveform Generator (with 50 Ω termination)	Q,P
Triaxial - Banana Adapter		Keysight M1401A	Q,P
Low thermal EMF four-terminal short	4-terminal short using only copper interconnections		Q,P

1.F = Functional Test, Q = Quick Verification Test, P = Performance Verification

2.Accuracy requirements: <1/5 DMM 24 hour spec

3.Accuracy requirements for DC Voltage: <1/5 DMM 24 hour spec ±1 ppm linearity
Accuracy requirements for DC Current: <1/5 DMM 24 hour spec

Test Conditions

For adequate performance, all test procedures should comply with the following test conditions.

- Ambient temperature of the test area is between 18°C and 28°C, and stable to within ±1°C.
- Ambient relative humidity of the test area is <80%.
- Must have a one-hour warm-up with all input signals removed.
- Use only copper connections to minimize thermal offset voltages.
- Shielded twisted PTFE insulated cables or other high impedance, low dielectric absorption cables are recommended for all measurements.
- Keep cables as short as possible. Long test leads can act as an antenna causing the pick-up of AC signals and contributing to measurement error.
- Allow 5 minutes after handling input connections for thermal offset voltage settling.

Calibration Interval

The M1412A multimeter should be calibrated on a regular interval determined by the measurement accuracy requirements of your application. A 90-day interval is recommended for the most demanding applications, while a 1-year or 2-year interval may be adequate for less demanding applications. Keysight does not recommend extending calibration intervals beyond 2 years in any application.

Whatever calibration interval you select, Keysight recommends that complete re-adjustment should always be performed at the calibration interval. This will increase your confidence that the M1412A will remain in specification for the next calibration interval. This criteria for readjustment provides the best measure of the multimeter's long-term stability. Performance data measured this way can easily be used to extend future calibration intervals.

Keysight Technologies Calibration Services

Contact your local Keysight Technologies Service Center for recalibration when your Multimeter is due for calibration.

Functional Test (Self-Test)

This section describes the procedure of the Functional Test. The functional test can be used at any time to verify that the multimeter is connected properly and is responding to the self-test command.

Functional Test Procedure

This test verifies that the M1412A is communicating with the command module, external controller, and/or external terminal by performing a self-test.

1. Verify that the multimeter and system module or embedded controller are properly installed in the mainframe.
2. Remove any input connections to the multimeter input terminals. The input and sense terminals should be open. Errors may be induced by AC signals present on the multimeter's input terminals during the self-test.
3. Execute the multimeter the self-test using the `*TST?` command.
4. A "0" returned means the self-test passed with no failures. Any other value returned is a self-test error code and means a failure was detected.

NOTE If an incorrect address is used, the multimeter will not respond. you have selected a valid address.

Example This example performs a multimeter self-test.

Any number other than 0 returned indicates a test failure.

`*TST?`	*Send the self-test command.*
`ENTER`	*The response Read self-test result.*

Quick Verification Tests

The Quick Verification procedure is a combination of the internal self-test and an abbreviated set of the Performance Verification Tests (specified by the letter Q in the performance verification test tables). This test provides a simple method to achieve high confidence in the multimeter's ability to functionally operate and meet specifications. These tests represent the absolute minimum set of performance tests that are recommended following any service activity. These tests are designed to provide a moderate level of confidence that the instrument is meeting specifications.

Perform the Quick Verification tests by doing the following.

- Perform a self-test using the `*TST?` command.
- Perform the performance verification tests indicated with the letter Q.

If your multimeter fails the Quick Verification, recalibrate the section that failed. Carefully review the test conditions for possible causes of performance verification test failures. Take into consideration all test conditions, your test set-up, and the handling of test connectors and shorting devices. Contact your nearest Keysight Technologies service office if your multimeter fails to meet specification.

Performance Verification

The procedures in this section are used to test the electrical performance of the multimeter using the specifications in the M1412A data sheet as the performance standards.

The Performance Verification Tests are recommended as acceptance tests when the instrument is first received. The acceptance test results should be compared against the 90-day test limits. The 24-hour test limits should only be used for verification of a function within 24 hours after performing a calibration of that function (this will have set a new calibration constant for that function).

The performance verification tests should be repeated at each calibration interval (90 days, 1 year) following acceptance. If the M1412A fails a performance verification, adjustment or repair is needed.

Zero Offset Verification

This procedure is used to check the zero offset performance of the M1412A.

1. Check the “Test Conditions”.
2. Verify that the Input and Sense terminals of the M1412A are open. To perform Zero Offset Verification of the DC current function, set the DC Current function and select each range in the order shown in Table 10-2 using the following commands. Compare the measurement results to the appropriate test limits shown in Table 10-2.

Reset the multimeter.	`*RST`
Set the DC Current input range to 100 μA.	`CONF:CURR:DC 1e-4`
Perform the measurement.	`READ?`

3. To perform Zero Offset Verification of other functions, first, attach the M1401A to the M1412A terminals. Then, apply a 4-wire short (Low thermal EMF four-terminal short) across the Input Hi-Lo and Sense Hi S-Lo S terminals of the M1401A as shown in Figure 10-1. Wait five minutes for thermal offset voltage settling.
4. Select each function and range in the order as shown in Table 10-2. Compare the measurement results to the appropriate test limits as shown in the table.

Figure 10-1 Zero Offset Verification Test Setup with 4-Wire Short

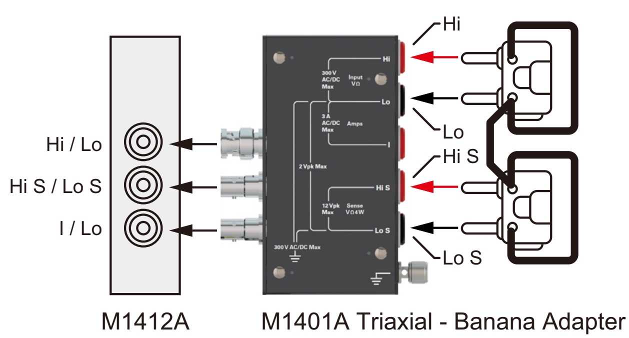


Table 10-2 Zero Offset Verification Test Points

Input	Function	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
Open	DC Current	100 µA	±2 nA	±2 nA	±2 nA	Q
		1 mA	±0.02 µA	±0.02 µA	±0.02 µA	
		10 mA	±0.2 µA	±0.2 µA	±0.2 µA	
		100 mA	±2 µA	±2 µA	±2 µA	
		1 A	±0.1 mA	±0.1 mA	±0.1 mA	
		3 A	±0.6 mA	±0.6 mA	±0.6 mA	
4-wire Short	DC Voltage	100 mV	±2.1 µV	±2.1 µV	±2.1 µV	Q
		1 V	±2.5 µV	±2.5 µV	±2.5 µV	
		10 V	±7.0 µV	±7.0 µV	±7.0 µV	
		100 V	±0.25 mV	±0.25 mV	±0.25 mV	
		300 V	±0.6 mV	±0.6 mV	±0.6 mV	

Input	Function	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
4-wire Short	4-wire Resistance	10 Ω	±0.2 mΩ	±0.2 mΩ	±0.2 mΩ	
		100 Ω	±1.2 mΩ	±1.2 mΩ	±1.2 mΩ	
		1 kΩ	±1.5 mΩ	±1.5 mΩ	±1.5 mΩ	
		10 kΩ	±0.015 Ω	±0.015 Ω	±0.015 Ω	Q
		100 kΩ	±0.25 Ω	±0.25 Ω	±0.25 Ω	
		1 MΩ	±10 Ω	±10 Ω	±10 Ω	
		10 MΩ	±100 Ω	±100 Ω	±100 Ω	
		100 MΩ	±1.0 kΩ	±1.0 kΩ	±1.0 kΩ	
	2-wire Resistance	100 Ω	±3.0 mΩ	±3.0 mΩ	±3.0 mΩ	
		1 kΩ	±1.5 mΩ	±1.5 mΩ	±1.5 mΩ	
		10 kΩ	±0.015 Ω	±0.015 Ω	±0.015 Ω	
		100 kΩ	±0.25 Ω	±0.25 Ω	±0.25 Ω	
		1 MΩ	±10 Ω	±10 Ω	±10 Ω	
		10 MΩ	±100 Ω	±100 Ω	±100 Ω	
		100 MΩ	±1.0 kΩ	±1.0 kΩ	±1.0 kΩ	

DC Voltage Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the DC Standard across the M1401A Hi-Lo Input terminals as shown in Figure 10-2. See Table 10-1 "Recommended Test Equipment".
2. To compensate for thermal EMF of the test lead, set the DC Standard output to 0 V.
3. Enable the NULL function to compensate for the test lead thermal EMF on the multimeter as follows. Recommended for the 100 mV range, optional setup for other DC voltage ranges.

Reset the multimeter.	`*RST`
Set the DC voltage input range to 100 mV.	`CONF:VOLT:DC 0.1`
Enable the NULL function.	`VOLT:DC:NULL 1`
Apply the measured null value to following measurement.	`READ?`

4. Set the DC Standard output to 100 mV.
5. Perform the measurement using the `READ?` command.
6. Verify the result is within the specified limits and record the result.
7. Change the ranges using the `VOLT:DC:RANG` *<range>* command. Repeat steps 4 to 7 as shown in Table 10-3.

Figure 10-2 DC Voltage Gain Verification Test Setup

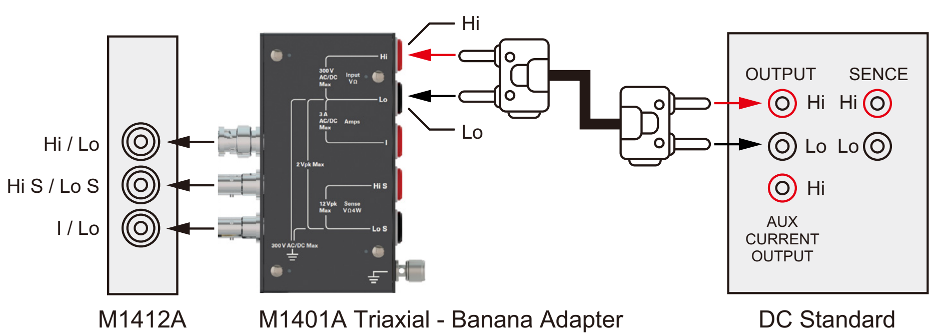


Table 10-3 Summary of DC Gain Verification Tests

Input from DC Standard	Function	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
100 mV	DC Voltage and DC2 Voltage	100 mV	±4.3 μV	±5.6 μV	±5.9 μV	
-100 mV		-100 mV	±4.3 μV	±5.6 μV	±5.9 μV	
1 V		1 V	±0.0125 mV	±0.0255 mV	±0.0285 mV	
-1 V		-1 V	±0.0125 mV	±0.0255 mV	±0.0285 mV	
10 V		10 V	±0.057 mV	±0.187 mV	±0.217 mV	Q
-10 V		-10 V	±0.057 mV	±0.187 mV	±0.217 mV	
100 V [1]		100 V	±1.65 mV	±2.95 mV	±3.25 mV	Q
-100 V [1]		-100 V	±1.65 mV	±2.95 mV	±3.25 mV	
300 V [1]		300 V	±6.3 mV	±10.2 mV	±11.1 mV	
-300 V [1]		-300 V	±6.3 mV	±10.2 mV	±11.1 mV	
10 Ω	4-wire Resistance	10 Ω	±0.45 mΩ	±1 mΩ	±1.2 mΩ	
100 Ω		100 Ω	±3.7 mΩ	±9.2 mΩ	±11.2 mΩ	
1 kΩ		1 kΩ	±16.5 mΩ	±81.5 mΩ	±101.5 mΩ	Q
10 kΩ		10 kΩ	±0.165 Ω	±0.815 Ω	±1.015 Ω	
100 kΩ		100 kΩ	±1.75 Ω	±8.25 Ω	±10.25 Ω	
1 MΩ		1 MΩ	±30 Ω	±90 Ω	±110 Ω	
10 MΩ		10 MΩ	±1.6 kΩ	±3.6 kΩ	±5.5 kΩ	Q
100 MΩ		100 MΩ	±301 kΩ	±351 kΩ	±541 kΩ	

Input from DC Standard	Function	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
100 Ω	2-wire Resistance	100 Ω	±5.5 mΩ	±11.0 mΩ	±13.0 mΩ	
1 kΩ		1 kΩ	±16.5 mΩ	±81.5 mΩ	±101.5 mΩ	Q
10 kΩ		10 kΩ	±0.165 Ω	±0.815 Ω	±1.015 Ω	
100 kΩ		100 kΩ	±1.75 Ω	±8.25 Ω	±10.25 Ω	
1 MΩ		1 MΩ	±30 Ω	±90 Ω	±110 Ω	
10 MΩ		10 MΩ	±1.6 kΩ	±3.6 kΩ	±5.5 kΩ	Q
100 MΩ		100 MΩ	±301 kΩ	±351 kΩ	±541 kΩ	
100 μA	DC Current	100 μA	±4 nA	±0.014 μA	±0.019 μA	
1 mA		1 mA	±0.04 μA	±0.14 μA	±0.19 μA	
10 mA		10 mA	±0.4 μA	±1.4 μA	±1.9 μA	Q
100 mA		100 mA	±5 μA	±15 μA	±20 μA	
1 A		1 A	±1.1 mA	±1.1 mA	±1.1 mA	
3 A		3 A	±9.6 mA	±9.6 mA	±9.6 mA	

1.This is applicable to DC voltage at Hi and Lo input only.

DC Voltage and DC2 Voltage Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the DC Standard across the M1401A Hi-Lo Input terminals and the Hi S-Lo S Sense terminals as shown in Figure 10-3. See Table 10-1 “Recommended Test Equipment”.
2. To compensate for thermal EMF of the test lead, set the DC Standard output to 0 V.

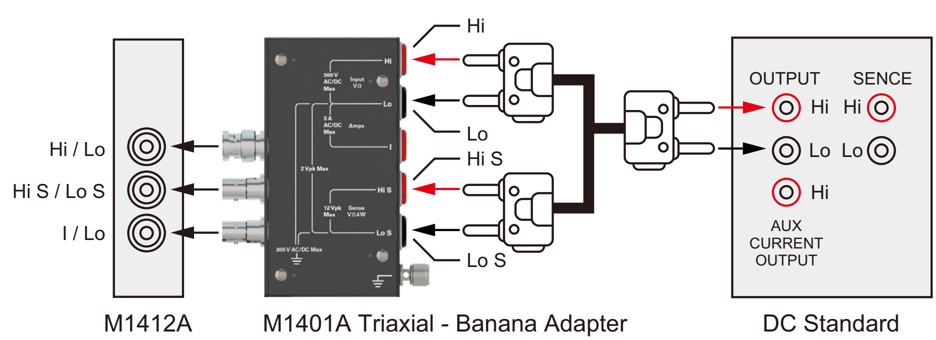
3. Enable the NULL function to compensate for the test lead thermal EMF on the multimeter as follows. Recommended for the 100 mV range, optional setup for other DC voltage ranges.

Reset the multimeter.	`*RST`
Enable DC voltage and DC2 voltage.	`FUNC “VOLT”,”VOLT:DC2”`
Set the DC voltage input range to 100 mV.	`VOLT:DC:RANG 0.1`
Set the DC2 voltage input range to 100 mV.	`VOLT:DC2:RANG 0.1`
Enable the NULL function for DC.	`VOLT:DC:NULL 1`
Enable the NULL function for DC2.	`VOLT:DC2:NULL 1`
Apply the measured null value to the following measurement.	`READ?`

4. Set the DC Standard output to 100 mV.
5. Perform the measurement using the `READ?` command.
6. Verify the result is within the specified limits and record the result.
7. Change the ranges using the `VOLT:DC:RANG` *<range>* and `VOLT:DC2:RANG` *<range>* commands. Repeat steps 4 to 7 as shown in Table 10-3.

CAUTION Maximum input voltage for DC2 voltage is 10 V only.

Figure 10-3 DC Voltage and DC2 Voltage Gain Verification Test Setup



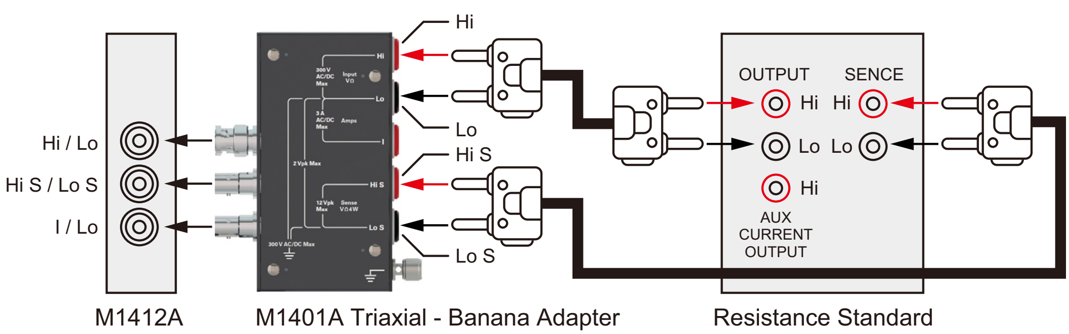
4-Wire Resistance Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the Resistance Standard across the M1401A Hi-Lo Input terminals and the Hi S-Lo S Sense terminals as shown in Figure 10-4. See Table 10-1 “Recommended Test Equipment”.
2. Configure the multimeter for 4-wire Resistance 10 Ω range as follows.

Reset the multimeter.	`*RST`
Set the 4-wire resistance range to 10 Ω.	`CONF:FRES 10`

3. Set the Resistance Standard output to 4-wire 10 Ω. (this requires EXTSENSE ON for the Fluke 5720A or 5730A, applicable up to 10 MΩ range.)
4. Perform a measurement using the **`READ?`** command.
5. Verify the result is within the specified limits and record the result.
6. Change the ranges using the `FRES:RANG` *`<range>`* command. Repeat steps 3 to 6 as shown in Table 10-3.

Figure 10-4 4-Wire Resistance Gain Verification Test Setup



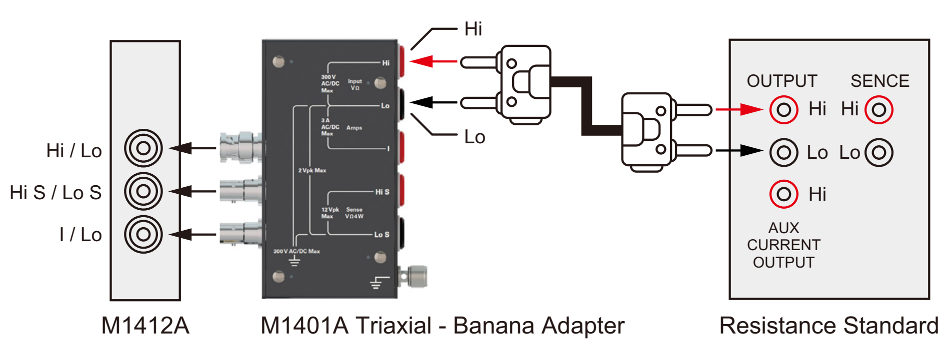
2-Wire Resistance Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the Resistance Standard across the M1401A Hi and Lo Input terminals as shown in Figure 10-5. See Table 10-1 “Recommended Test Equipment”.
2. Set the Resistance Standard output to 2-wire 0 Ω (with RCOMP ON for Fluke 5720A/5730A).
3. Enable the NULL function to compensate for the test lead resistance for the 2-wire Resistance function as follows.

Reset the multimeter.	`*RST`
Set the 2-wire resistance range to 10 Ω.	`CONF:RES 10`
Enable the NULL function.	`RES:NULL 1`
Apply the measured null value to the following measurement.	`READ?`

4. Set the Resistance Standard output to 2-wire 10 Ω (with RCOMP ON for Fluke 5720A/5730A).
5. Perform the measurement using the `READ?` command.
6. Verify the result is within the specified limits and record the result.
7. Change the ranges using the `RES:RANG` *<range>* commands. Repeat steps 4 to 7 as shown in Table 10-3.

Figure 10-5 2-Wire Resistance Gain Verification Test Setup



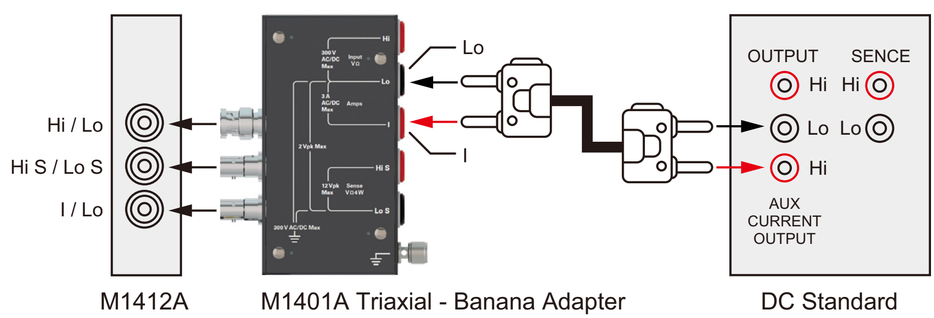
DC Current Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the DC Standard across the M1401A I-Lo Input terminals as shown in Figure 10-6. See Table 10-1 “Recommended Test Equipment”.
2. Configure the multimeter for the DC current 100 μA range as follows.

Reset the multimeter.	`*RST`
Set the DC Current input range to 100 μA.	`CONF:CURR:DC 0.0001`

3. Set the DC Standard output to 100 μA.
4. Perform the measurement using the `READ?` command.
5. Verify the result is within the specified limits and record the result.
6. Change the ranges using the `CURR:DC:RANG <range>` command. Repeat steps 3 to 6 as shown in Table 10-3.

Figure 10-6 DC Current Gain Verification Test Setup



AC Voltage Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the AC Standard across the M1401A Hi and Lo Input terminals as shown in Figure 10-7. See Table 10-1 “Recommended Test Equipment”.
2. Configure the multimeter for the AC voltage 100 mV range as follows.

Reset the multimeter.	`*RST`
Set the AC voltage input range for 100 mV.	`CONF:VOLT:AC 0.1`
Select Slow AC filter.	`VOLT:AC:BAND 3`

3. Set the AC Standard output to 100 mV at 1 kHz.
4. Perform the measurement using the `READ?` command.
5. Verify the result is within the specified limits and record the result.
6. Change the ranges using the `VOLT:AC:RANG` *<range>* command. Repeat steps 3 to 6 as shown in Table 10-4.

Figure 10-7 AC Voltage Gain Verification Test Setup

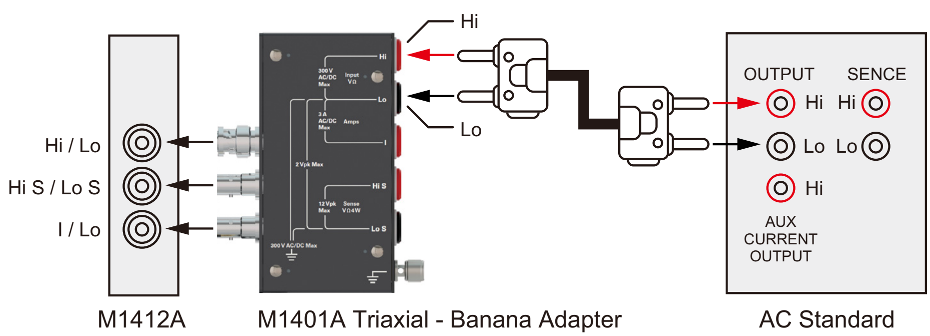


Table 10-4 AC voltage Gain Verification Tests

Input from Calibrator	Input Frequency	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
100 mV	1 kHz	100 mV	±0.07 mV	±0.09 mV	±0.10 mV	
	50 kHz		±0.15 mV	±0.16 mV	±0.17 mV	
	300 kHz		±5.5 mV	±5.5 mV	±5.5 mV	Q
1 V	1 kHz	1 V	±0.6 mV	±0.8 mV	±0.9 mV	
	50 kHz		±1.4 mV	±1.6 mV	±1.7 mV	
	300 kHz		±0.055 V	±0.055 V	±0.055 V	
10 V	10 Hz	10 V	±0.037 V	±0.038 V	±0.038 V	
	1 kHz		±0.006 V	±0.008 V	±0.009 V	
	50 kHz		±0.014 V	±0.016 V	±0.017 V	Q
	300 kHz		±0.55 V	±0.55 V	±0.55 V	
100 V	1 kHz	100 V	±0.06 V	±0.08 V	±0.09 V	Q
	50 kHz		±0.14 V	±0.16 V	±0.17 V	
70 V	300 kHz		±4 V	±4 V	±4 V	
300 V	1 kHz	300 V	±0.18 V	±0.24 V	±0.27 V	
210 V	50 kHz		±0.33 V	±0.381 V	±0.402 V	
70 V	300 kHz		±4 V	±4 V	±4 V	

AC Current Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the AC Standard across the M1401A I-Lo Input terminals as shown in Figure 10-8. See Table 10-1 “Recommended Test Equipment”.
2. Configure the multimeter for the AC current 1 A range as follows.

Reset the multimeter.	`*RST`
Set the AC Current input range to 1 A.	`CONF:CURR:AC 1`
Select Slow AC filter.	`CURR:AC:BAND 3`

3. Set the AC Standard output to 1 A at 1 kHz.
4. Perform the measurement using the `READ?` command.
5. Verify the result is within the specified limits and record the result.
6. Change the ranges using the `CURR:AC:RANG` *<range>* command. Repeat steps 3 to 6 as shown in Table 10-5.

Figure 10-8 AC Current Gain Verification Test Setup

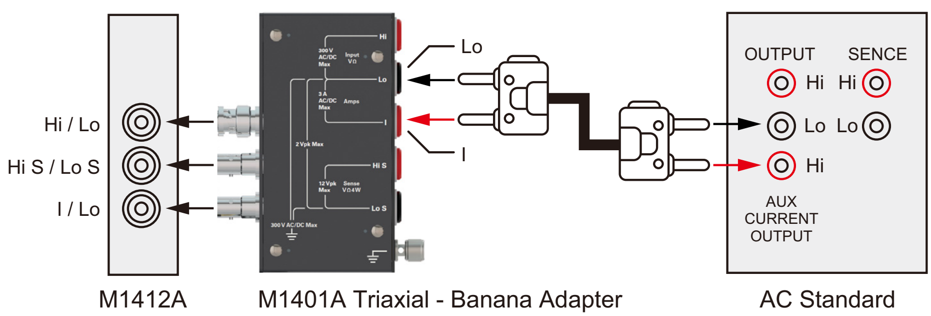


Table 10-5 AC Current Gain Verification Tests

Input from Calibrator	Input Frequency	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
1 A	1 kHz	1 A	±1.9 mA	±1.9 mA	±1.9 mA	
	5 kHz		±4.4 mA	±4.4 mA	±4.4 mA	Q
2 A	1 kHz	3 A	±0.0168 A	±0.0168 A	±0.0168 A	
	5 kHz		±0.0218 A	±0.0218 A	±0.0218 A	

Frequency Gain Verification

1. Attach the M1401A adapter to the M1412A terminals. Connect the Frequency Standard across the M1401A Hi and Lo Input terminals as shown in Figure 10-9. See Table 10-1 “Recommended Test Equipment”.
2. Configure the multimeter for Frequency input as follows.

Reset the multimeter.	`*RST`
Set the frequency function.	`CONF:FREQ`
Set the AC voltage input range of frequency to 100 mV.	`FREQ:VOLT:RANG 0.1`
Set the frequency aperture time to 1 s.	`FREQ:APER 1`

3. Set the Frequency Standard output to 10 mV at 100 Hz.
4. Perform the measurement using the **READ?** command.
5. Verify the result is within the specified limits and record the result.
6. Change the AC Voltage ranges using the **FREQ:VOLT:RANG** *<range>* command. Repeat steps 3 to 6 as shown in Table 10-6.

Figure 10-9 Frequency Verification Test Setup

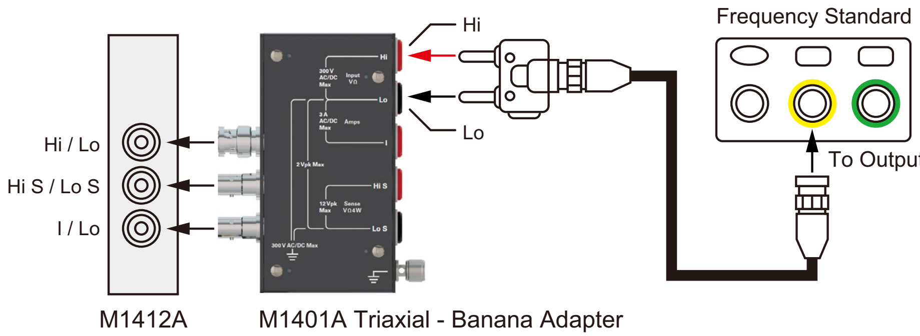


Table 10-6 Frequency Gain Verification Tests

Input from Calibrator	Input Frequency	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
10 mV	100 Hz	100 mV	±0.06 Hz	±0.1 Hz	±0.1 Hz	
1 V	100 kHz	1 V	±6 Hz	±10 Hz	±10 Hz	Q

Optional AC Voltage Gain Verification

These tests are NOT intended to be performed during every calibration. This procedure is used to verify additional instrument AC voltage specifications.

1. Attach the M1401A adapter to the M1412A terminals. Connect the AC Standard across the M1401A Hi and Lo Input terminals as shown in Figure 10-7. See Table 10-1 "Recommended Test Equipment".
2. Configure the multimeter for the AC voltage 1 V range as follows.

Reset the multimeter.	`*RST`
Set the AC voltage input range for 1 V.	`CONF:VOLT:AC 1`
Select Slow AC filter.	`VOLT:AC:BAND 3`

3. Set the AC Standard output to 1 V at 20 kHz.
4. Perform the measurement using the `READ?` command.
5. Verify the result is within the specified limits and record the result.
6. Change the ranges using the `VOLT:AC:RANG` *<range>* command. Repeat steps 3 to 6 as shown in Table 10-7.

Figure 10-10 AC Voltage Gain Verification Test Setup

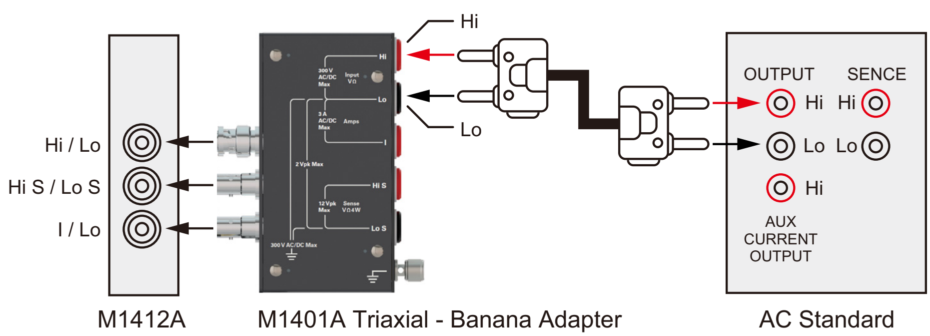


Table 10-7 Optional AC voltage Gain Verification Tests

Input from Calibrator	Input Frequency	M1412A Range	Error			Quick Verification
			24 Hours	90 Days	1 Year	
1 V	20 Hz	1 V	±0.6 mV	±0.8 mV	±0.9 mV	
	1 kHz		±0.6 mV	±0.8 mV	±0.9 mV	
	20 kHz		±0.6 mV	±0.8 mV	±0.9 mV	
	50 kHz		±1.4 mV	±1.6 mV	±1.7 mV	
	100 kHz		±6.3 mV	±6.8 mV	±6.8 mV	
	300 kHz		±0.055 V	±0.055 V	±0.055 V	
	1 kHz	10 V	±2.4 mV	±3.5 mV	±3.6 mV	
100 mV	1 kHz	10 V	±2.04 mV	±3.05 mV	±3.06 mV	

Performance Test Record

Table 10-8, Performance Test Record for the M1412A, is a form you can copy and use to record performance test results for the multimeter. This form shows the multimeter accuracy limits, the measurement uncertainty from the source, and the test accuracy ratio (TAR).

NOTE The accuracy, measurement uncertainty, and TAR values shown in Table 10-9 are valid ONLY for the specific test conditions, test equipment, and assumptions described. If you use different test equipment or change the test conditions, you will need to calculate the specific values for your test setup.

Multimeter Accuracy

Accuracy is defined for DC voltage, AC voltage, 2-wire resistance, 4-wire resistance, DC current, AC current, and frequency measurements using the 1-year specifications in the M1412A data sheet. The “High Limit” and “Low Limit” columns represent the multimeter accuracy for the specified test conditions (reading and range).

Measurement Uncertainty

Measurement uncertainties listed in Table 10-8 are calculated assuming a Keysight 33500B series model as the source for frequency measurements and a Fluke 5720A/5730A/5725A/5560A for all other measurements. The uncertainties describe the error you can expect from the source. These uncertainties are calculated from the 90-day accuracy specifications for the Fluke 5720A/5730A/5725A/5560A and the 1-year specification for the Keysight 33500B series.

Test Accuracy Ratio (TAR)

The “Test Accuracy Ratio (TAR)” is calculated from (high limit - expected measurement)/measurement uncertainty. “N/A” means measurement uncertainty and TAR do not apply to the measurement. A small TAR indicates the uncertainty of the source signal starts to approach the multimeter’s specification limit.

Table 10-8 Performance Test Record for the M1412A

Test Facility:

Name:	Report No.:
Address:	Date:
City/State:	Customer:
Phone:	Tested By:

Model:	Ambient temperature:	°C
Serial No.:	Relative humidity:	%
Firmware Rev.:	Line frequency:	Hz (nominal)

Special Notes:

Test Equipment Used: Model No. Trace No. Cal Due Date
1.
2.
3.
4.
5.

Table 10-9 M1412A DC Voltage Zero Offset Test Limit with TAR

Test Input [V]	DMM Range [V]	Low Limit [V]	High Limit [V]	Measurement Uncertainty	TAR
0	100 m	-2.1 µ	2.1 µ	N/A	N/A
0	1	-2.5 µ	2.5 µ	N/A	N/A
0	10	-7.0 µ	7.0 µ	N/A	N/A
0	100	-0.25 m	0.25 m	N/A	N/A
0	300	-0.60 m	0.60 m	N/A	N/A

Table 10-10 M1412A 4-Wire Resistance Zero Offset Test Limit with TAR

Test Input [Ω]	DMM Range [Ω]	Low Limit [Ω]	High Limit [Ω]	Measurement Uncertainty	TAR
0	10	-0.2 m	0.2 m	N/A	N/A
0	100	-1.2 m	1.2 m	N/A	N/A
0	1 k	-1.5 m	1.5 m	N/A	N/A
0	10 k	-0.0150	0.0150	N/A	N/A
0	100 k	-0.2500	0.2500	N/A	N/A
0	1 M	-10.000	10.000	N/A	N/A
0	10 M	-100.00	100.00	N/A	N/A
0	100 M	-1.0 k	1.0 k	N/A	N/A

Table 10-11 M1412A 2-Wire Resistance Zero Offset Test Limit with TAR

Test Input [Ω]	DMM Range [Ω]	Low Limit [Ω]	High Limit [Ω]	Measurement Uncertainty	TAR
0	100	-3.0 m	3.0 m	N/A	N/A
0	1 k	-1.5 m	1.5 m	N/A	N/A
0	10 k	-0.0150	0.0150	N/A	N/A
0	100 k	-0.2500	0.2500	N/A	N/A
0	1 M	-10.000	10.000	N/A	N/A
0	10 M	-100.00	100.00	N/A	N/A
0	100 M	-1.0 k	1.0 k	N/A	N/A

Table 10-12 M1412A DCI Zero Offset Test Limit with TAR

Test Input [A]	DMM Range [A]	Low Limit [A]	High Limit [A]	Measurement Uncertainty	TAR
0	1 m	-0.02 μ	0.02 μ	N/A	N/A
0	10 m	-0.2 μ	0.2 μ	N/A	N/A
0	100 m	-2 μ	2 μ	N/A	N/A
0	1	-0.1 m	0.1 m	N/A	N/A
0	3	-0.6 m	0.6 m	N/A	N/A

Table 10-13 M1412A DC Voltage Gain Test Limit with TAR

Test Input [V]	DMM Range [V]	Low Limit [V]	High Limit [V]	Measurement Uncertainty	TAR
100 m	100 m	0.0999957	0.1000043	0.0000014	3:1
1	1	0.9999875	1.0000125	0.0000068	1.8:1
10	10	9.9999430	10.000057	0.0000430	1.3:1
100	100	99.998350	100.00165	0.0006500	2.5:1
300	300	299.99370	300.00630	0.0029000	2.1:1

Table 10-14 M1412A 4-Wire Resistance Gain Test Limit with TAR

Test Input [Ω]	DMM Range [Ω]	Low Limit [Ω]	High Limit [Ω]	Measurement Uncertainty	TAR
10	10	9.99955	10.00045	0.00027	1.6:1
100	100	99.9963	100.0037	0.00120	3:1
1 k	1 k	999.9835	1000.0165	0.00800	2:1
10 k	10 k	9999.835	10000.165	0.08000	2:1
100 k	100 k	99998.25	100001.75	1.00000	1.7:1
1 M	1 M	999970.0	1000030.0	15.0000	2:1
10 M	10 M	9998400	10001600	460.000	3.4:1
100 M	100 M	99699000	100301000	12000.0	> 10:1

Table 10-15 M1412A 2-Wire Resistance Gain Test Limit with TAR

Test Input [Ω]	DMM Range [Ω]	Low Limit [Ω]	High Limit [Ω]	Measurement Uncertainty	TAR
0	100	99.9945	100.0055	0.00120	4.5:1
0	1 k	999.9835	1000.0165	0.00800	2:1
0	10 k	9999.835	10000.165	0.08000	2:1
0	100 k	99998.25	100001.75	1.00000	1.7:1
0	1 M	999970.0	1000030.0	15.0000	2:1
0	10 M	9998400	10001600	460.000	3.4:1
0	100 M	99699000	100301000	12000.0	> 10:1

Table 10-16 M1412A DCI Gain Test Limit with TAR

Test Input [A]	DMM Range [A]	Low Limit [A]	High Limit [A]	Measurement Uncertainty	TAR
0	1 m	0.99996 m	1.00004 m	0.000000048	0.8:1
0	10 m	9.9996 m	0.01000040	0.00000045	0.8:1
0	100 m	0.09999500	0.10000500	0.0000058	0.8:1
0	1	0.99890000	1.00110000	0.0001050	> 10:1
0	3	2.09310000	2.10690000	0.0002040	> 10:1

Table 10-17 M1412A AC Voltage Gain Test Limit with TAR

Test Input [V]	Test Input Frequency [Hz]	DMM Range [V]	Low Limit [V]	High Limit [V]	Measurement Uncertainty	TAR
0.1	1 k	0.1	0.09993	0.10007	0.000015	4.6:1
0.1	50 k	0.1	0.09985	0.10015	0.000023	6.5:1
0.1	300 k	0.1	0.09450	0.10550	0.000105	> 10:1
1	1 k	1	0.99940	1.00060	0.000058	> 10:1
1	50 k	1	0.99860	1.00140	0.000092	> 10:1
1	300 k	1	0.94500	1.05500	0.000500	> 10:1
10	10	10	9.96300	10.0370	0.003500	> 10:1
10	1 k	10	9.99400	10.0060	0.000550	> 10:1
10	50 k	10	9.98600	10.0140	0.000920	> 10:1
10	300 k	10	9.45000	10.5500	0.003800	> 10:1
100	1 k	100	99.9400	100.060	0.007200	8:1
100	50 k	100	99.8600	100.140	0.011200	> 10:1
70	300 k	100	66.0000	74.0000	0.097000	> 10:1
300	1 k	300	299.820	300.180	0.029500	6.1:1
210	50 k	300	209.670	210.330	0.022200	> 10:1
70	300 k	100	66.0000	74.0000	0.097000	> 10:1

Table 10-18 M1412A Optional AC Voltage Gain Test Limit with TAR

Test Input [V]	Test Input Frequency [Hz]	DMM Range [V]	Low Limit [V]	High Limit [V]	Measurement Uncertainty	TAR
1	20 Hz	1	0.99940	1.00060	0.000130	4.6:1
1	1 kHz	1	0.99940	1.00060	0.000058	> 10:1
1	20 kHz	1	0.99940	1.00060	0.000058	> 10:1
1	50 kHz	1	0.99860	1.00140	0.000092	> 10:1
1	100 kHz	1	0.99370	1.00630	0.000140	> 10:1
1	300 kHz	1	0.94500	1.05500	0.000500	> 10:1
1	1 kHz	10	0.99760	1.00240	0.000058	> 10:1
0.1	1 kHz	10	0.09796	0.10204	0.000015	> 10:1

Table 10-19 M1412A AC Current Gain Test Limit with TAR

Test Input [A]	Test Input Frequency [Hz]	DMM Range [A]	Low Limit [A]	High Limit [A]	Measurement Uncertainty	TAR
1	1 k	1	0.9981	1.0019	0.00034	5.5:1
1	5 k	1	0.9956	1.0044	0.00060	7.3:1
2	1 k	3	1.9832	2.0168	0.00064	> 10:1
2	5 k	3	1.9782	2.0218	0.00110	> 10:1

Table 10-20 M1412A Frequency Gain Test Limit with TAR

Test Input [V]	Test Input Frequency [Hz]	DMM Range [V]	Low Limit [V]	High Limit [V]	Measurement Uncertainty	TAR
0.01	100	0.1	99.940	100.060	0.0001	> 10:1
1	100000	1	99994	100006	0.1000	> 10:1

NOTE

Measurement accuracy for resistance values applies to the Fluke 5720A/5730A/5725A/5560A displayed value, not the nominal value. For example, a programmed output of 1000 Ω may actually output 1000.0231 Ω. Therefore, you must use the actual displayed output value for true accuracy, not the nominal value of 1000, or an additional error of 23 mΩ is introduced. The 24-hour specification for the 1 kΩ range is 25 mΩ and the additional 23 mΩ nearly compromises the specification.

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