

Contents

HP E1312A and HP E1412A 6 1/2 Digit Multimeter User's Manual Edition 3

Warranty	5
WARNINGS	6
Safety Symbols	6
Declaration of Conformity	7
Declaration of Conformity	8
Reader Comment Sheet	10
 1. HP E1312A and HP E1412A Multimeter Module Setup	 12
General Information	12
Setting the Module Address Switch	13
Interrupt Priority	14
Setting the Line Frequency Reference	14
Checking the Line Frequency Reference	14
Initial Operation	20
 2. HP E1312A/E1412A Multimeter Application Information	 22
Thermal EMF Errors	22
Loading Errors (dc volts)	23
Leakage Current Errors	23
Rejecting Power Line Noise Voltages	24
Common Mode Rejection (CMR)	24
Noise Caused by Magnetic Loops	25
Noise Caused by Ground Loops	25
4-Wire Ohms Measurements	26
Removing Field Wiring Resistance Errors in 2-Wire Ohms Measurements	26
Power Dissipation Effects	28
Settling Time Effects	28
Errors in High Resistance Measurements	28
Making High-Speed DC and Resistance Measurements	29
Crest Factor Errors (non-sinusoidal inputs)	31
Loading Errors (ac volts)	32
AC Measurements Below Full Scale	32
Function and Range Change Internal Offset Correction	32
Low-Level Measurement Errors	33
AC Turnover Errors	33
AC Signal Filter	35
DC Input Resistance	35
Resolution	35
Integration Time	36
Autozero	37

Ranging	38
AVERage Function	39
NULL (Relative) Function	39
dB Measurements	40
dBm Measurements	41
LIMit Function	42
The Trigger Source	44
External Triggering	45
Internal Triggering	46
Bus Triggering	46
The Wait-for-Trigger State	46
The Trigger Count	47
Checking the Trigger Count	47
Inserting a Trigger Delay	48
Default Delays	49
Querying the Delay Time	50
The Sample Count	50
Checking the Sample Count	50
HP VTL Software (VISA)	51
Example Programs	51
Making Multimeter Measurements	52
Synchronizing the Multimeter With a Switch Module	56
Multimeter Status System Examples	59
HP VEE Programming Example	63
3. Multimeter Command Reference	66
Command Types	66
Common Command Format	66
SCPI Command Format	66
Linking Commands	68
Multimeter Range and Resolution Tables	69
SCPI Command Reference	71
IEEE 488.2 Common Command Quick Reference	161
SCPI Command Quick Reference	166
A. HP E1312A and HP E1412A Multimeter Specifications	170
Measuring Characteristics	171
Operating Characteristics [8]	172
Measuring Characteristics	174
To Calculate Total Measurement Error	179
Understanding the “% of reading” Error	179
Understanding the “% of range” Error	180
Interpreting Multimeter Specifications	181
Number of Digits and Overrange	181
Sensitivity	181
Resolution	181

Accuracy	181
Transfer Accuracy	182
24-Hour Accuracy	182
90-Day and 1-Year Accuracy	182
Temperature Coefficients	182
Configuring for Highest Accuracy Measurements	183
B. HP E1312A and HP E1412A Multimeter Error Messages	184
C. Measurement Speed and Accuracy Tradeoffs	194
Speed Advantage Using the Special Non-SCPI Commands (F1-F4 and R1-R7)	195
Resolution Example	196
Avoid Function Changes	197
Avoid Aperture Changes	197
Minimize the Number of Command / Response Sessions	197
Set Autozeroing to ONCE or OFF	198
Turn Auto Ranging OFF	198
Decrease Aperture Time or NPLCs	199
Store the Readings in Multimeter RAM Instead of Sending them Directly to the Computer	199

Notes

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HP E1312A and HP E1412A 6 1/2 Digit Multimeter User's Manual and SCPI Programming Guide
Edition 3

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Documentation History

All editions and updates of this manual and their creation date are listed below. The first edition of the manual is Edition 1. The edition number increments by 1 whenever the manual is revised. Updates, which are issued between editions, contain replacement pages to correct or add additional information to the current edition of the manual. Whenever a new edition is created, it will contain all of the update information for the previous edition. Each new edition or update also includes a revised copy of this documentation history page.

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Edition 3 June 1996

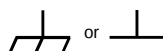
Safety Symbols



Instruction manual symbol affixed to product. Indicates that the user must refer to the manual for specific WARNING or CAUTION information to avoid personal injury or damage to the product.



Indicates the field wiring terminal that must be connected to earth ground before operating the equipment—protects against electrical shock in case of fault.



Frame or chassis ground terminal—typically connects to the equipment's metal frame.



Alternating current (AC).



Direct current (DC).



Indicates hazardous voltages.

WARNING

Calls attention to a procedure, practice, or condition that could cause bodily injury or death.

CAUTION

Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

WARNINGS

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 violates safety standards of design, manufacture, and intended use of the product. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

Ground the equipment: For Safety Class 1 equipment (equipment having a protective earth terminal), an uninterruptible safety earth ground must be provided from the mains power source to the product input wiring terminals or supplied power cable.

DO NOT operate the product in an explosive atmosphere or in the presence of flammable gases or fumes.

For continued protection against fire, replace the line fuse(s) only with fuse(s) of the same voltage and current rating and type. DO NOT use repaired fuses or short-circuited fuse holders.

Keep away from live circuits: Operating personnel must not remove equipment covers or shields. Procedures involving the removal of covers or shields are for use by service-trained personnel only. Under certain conditions, dangerous voltages may exist even with the equipment switched off. To avoid dangerous electrical shock, DO NOT perform procedures involving cover or shield removal unless you are qualified to do so.

DO NOT operate damaged equipment: Whenever it is possible that the safety protection features built into this product have been impaired, either through physical damage, excessive moisture, or any other reason, REMOVE POWER and do not use the product until safe operation can be verified by service-trained personnel. If necessary, return the product to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

DO NOT service or adjust alone: Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT substitute parts or modify equipment: Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the product. Return the product to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

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according to ISO/IEC Guide 22 and EN 45014

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Loveland Manufacturing Center

Manufacturer's Address: 815 14th Street S.W.
Loveland, Colorado 80537

declares, that the product:

Product Name: 6 1/2 Digit Multimeter Module

Model Number: E1312A

Product Options: All

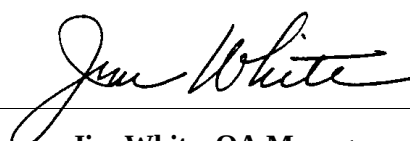
conforms to the following Product Specifications:

Safety: IEC 1010-1 (1990) Incl. Amend 1 (1992)/EN61010-1 (1993)
CSA C22.2 #1010.1 (1992)
UL 3111-1

EMC: CISPR 11:1990/EN55011 (1991): Group1 Class A
EN50082-1:1992
IEC 801-2:1991: 4kV CD, 8kV AD
IEC 801-3:1984: 3 V/m
IEC 801-4:1988: 1kV Power Line, 0.5kV Signal Lines

Supplementary Information: The product herewith complies with the requirements of the low voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the "CE" marking accordingly.

Tested in a typical HP B-Size VXI mainframe.


Jim White, QA Manager

May 8, 1996

European contact: Your local Hewlett-Packard Sales and Service Office or Hewlett-Packard GmbH, Department ZQ/Standards Europe, Herrenberger Straße 130, D-71034 Böblingen, Germany.

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Manufacturer's Address: 815 14th Street S.W.
Loveland, Colorado 80537

declares, that the product:

Product Name: 6 1/2 Digit Multimeter Module

Model Number: E1412A

Product Options: All

conforms to the following Product Specifications:

Safety: IEC 1010-1 (1990) Incl. Amend 1 (1992)/EN61010-1 (1993)
CSA C22.2 #1010.1 (1992)
UL 3111-1

EMC: CISPR 11:1990/EN55011 (1991): Group1 Class A
EN50082-1:1992
IEC 801-2:1991: 4kV CD, 8kV AD
IEC 801-3:1984: 3 V/m
IEC 801-4:1988: 1kV Power Line, 0.5kV Signal Lines

Supplementary Information: The product herewith complies with the requirements of the low voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the "CE" marking accordingly.

Tested in a typical HP C-Size VXI mainframe.


Jim White, QA Manager

July 31, 1995

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NOTES

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HP E1312A and HP E1412A 6 1/2 Digit Multimeter User's Manual and SCPI Programming Guide
Edition 3

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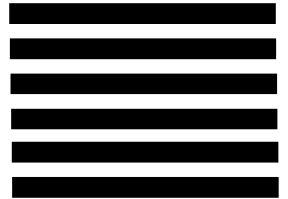
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HP E1312A and HP E1412A Multimeter Module Setup

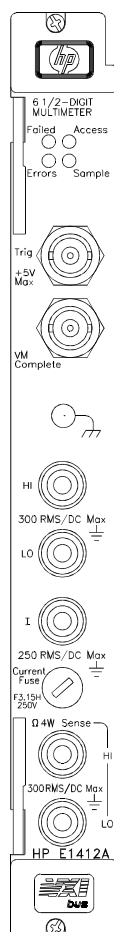
Using This Chapter

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

- Setting the Module Address Switch
- Interrupt Priority
- Setting and Checking the Line Frequency Reference
- Input Terminals and Front Panel Indicators
- Multimeter Functional Connections
- Initial Operation

General Information

- The HP E1312A (VXI B-size) and HP E1412A (VXI C-size) multimeters are VXIbus message-based slave devices.
- Programming the multimeter can either be through a command module using an HP-IB interface or an embedded controller. You use the Standard Commands for Programmable Instruments (SCPI; see Chapter 3) with the Standard Instrument Control Language (SICL) or VISA (Virtual Instrument Software Architecture).
- Maximum voltage is 300 V_{rms} or 300 V_{dc}.
- Maximum current is 3A AC_{rms} or DC.
- Resolution is from 4 1/2 digits for fast measurements to 6 1/2 digits for more accuracy. Resolution is set by specifying the integration time in number of power line cycles (NPLCs) or corresponding aperture time. The following table shows the correlation between NPLCs and resolution.



Power Line Cycles	Resolution
0.02	0.0001 x Full-Scale
0.2	0.00001 x Full-Scale
1	0.000003 x Full-Scale
10	0.000001 x Full-Scale
100	0.0000003 x Full-Scale

Setting the Module Address Switch

The logical address switch factory setting is 24. Valid addresses are from 1 to 254 for static configuration (the address you set on the switch) and address 255 for dynamic configuration. The HP E1312A and HP E1412A support dynamic configuration of the address. This means the address is set programmatically by the resource manager when it encounters a module with address 255 that supports dynamic configuration.

If you install more than one multimeter, each module must have a different logical address. If you use a VXIbus command module, the logical address must be a multiple of eight (e.g., 32, 40, 48, etc.) Each instrument must have a unique secondary address which is the logical address divided by eight.

Note

When using an HP E1405A/B or E1406A as the VXIbus resource manager with SCPI commands, the multimeter's address switch value must be a multiple of 8.

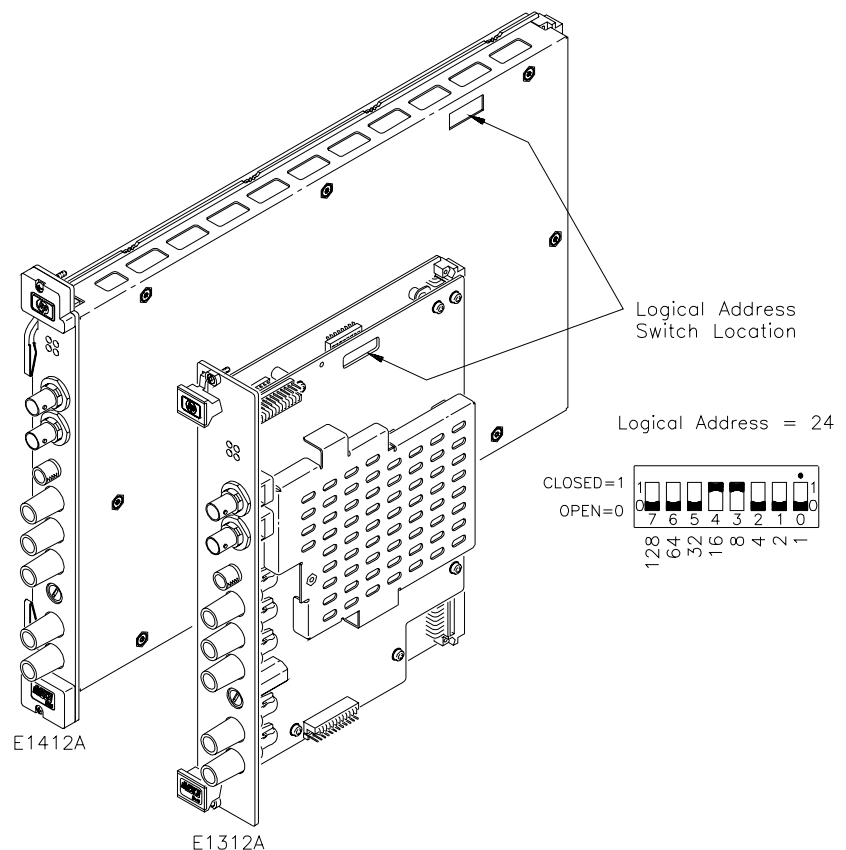


Figure 1-1. Setting the Logical Address

Interrupt Priority

The HP E1312A and E1412A Multimeter are VXIbus interrupters. However, there is no interrupt priority level setting to be made on the module. Interrupt priority level, setup and activation are configured on the resource manager which is the interface to the VXIbus and contains any instrument drivers required to communicate with a VXI module. Your resource manager could be a VXI command module, embedded PC controller, the PC-based VXLINK Interface (ISA-to-VXI), the Series 700 workstation VXI-MXIbus interface or another VXI controller. To configure the interrupt priority on the HP E1405B and E1406A Command Modules, you would use the DIAGNOSTIC :INTERRUPT command subsystem. Refer to your resource manager's documentation for information on setting the system's interrupt priority.

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 ohms 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:LFFREQUENCY command to set the line frequency reference. The default setting at power-on 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:LFFREQUENCY? 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

Checking the Line Frequency Reference

The CALIBRATION:LFFREQUENCY? command returns the present setting of the power line frequency reference. The command returns "+50" or "+60". For a setting of 400 Hz, "+50" is returned since 50 Hz is a sub harmonic of 400 Hz.

Front Panel Indicator

"Failed" turns on momentarily during the multimeter's power-on self-test. If the multimeter successfully establishes internal communication, the indicator turns off. If the multimeter fails to establish internal communication, the indicator remains on.

"Access" turns on only when the resource manager is communicating with the multimeter.

"Errors" turns on only when an error is present in the multimeter's error queue. The error can result from improperly executing a command or the multimeter being unable to pass self-test or calibration. Use the SYST:ERR? command repeatedly to read and clear the error queue (or use *CLS to clear the error queue without reading the errors). A response of +0,"No error" indicates the error queue is empty. See Appendix B, HP E1312A and E1412A Multimeter Error Messages, for a list of all errors.

"Sample" turns on while the multimeter is sampling the input for a measurement. The "Sample" indicator typically will blink.

Input Terminals

The multimeter's front panel contains terminals for connecting input signals, receiving external trigger signals and accessing the voltmeter complete pulse.

NOTE: The outer shells of the "Trig" and "VM Complete" BNC connectors are connected to chassis as is the knurled knob above the HI terminal.

NOTE

The HP E1412A front panel layout is shown in this figure; HP E1312A front panel indicators and input terminal layout is dimensionally the same as this figure.

Figure 1-2. Multimeter Measurement Terminals.

Multimeter Functional Connections

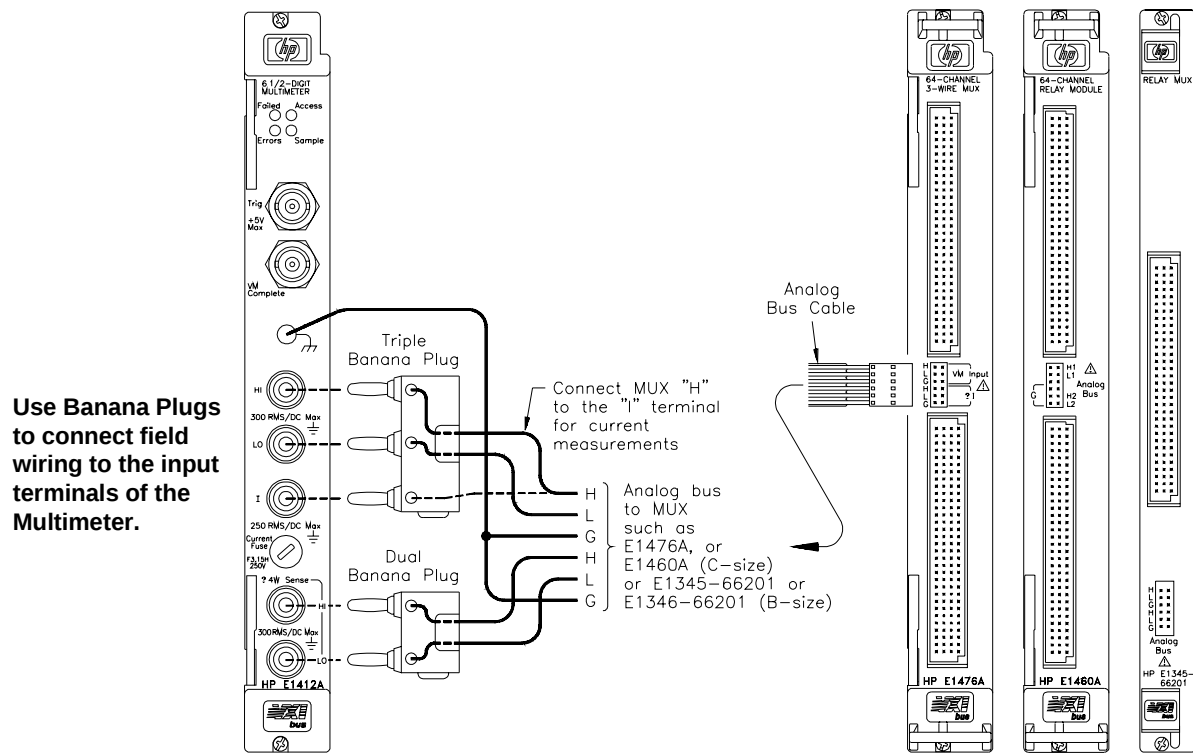


Figure 1-3. Switch Module Analog Bus Connections

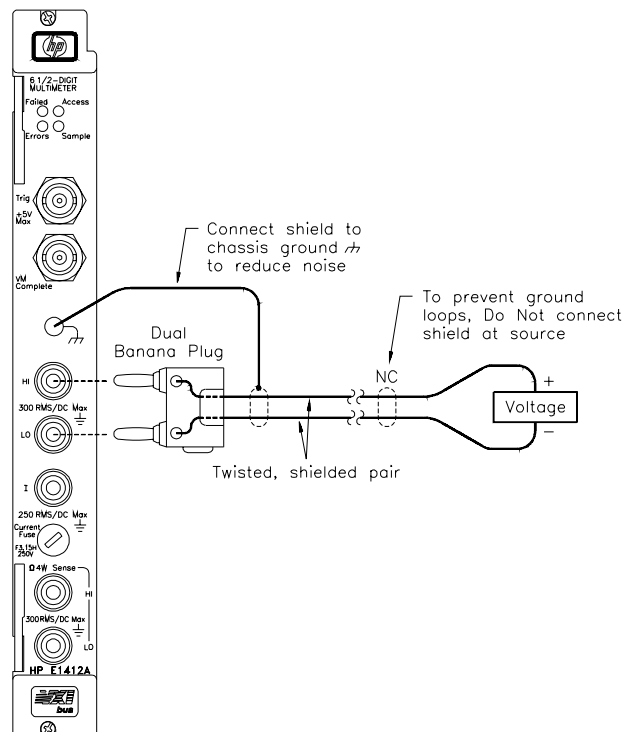


Figure 1-4. Voltage Measurement Connections

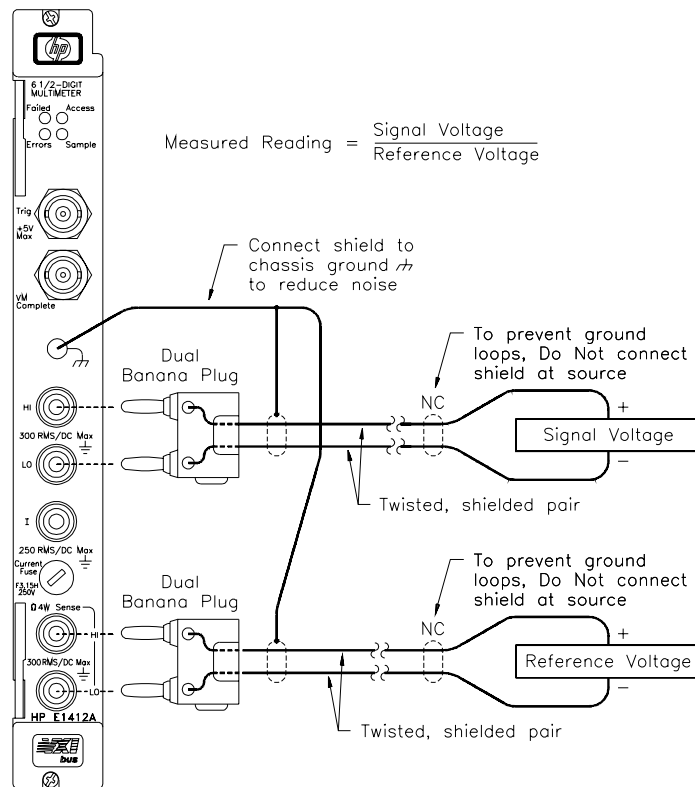


Figure 1-5. Voltage Ratio (Vdc) Measurement Connections

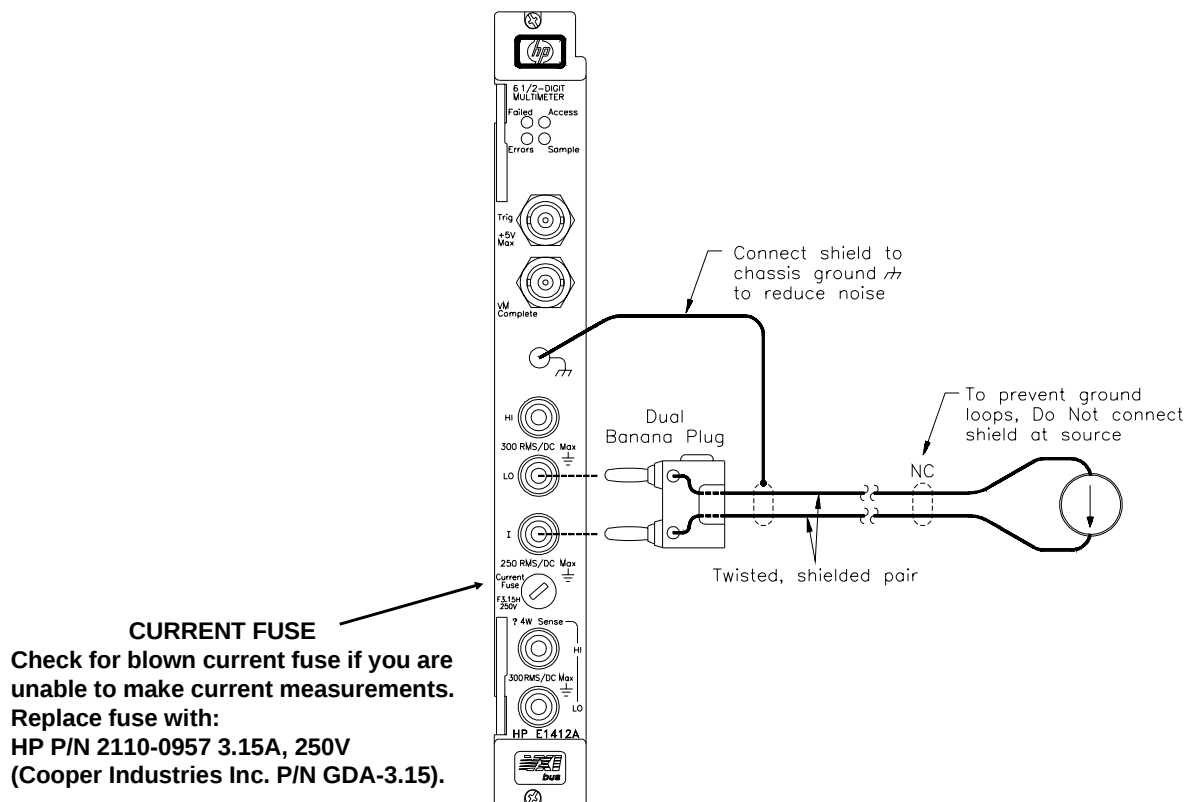


Figure 1-6. Current Measurement Connections

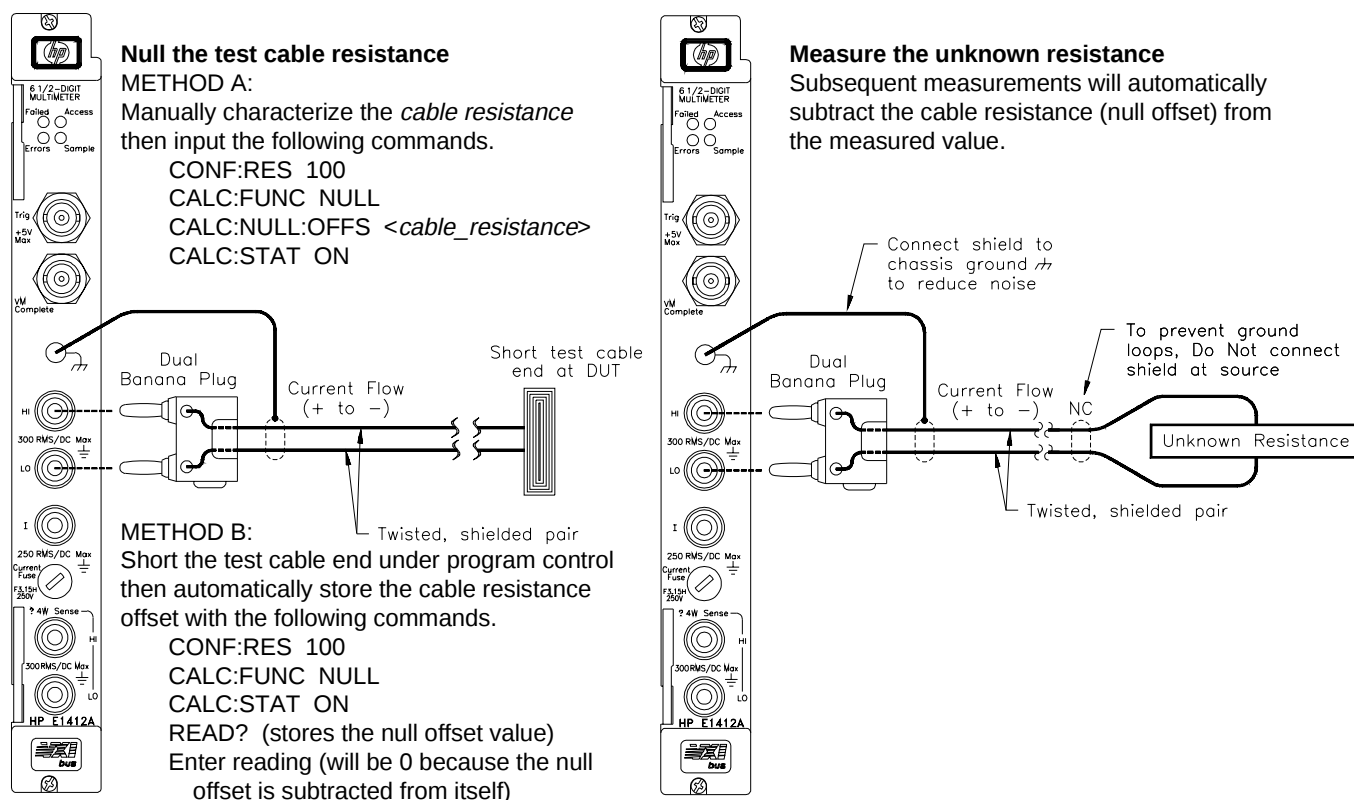


Figure 1-7. 2-Wire Ohms Measurement Connections

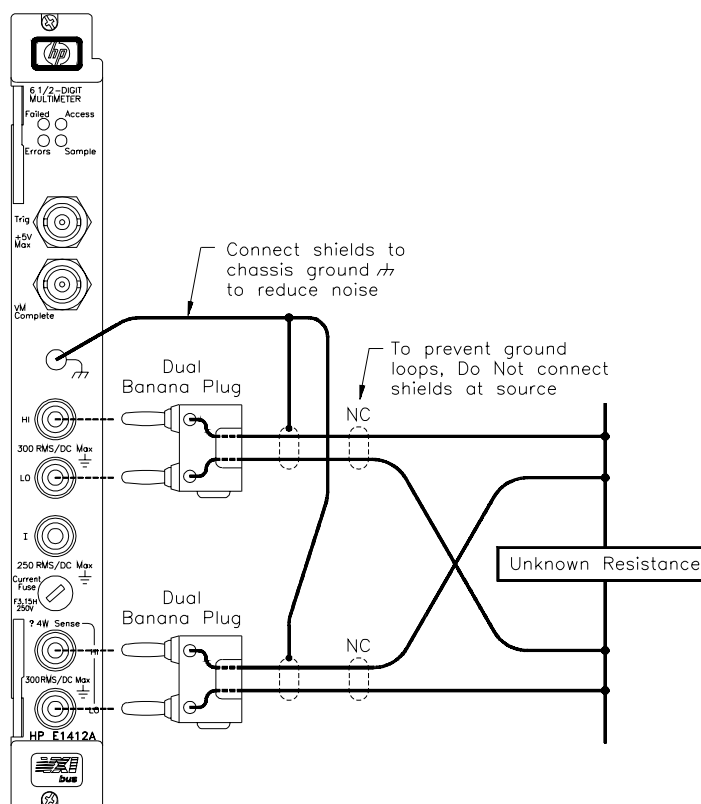


Figure 1-8. 4-Wire Ohms Measurement Connections

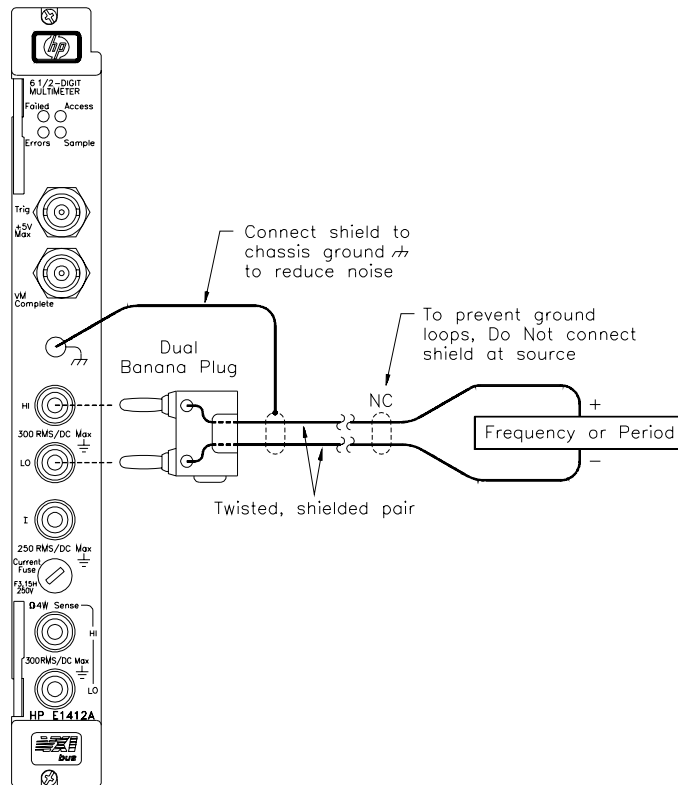


Figure 1-9. Frequency or Period Measurement Connections

Initial Operation

To program the Multimeter using SCPI, you must select the interface address and SCPI commands to be used. General information about using SCPI commands is presented at the beginning of Chapter 3. See the HP 75000 Series C Installation and Getting Started Guide for interface addressing.

Note

This discussion applies only to SCPI (Standard Commands for Programmable Instruments) programming. The program is written using VISA (Virtual Instrument Software Architecture) function calls. VISA allows you to execute on *VXIplug&play* system frameworks that have the VISA I/O layer installed (visa.h include file).

Programming the Multimeter

Example: Perform a Self-Test of the Multimeter and Read the Result.

Programming the multimeter using Standard Commands for Programmable Instruments (SCPI) requires that you select the controller language (e.g., C, C++, Basic, etc.), interface address and SCPI commands to be used. See the "C-Size Installation and Getting Started Guide" (or equivalent) for interfacing, addressing and controller information.

The following C program verifies communication between the controller, mainframe and multimeter. It resets the module (*RST), queries the identity of the module (*IDN?) and initiates a self-test of the multimeter.

```
#include <stdio.h>
#include <visa.h>

/** FUNCTION PROTOTYPE **/
void err_handler (ViSession vi, ViStatus x);

void main(void)
{
    char buf[512] = {0};

    #if defined(_BORLANDC_) && !defined(_WIN32_)
        _InitEasyWin();
    #endif

    ViStatus err;
    ViSession defaultRM;
    ViSession dmm;

    /* Open resource manager and multimeter sessions. */
    viOpenDefaultRM (&defaultRM);
    viOpen(defaultRM, "GPIB-VXI0::9::24", VI_NULL, VI_NULL, &dmm);
```

```

/* Set the timeout value to 10 seconds. */
viSetAttribute (dmm, VI_ATTR_TMO_VALUE, 10000);

/* Reset the module. */
err = viPrintf (dmm, "*RST/n");
if (err<VI_SUCCESS) err_handler (dmm, err);

/* Query the module identification. */
err = viPrintf(dmm, "*IDN?/n");
if (err<VI_SUCCESS) err_handler (dmm, err);
err = viScanf(dmm, "%t", buf);
if (err<VI_SUCCESS) err_handler (dmm, err);
printf ("Module ID = %s/n/n", buf);

/* Perform a module self-test. */
err = viPrintf (dmm, "*TST?/n");
if(err<VI_SUCCESS) err_handler (dmm, err);
err = viScanf (dmm, "%t", buf);
if (err<VI_SUCCESS) err_handler (dmm, err);
printf ("Self-test response = %s/n/n", buf);

/* Check for system errors. */
err = viPrintf (dmm, "SYST:ERR?/n");
if (err<VI_SUCCESS) err_handler (dmm, err);
err = viScanf (dmm, "%t", buf);
if (err<VI_SUCCESS) err_handler (dmm, err);
printf ("System error response = %s/n/n", buf);

} /* end of main */

**** Error handling function ****/

void err_handler (ViSession dmm, ViStatus err)
{
    char buf[1024] = {0};

    viStatusDesc (dmm, err, buf);
    printf ("ERROR = %s/n", buf);
    return;
}

```

HP E1312A/E1412A Multimeter Application Information

Using this Chapter

This chapter provides multimeter application information in five parts.

- Measurement Tutorial.
- Measurement Configuration.
- Math Operations.
- Triggering the Multimeter.
- HP E1312A and HP E1412A Multimeter Application Examples.

Measurement Tutorial

The HP E1312A and E1412A are 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

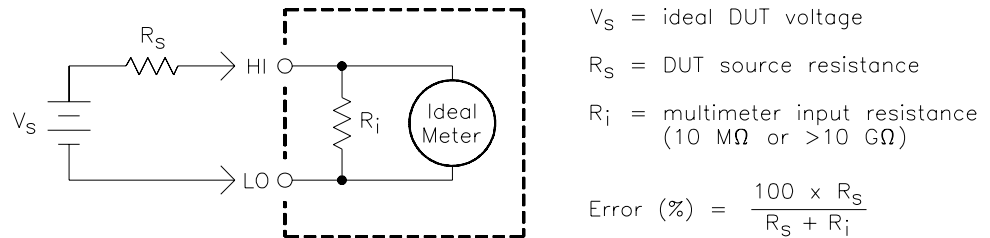
Thermal EMF Errors

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. The table below shows common thermoelectric voltages for connections between dissimilar metals.

Copper-to-	Approx. $\mu\text{V}/^{\circ}\text{C}$
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

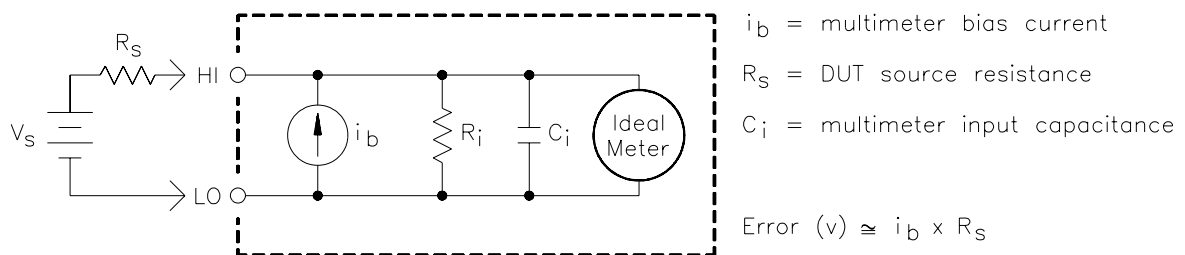
The HP E1312A and HP E1412A input terminals are copper alloy.

Loading Errors (dc volts) 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 G Ω for the 100 mVdc, 1 Vdc, and 10 Vdc ranges. The input resistance is maintained at 10 M Ω for the 100 Vdc and 300 Vdc 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 G Ω). The multimeter's measuring circuitry exhibits approximately 30 pA of input bias current for ambient temperatures from 0°C to 30°C. Bias current will double ($\times 2$) for every 8°C change in ambient temperature above 30°C. This current generates small voltage offsets dependent upon the source resistance of the device-under-test. This effect becomes evident for a source resistance of greater than 100 k Ω , or when the multimeter's operating temperature is significantly greater than 30°C.



Rejecting Power Line Noise Voltages

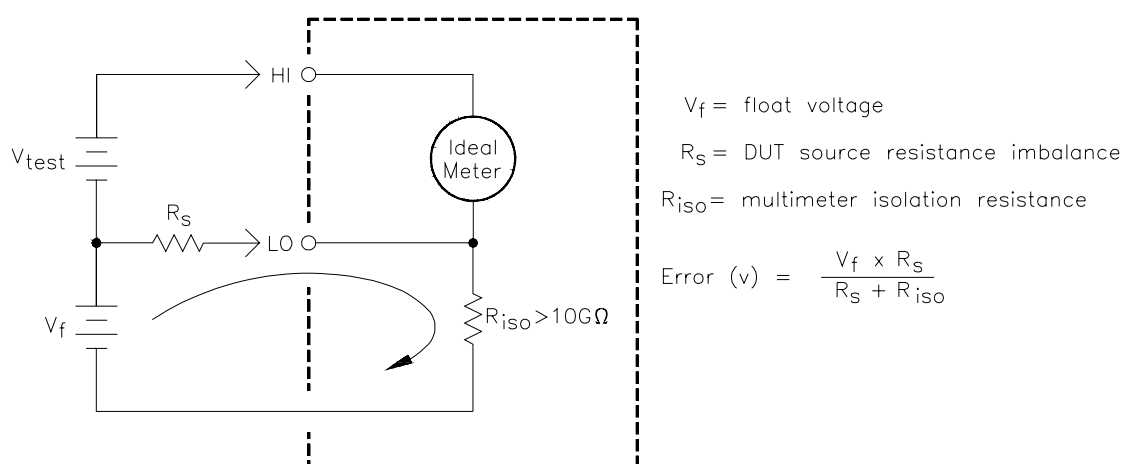
A desirable characteristic of integrating analog-to-digital (A/D) converters is their ability to reject spurious signals. The integrating techniques reject power-line related noise present with a dc signal on the input. This is called *normal mode rejection* or NMR. Normal mode noise rejection is achieved 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 HP E1312A and E1412A provide three A/D integration times (1, 10 and 100 PLCs) to reject power line frequency noise (and power-line frequency harmonics). 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. The table below shows the noise rejection achieved with various configurations. Select a longer integration time for better resolution and increased noise rejection.

Power Line Cycles (PLCs)	Integration Time		NMR
	60 Hz	(50Hz)	
0.02	400 μ s	(400 μ s)	NONE
0.2	3 ms	(3 ms)	NONE
1	16.7 ms	(20 ms)	60 dB
10	167 ms	(200 ms)	60 dB
100	1.67 sec	(2 sec)	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.



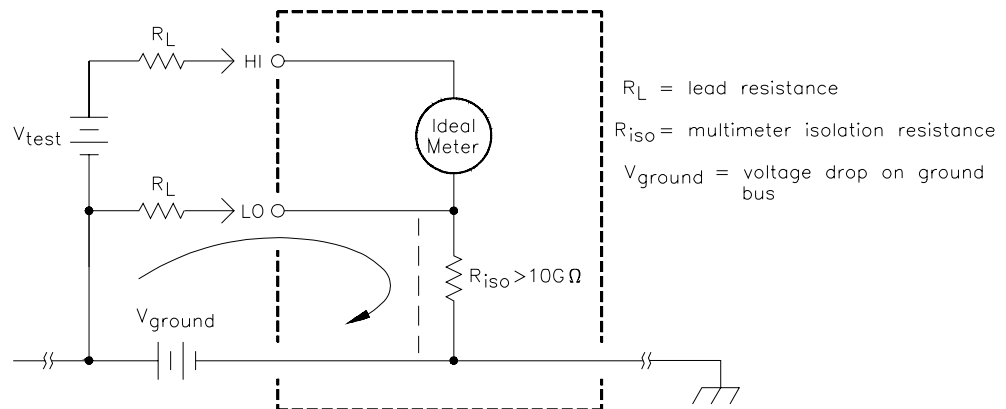
Noise Caused by Magnetic Loops

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 problem magnetic field sources.

Noise Caused by Ground Loops

When measuring voltages in circuits where the multimeter and the device-under-test 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 device-under-test, to the same common ground point. This will reduce or eliminate any voltage difference between the devices. Also make sure the multimeter and device-under-test are connected to the same electrical outlet whenever possible.



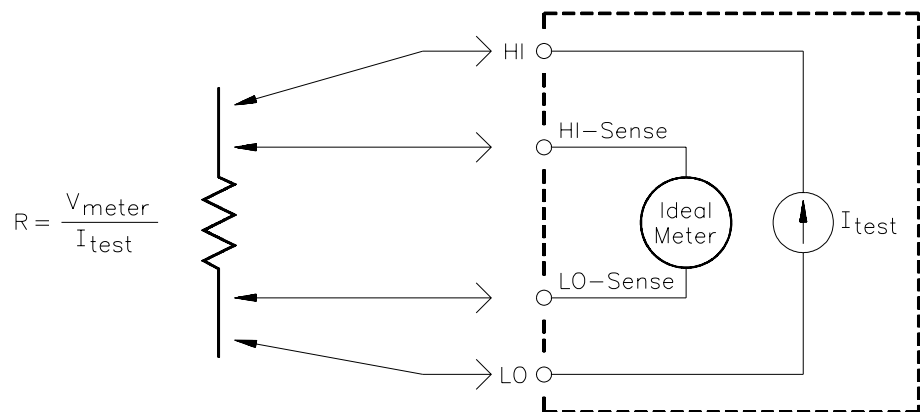
Resistance Measurements

The HP E1312A and HP E1412A offer two methods for measuring resistance: 2-wire and 4-wire ohms. For both methods, the test current flows from the input HI terminal and then through the resistor being measured. For 2-wire ohms, the voltage drop across the resistor being measured is sensed internal to the multimeter. Therefore, input cable resistance is also measured. For 4-wire ohms, separate “sense” connections are required. Since no current flows in 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 Ohms Measurements

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



Removing Field Wiring Resistance Errors in 2-Wire Ohms 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 ohms measurements. You short the field wiring at the DUT location and measure the 2-wire lead resistance. This value is subtracted from subsequent DUT 2-wire ohms 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).

See the next page for SCPI examples to store a NULL value.

CONF:RES *Set to 2-wire ohms function*
 short the lead resistance at the DUT location
 READ? *Measure the 2-wire ohms lead resistance*
 enter lead resistance value into computer
 CALCulate:FUNctioN NULL *Set math operation to NULL*
 CALCulate:STATe ON *Turn math operation ON*
 CALCulate:NULL:OFFSet <value> *Store the NULL offset value*

Subsequent 2-wire ohms 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.

CONF:RES *Set to 2-wire ohms function*
 short the lead resistance at the DUT location
 CALCulate:FUNctioN NULL *Set math operation to NULL*
 CALCulate:STATe ON *Turn math operation ON*
 READ? *Measure the 2-wire ohms lead resistance*
 Enter lead resistance value into 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.
 READ? *Make a 2-wire ohms resistance measurement*
 Enter lead resistance value into 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 device-under-test. If power dissipation is a problem, you should select the multimeter's next higher measurement range to reduce the errors to acceptable levels. The following table shows several examples.

Range	Test Current	DUT Power at Full Scale
100 Ω	1 mA	100 μ W
1 k Ω	1 mA	1 mW
10 k Ω	100 μ A	100 μ W
100 k Ω	10 μ A	10 μ W
1 M Ω	5 μ A	25 μ W
10 M Ω	500 nA	2.5 μ W

Settling Time Effects

Both the HP E1312A and HP E1412A have 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 k Ω . Settling due to RC time constant effects can be quite long. Some precision resistors and multi-function calibrators use large parallel capacitors (1000 pF to 0.1 μ F) 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 you are 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 ohms) when compared to PTFE Teflon[®] insulators (10^{13} ohms). Leakage from nylon or PVC insulators can easily contribute a 0.1% error when measuring a 1 M Ω resistance in humid conditions.

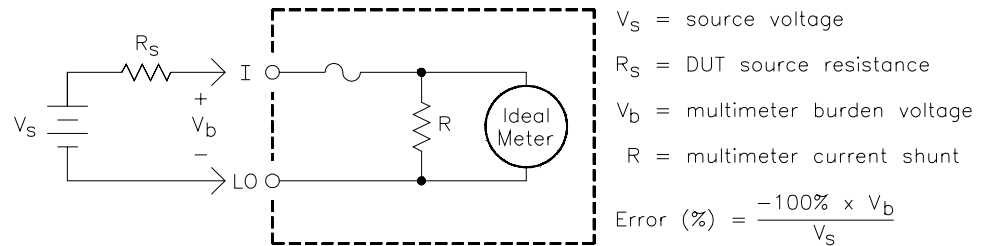
Teflon is a registered trademark of E.I. duPont deNemours and Co.

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.

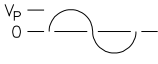
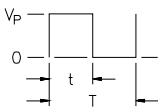
DC Current Measurement Errors

When you connect the multimeter in series with a test circuit to measure current, a measurement error is introduced. The 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 responding multimeters, like the HP E1312A and HP E1412A, 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 by 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 are 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 power line cycles of integration (6 digit mode) 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.” Actually, the shape of the input signal can dramatically affect measurement accuracy. A common way to describe signal waveshapes is *crest factor*. 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 $\sqrt{\frac{T}{t}}$.

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. HP E1312A and HP E1412A crest factor errors are shown in the AC Characteristics Accuracy Specifications listed in Appendix A 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:

$$\text{Total Error} = \text{Error (sine)} + \text{Error (crest factor)} + \text{Error (bandwidth)}$$

Error (sine): error for sinewave as shown in Appendix A, Specifications.
Error (crest factor): crest factor additional error as shown in Appendix A.
Error (bandwidth): estimated bandwidth error as shown below.

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

C.F. = signal’s crest factor

f = signal’s fundamental frequency

BW = multimeter’s -3 dB bandwidth (1 MHz for the HP E1312A/E1412A)

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:
 $\pm (0.05\% + 0.03\%)$.

$$\text{Total Error} = 0.08\% + 0.15\% + 1.4\% = 1.6\%$$

Loading Errors (ac volts) In the ac voltage function, the input of the HP E1312A and HP E1412A 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 $(f \times R_s) \leq 15(10^6) \Omega \cdot \text{Hz}$:

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

For any frequency:

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

R_s = source resistance

f = input frequency

C_{in} = 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 $\leq 10\%$ and $\geq 120\%$ 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., 10V on the 10V range or 10V on the 100V range). The accuracy will be significantly different for these two cases. For highest accuracy, you should specify the range to assure the lowest range possible for the measurement (this turns autorange off).

Function and Range Change Internal Offset Correction The HP E1312A and HP E1412A uses an ac measurement technique that measures and removes internal offset voltages when you select a different function or range. The next two sections discuss two ways these offset errors can be generated and how the multimeter deals with them.

Temperature Coefficient Errors If you leave the multimeter in the same range for an extended period of time, and the ambient temperature changes significantly (or if the multimeter is not fully warmed up), the internal offsets may change. This temperature coefficient is typically 0.002% of range per °C and is automatically removed when you change functions or ranges.

Overload Errors When you specify a new range in an *overload condition*, the internal offset measurement may be degraded for the selected range. Typically, an additional 0.01% of range error may be introduced. This additional error is automatically removed when you remove the overload condition and change function or range; the error remains if the function or range is not changed.

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 some loading error.

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

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

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 "backwards." Ideally, a multimeter reads the same regardless of how the source is connected. 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 HP E1312A and HP E1412A), 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 100Vac and 300Vac 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 7 seconds, and is useful for frequencies above 3 Hz.

With a few precautions, you can perform ac measurements at speeds up to 50 readings per second. Use manual ranging to eliminate autoranging delays. By setting the preprogrammed settling (trigger) delays to 0, each filter 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 5 readings per second, and the fast filter will provide reduced accuracy results at 50 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 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.

Measurement Configuration

This section contains information to help you configure the multimeter for making measurements. The parameters discussed in this section give you measurement flexibility when using the CONFigure command.

AC Signal Filter The HP E1412A Multimeter has three different ac filters which enable you to either optimize low frequency accuracy or achieve faster ac settling times for ac voltage or ac current measurements. Only these functions use the ac filter.

AC Voltage or Current Input Frequency	AC Filter Selected	Max Reading Rate for Adequate Settling
3 Hz to 300 kHz	Slow filter	1 reading/ 7 seconds
20 Hz to 300 kHz	Medium filter	1 reading/second
200 Hz to 300 kHz	Fast filter	10 readings/second

NOTE: These reading rates account for only the AC filters behavior. See Page 33 for the effect of DC blocking circuitry.

- The ac filter selection is stored in volatile memory. 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 HP E1412 Multimeter's input resistance is normally fixed at 10 M Ω for all dc voltage ranges to minimize noise pickup. You can set the input resistance to greater than 10 G Ω for the 100 mVdc, 1 Vdc and 10 Vdc ranges to reduce the effects of measurement loading errors. You select increased input resistance using the INPut:IMPedance:AUTO ON command and this applies to the dc voltage function only.

	DC Input Resistance 100 mV, 1V, 10V ranges	DC Input Resistance 100V and 300V ranges
INP:IMP:AUTO OFF (DEFAULT)	10 M Ω	10 M Ω
INP:IMP:AUTO ON	>10 G Ω	10 MW

- 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 number of digits the multimeter can measure. You can set the resolution to 4 1/2, 5 1/2 or 6 1/2 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.

The resolution for math operations is the same resolution for the measurement function being measured. The table below illustrates the correlation between Number of Power Line Cycles and Resolution. See the tables at the beginning of Chapter 3, Command Reference, for detailed cross-reference of function ranges to resolution as a function of NPLCs or Aperture Time.

Number of Power Line Cycles (NPLC)	Resolution
0.02	0.0001 X Full-Scale
0.2	0.00001 X Full-Scale
1	0.000003 X Full-Scale
10	0.000001 X Full-Scale
100	0.0000003 X Full-Scale

- 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 4W 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
```

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 four-wire resistance functions only. The integration time for the math operations is the same as the integration time for the measurement function in use.
- Except for FREQuency and PERiod functions, integration time is usually specified in number of power line cycles (NPLC). The default NPLC is 10. You can also specify an integration time in seconds for dc voltage, dc current, resistance, four-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 which do not use NPLC) and is shown in the tables at the beginning of Chapter 3, Command Reference. 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 following information for FREQuency and PERiod aperture time.
- Only integral numbers of power line cycles (1, 10 or 100 PLCs) provide normal mode (line frequency noise) rejection.
- You cannot control the reading rate for ac measurements with integration time because integration time is fixed at 10 PLCs for all ac measurements. You must use a trigger delay to pace ac voltage and ac current measurements.
- NPLCs are not applicable to the FREQuency and PERiod functions. Frequency and period measurements set resolution by specifying aperture time. The aperture time for the FREQuency and PERiod functions default to 100 mS. Specify an aperture time of 10 mS for 4 1/2 digits, 100 mS for 5 1/2 digits or 1 second for 6 1/2 digits of resolution.
- Set integration time using the following commands:

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

Autozero Autozero applies to dc voltage, dc current and 2-wire resistance measurements. The multimeter internally disconnects the input signal following each measurement and takes a *zero reading* when autozero is enabled. Autozero enabled is the default setting. It then subtracts the zero reading from the preceding reading. This prevents offset voltages present on the multimeter's input circuitry from affecting measurement accuracy.

- 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 function, range or integration time. You can disable autozero on dc voltage, dc current and 2-wire ohms measurements only (it is always disabled for ACV and ACI functions). Autozero is always enabled when you select 4-wire ohms or ratio measurements.
- The autozero mode is stored in volatile memory. The multimeter automatically enables autozero at power-on and after a module reset.
- 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:]ZERO:AUTO OFF|ONCE|ON

Ranging You can let the multimeter automatically select the range using autoranging or you can specify a range. If you specify an expected value for the signal you are measuring, the multimeter selects the range to accommodate the expected input signal and turns autoranging off. Specify a range for faster measurements to eliminate the autoranging time.

- The multimeter has autorange mode enabled at power-on and after a module reset.
- Autorange thresholds:
Down range at <10% of range.
Up range at >120% of range.
- 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 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 "3 Hz". 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
```

Math Operations (CALCulate Subsystem)

This section provides more information about using the math functions in the CALCulate command. The math operations and registers used to store mathematical data are controlled using the CALCulate command subsystem. See Chapter 3, HP E1312A and HP E1412A multimeter Command Reference. There are two steps to initiating a math operation.

1. Select the desired math function:

CALCulate:FUNCTION NULL | DB | DBM | AVERage | LIMit

2. Enable the selected math function by turning the calculate state on:

CALCulate:STATe ON

AVERage Function The AVERage function allows you to store the minimum and the maximum reading from a group of measurements then calculate the average value of all the readings. It also records the number of readings taken since the average function was activated.

The first reading that the multimeter takes is stored as both the minimum and maximum value following activation of the average function. The minimum value is replaced with any subsequent value that is less. The maximum value is replaced with any subsequent value that is greater.

The minimum, maximum, average and count are stored in volatile memory. The multimeter clears the values when the average function is turned on, when power is turned off or after the module is reset.

You use the following commands to activate the average function and query the results from the group of measurements made following activation.

CALCulate:FUNCTION AVERage	<i>selects the average function</i>
CALCulate:STATe OFF ON	<i>activates the average function</i>
<i>take measurements here</i>	
CALCulate:AVERage:MINimum?	<i>read the minimum value</i>
CALCulate:AVERage:MAXimum?	<i>read the maximum value</i>
CALCulate:AVERage:AVERage?	<i>read the average value</i>
CALCulate:AVERage:COUNt?	<i>read the number of measurements</i>

NULL (Relative) Function A null measurement, also called relative, provides the difference between a stored null value and the input signal. One possible application is in making more accurate two-wire ohms measurements by nulling the test lead resistance.

Result = reading - null value

- Does not apply to the DC-to-DC Ratio measurements.

Two Ways to Store the NULL Offset Value

- The null value is adjustable and you can set it to any value between 0 and $\pm 120\%$ of the highest range, for the present function.
- Clearing the NULL value. The null value is stored in volatile memory; the value is cleared when power is removed, after resetting the multimeter or after a function change.
- The null value is stored in the multimeter's Null Register. 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>	<i>clears the null offset value</i>
CALCulate:FUNCTION NULL	<i>set math function to NULL</i>
CALCulate:STATe ON	<i>enable math operation</i>
CALCulate:NULL:OFFSet <value>	<i>store a null offset value</i>

- Another way to enter the 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). 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 <value> as in the commands in the above bullet, the first reading does not overwrite the stored offset value but returns with the previous offset value subtracted.

CONF:<function>	<i>clears the null offset value</i>
CALCulate:FUNCTION NULL	<i>set math function to NULL</i>
CALCulate:STATe ON	<i>enable math operation</i>
<i>** set up the system to generate the offset of concern (e.g., short</i>	
<i>** input leads for 2-wire ohms measurements that will follow)</i>	
READ?	<i>measures and stores the offset value</i>

dB Measurements Each dB measurement is the difference between the input signal and a stored relative value, with both values converted to dBm.

dB = reading in dBm - relative value in dBm

- Applies to dc voltage and ac voltage measurements only.
- The relative value is adjustable and you can set it to any value between 0 dBm and ± 200.00 dBm (well beyond the multimeter's measurement capabilities).
- Clearing the relative value. The relative value is stored in volatile memory; the value is cleared when power is removed, after the module is reset or after a function change.

Storing the dB Reference Value

Do not confuse this operation with the dBm reference (DBM) function. See the next section, "dBm Measurements", and take note of the multimeter's reference resistance setting (dB uses a reference level, dBm uses a reference resistance).

- The dB reference value is stored in the multimeter's dB Relative Register. You can enter a specific number into the register using the CALCulate:DB:REfERENCE <value> command. Any previously stored value is replaced with the new value. Use the following commands to activate the dBm function and input a reference value. The calculate state must be enabled before you can store a value in the dB Relative Register.

CALCulate:FUNCTION DB	<i>set math function to DB</i>
CALCulate:STATe ON	<i>enable math operation</i>
CALCulate:DB:REfERENCE <value>	<i>store a dB reference value</i>

dBm Measurements The dBm operation calculates the power delivered to a resistance referenced to 1 milliwatt.

$$\text{dBm} = 10 \times \log_{10} \frac{\text{reading}^2}{(\text{reference resistance}) \times (1 \text{ mW})}$$

- Applies to dc voltage and ac voltage measurements only.
- You can choose from 17 different reference resistance values. The factory setting for the reference resistance is 600Ω. Set your desired value with the CALC:DBM:REF <value> command.

The choices for <value> are: 50, 75, 93, 110, 124, 125, 135, 150, 250, 300, 500, 600, 800, 900, 1000, 1200, or 8000 ohms.

- The reference resistance is stored in non-volatile memory, and does not change when power is removed or after the multimeter is reset.

Storing the dBm Reference Resistance Value

Do not confuse this operation with the dB reference (DB) function. See the previous section, "dB Measurements", and take note of the multimeter's dB reference setting (dB uses a reference level, dBm uses a reference resistance).

- Use the following commands to activate the dBm function and input a reference resistance value. The calculate state must be enabled before you can store a value in the Reference Resistance Register.

CALCulate:FUNCTION DBm	<i>set math function to DBm</i>
CALCulate:STATe ON	<i>enable math operation</i>
CALCulate:DBM:REfERENCE <value>	<i>store a dBm reference</i>

LIMit Function The limit test operation enables you to perform pass/fail testing against limits you specify using the CALCulate:LIMit:UPPer and LOWer commands.

- Applies to all measurement functions.
- You can set the upper and lower limits to any value between 0 and $\pm 120\%$ of the highest range, for the present function. The upper limit selected should always be a more positive number than the lower limit. The default upper and lower limits are both "0".
- The upper and lower limits are stored in volatile memory; the multimeter sets both limits to 0 when power is removed from the multimeter, after the multimeter is reset or after a function change.
- You can configure the multimeter to generate a request for service (SRQ) on the first occurrence of a failed reading. See the Status System Register Diagram in the STATus command in Chapter 3, Command Reference. Bits 11 and 12 of the Questionable Data Register provide the high and low limit error signals that can be enabled in the status byte to generate the request for service.
- Use the following commands to activate the LIMit function and input upper and lower limit values. The calculate state must be enabled before you can store a value in the Upper Limit and Lower Limit Registers.

```
CALCulate:FUNCtion LIMit
CALCulate:STATe ON
CALCulate:LIMit:UPPer <value>
CALCulate:LIMit:LOWer <value>
```

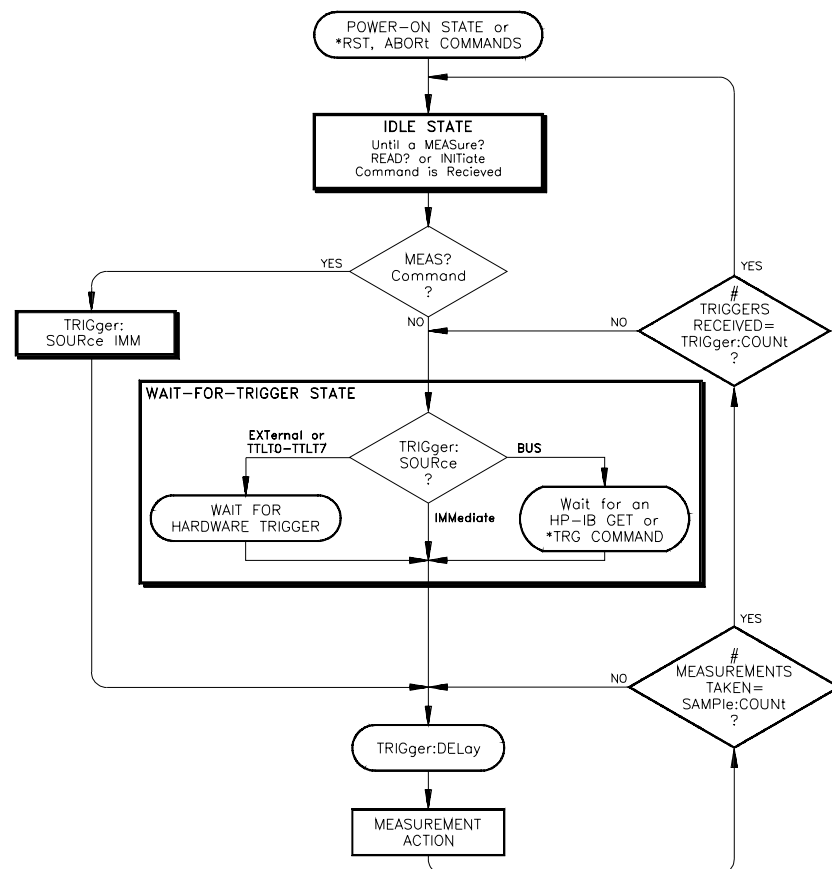
- The STATus:QUEStionable:CONDition register will indicate when an upper or lower limit has been exceeded failing either a HI or LO limit test. Use the STAT:QUES[:EVEN]? command to query the status questionable register and determine what failure occurred. Sending this command also clears the questionable data register (or send a Clear Status *CLS command to clear the register before testing begins).

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 MEASure and CONFigure commands. However, you'll need the information in this section to take advantage of the flexibility of the HP E1312A/E1412A trigger system when using the CONFigure command.

The multimeter's trigger system synchronizes measurements with specified internal or external events. These events include software trigger commands, negative-going edges on the VXIbus trigger lines (TTLT0 - TTLT7), and negative-going pulses on the multimeter's external trigger ("Trig") BNC connector. 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 between the trigger and each reading.

The diagram below illustrates 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.



Triggering the multimeter is a multi-step process.

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 from the VXIbus, an external trigger from the front panel "Trig" BNC connector or an immediate trigger from the multimeter's internal trigger system.
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 MEAS:<FUNC>? command always uses an immediate trigger (see the flow chart on the preceding page).

The 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:

- **BUS:** Trigger source is the HP-IB Group Execute Trigger (GET) or the *TRG common command. Within the HP 75000 Series C mainframes, the instrument whose trigger source is "BUS" and was the last instrument addressed to listen will respond to the HP-IB Group Execute Trigger. The *TRG command differs from GET because it is sent to a specific instrument not a group of instruments. NOTE: B-size controllers do not support the BUS trigger (e.g., HP E1306A command module, E1300/E1301A B-size mainframes).
- **EXternal:** Trigger source is the multimeter's external trigger BNC connector (labeled "Trig" on the front panel). A falling (negative-going) edge of the input signal triggers the multimeter. The external pulse signal must be >1 μ s, +5V maximum to 0V (TTL levels).
- **IMMediate:** Internal trigger is always present. If the multimeter is in the wait-for-trigger state (INITiate), TRIGger:SOURce IMMediate sends the trigger. The MEASure and CONFigure commands automatically set the trigger source to IMMediate.
- **TTLTrg0 through TTLTrg7:** Trigger source is the VXIbus TTL trigger lines. The multimeter is triggered on the falling (negative-going) edge of a TTL input signal. NOTE: B-size controllers do not support VXIbus TTL triggers (e.g., HP E1306A command module, E1300/E1301A B-size mainframes).

For example, the following program statement selects the external trigger BNC connector as the trigger source.

```
TRIGger:SOURce EXternal
```

You can change the trigger source only when the multimeter is in the idle state. Attempting to change the trigger source while the multimeter is in the wait-for-trigger state will generate the “Settings conflict” error.

Checking the Trigger Source

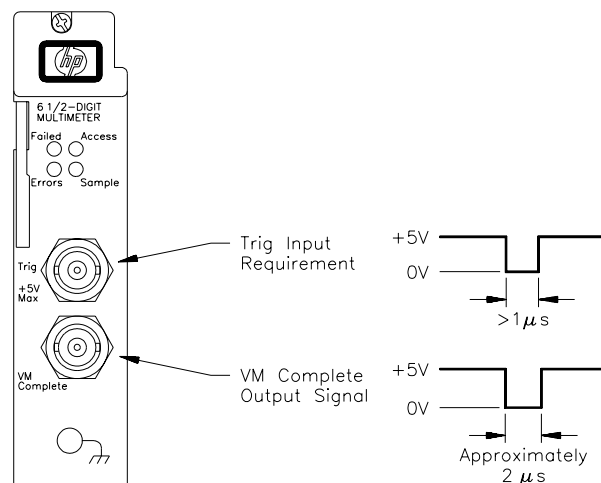
The TRIGger:SOURce? command returns “BUS”, “EXT”, “IMM”, or “TTLTrn” to show the present trigger source. The string is sent to the output buffer.

NOTE

Note that a CONFigure or MEASure? command automatically sets the trigger source to IMMEDIATE. You must follow the CONFigure command with the TRIG:SOUR command to set the trigger source to BUS, EXTERNAL or to TTLTrg<n>. The MEAS? command always uses TRIG:SOUR IMM.

External Triggering 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 μ s. The trigger signal level accepted is TTL (+5V maximum negative-going to 0V). See the following diagram for the "Trig" input requirement. The diagram also shows the "VM Complete" output you can use to synchronize with a switch module.



- The multimeter takes one reading (or the number specified by SAMPLE:COUNT) for each external trigger received on the front panel "Trig" BNC connector.

Internal Triggering 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 at the beginning of this "Triggering" section.

Bus Triggering The multimeter is triggered from the VXIbus. This mode is selected with the TRIGger:SOURce BUS command.

NOTE
TRIG:SOUR BUS is not implemented on B-size resource managers such as the E1306A command module or the E1300A and E1301A B-size mainframes.

- Use the *TRG command from the GPIB to trigger the multimeter when TRIG:SOUR BUS is used. The *TRG command will not be accepted unless the multimeter is in the wait-for-trigger state.
- You can also trigger the multimeter from the HP-IB interface by sending the IEEE-488 Group Execute Trigger (GET) message. The multimeter must be in the wait-for-trigger state. Send a GET from a Hewlett-Packard controller with the following command:

TRIGGER 70903

The 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 20 ms of set up time after you send a command to change to the "wait-for-trigger" state. Any triggers that occur during this set up time are ignored.

The Trigger Count The TRIGger:COUNt <number> command sets the number of triggers the multimeter will accept in the wait-for-trigger state before returning to the idle state. Use the *number* parameter to set the trigger count to a value between 1 and 50,000. The MEASure and CONFigure commands set trigger count to 1.

Substituting MIN for the *number* parameter sets the trigger count to 1.
 Substituting MAX for the *number* parameter sets the trigger count to 50,000.

Example: Setting the Trigger Count In the following example, one DC voltage measurement is made each time the multimeter's external trigger BNC connector is pulsed low. After 10 external triggers are received, the multimeter returns to the idle state.

dimension array	<i>Dimension computer array</i>
CONF:VOLT:DC	<i>Function: DC voltage</i>
TRIG:SOUR EXT	<i>Trigger source is external BNC on multimeter front panel</i>
TRIG:COUN 10	<i>Multimeter will accept 10 external triggers (one measurement is taken per trigger)</i>
READ?	<i>Place multimeter in wait-for-trigger state; make measurements when external trigger is received; send readings to output buffer</i>
timeout may occur	<i>may require INIT, monitor the status byte for completion (standard event bit 0), FETC? to transfer readings to the output buffer (vs READ?)</i>
enter statement	<i>Enter readings into computer</i>

Checking the Trigger Count The TRIGger:COUNt? [MINimum | MAXimum] command returns one of the following numbers to the output buffer:

- The present trigger count (1 through 50,000) if neither MIN nor MAX is specified.
- The minimum trigger count available (1) if MIN is specified.
- The maximum trigger count available (50,000) if MAX is specified.

Inserting a Trigger Delay The TRIGger:DElay <seconds> command inserts a delay between the trigger and each measurement. This includes a delay between the trigger and the first measurement and again before each subsequent measurement when sample count is greater than one. The <seconds> time parameter sets the delay to a value between 0 and 3600 seconds (with 1 μ s resolution).

Substituting MIN for the <seconds> time parameter sets the trigger delay to 0. Substituting MAX for the <seconds> time parameter sets the trigger delay to 3600 seconds.

Example: Inserting a Trigger Delay

In the following example, the multimeter will accept 5 triggers from the external trigger BNC connector. Four measurements are taken per trigger (sample count is set to 4) and the trigger delay is 2 seconds.

dimension array	<i>Dimension computer array</i>
CONF:VOLT:DC	<i>Function: DC voltage</i>
TRIG:SOUR EXT	<i>Trigger source is external BNC on multimeter front panel</i>
TRIG:COUN 5	<i>Multimeter will accept 5 external triggers (one measurement is taken per trigger)</i>
SAMP:COUN 4	<i>Take 4 measurements for each trigger.</i>
TRIG:DEL 2	<i>Wait 2 seconds between trigger and start of first measurement and each subsequent measurement till sample count reached</i>
READ?	<i>Place multimeter in wait-for-trigger state; make measurements when external triggers are received; send readings to output buffer</i>
timeout may occur	<i>may require INIT, monitor the status byte for completion (standard event bit 0), FETC? to transfer readings to the output buffer (vs READ?)</i>
enter statement	<i>Enter readings into computer</i>

Default Delays If you do not specify a trigger delay, the multimeter automatically determines a delay time (default delay) based on the present measurement function, range, resolution, integration time and AC filter bandwidth setting. The delay time is actually the settling time required before measurements to ensure measurement accuracy. The default delay time is automatically updated whenever you change the function or range. Once you specify a delay time value, however, the value does not change until you specify another value, reset the multimeter or do a CONF or MEAS command. The table below shows the default trigger delay times for all functions. This delay will occur before *each* measurement (see the trigger system diagram on page 34).

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

Default Trigger Delays for DC Voltage and DC Current (all ranges):		
Integration Time		Trigger Delay
NPLC ≥1		1.5 ms
NPLC <1		1.0 ms
Default Trigger Delays for 2-Wire and 4-Wire Resistance:		
Range	Trigger Delay (For NPLC ≥1)	Trigger Delay (For NPLC <1)
100 Ω	1.5 ms	1.0 ms
1kΩ	1.5 ms	1.0 ms
10 kΩ	1.5 ms	1.0 ms
100 kΩ	1.5 ms	1.0 ms
1 MΩ	1.5 ms	10 ms
10 MΩ	100 ms	100 ms
100 MΩ	100 ms	100 ms
Default Trigger Delays for AC Voltage and AC Current (all ranges):		
AC Filter		Trigger Delay
3 Hz - 300 kHz filter		7.0 sec
20 Hz - 300 kHz filter		1.0 sec
200 Hz - 300 kHz filter		600 ms
Default Trigger Delay for Frequency and Period:		
1.0 s		

Querying the Delay Time The TRIGger:DElay? [MINimum|MAXimum] command returns one of the following numbers to the output buffer:

- The present trigger delay (1 μ s through 3600 seconds) if MIN or MAX is not specified.
- The minimum trigger delay available (1 μ s) if MIN is specified.
- The maximum trigger delay available (3600 seconds) if MAX is specified.

The Sample Count The SAMPlE:COUNt <number> command designates the number of readings per trigger. The *number* parameter sets the number of readings to a value between 1 and 50,000.

Substituting MIN for the *number* parameter sets the number of readings per trigger to 1. Substituting MAX for the *number* parameter sets the number of readings per trigger to 50,000.

Example: Setting the Sample Count In the following example, 10 DC voltage measurements are made when the multimeter’s external trigger BNC connector is pulsed low. After the 10 readings are taken, the multimeter returns to the idle state.

dimension array	<i>Dimension computer array</i>
CONF:VOLT:DC	<i>Function: DC voltage</i>
TRIG:SOUR EXT	<i>Trigger source is external BNC on multimeter front panel</i>
SAMP:COUN 10	<i>Specify 10 readings per trigger</i>
READ?	<i>Place multimeter in wait-for-trigger state; make measurements when external trigger is received; send readings to output buffer</i>
timeout may occur	<i>may require INIT, monitor the status byte for completion (standard event bit 0), FETC? to transfer readings to the output buffer (vs READ?)</i>
enter statement	<i>Enter readings into computer</i>

Checking the Sample Count The SAMPlE:COUNt? [MINimum|MAXimum] command returns one of the following numbers to the output buffer:

- The present sample count (1 through 50,000) if neither MIN nor MAX is specified.
- The minimum sample count available (1) if MIN is specified.
- The maximum sample count available (50,000) if MAX is specified.

HP E1312A and HP E1412A Multimeter Application Examples

This section contains example programs that demonstrate several applications using the HP E1312A or HP E1412A Multimeter. The examples described in this section list only the SCPI commands (see Chapter 3, HP E1312A and HP E1412A Command Reference) required to perform the application. The programming language is not included in print but C and Visual Basic programs are included on the *VXIplug&play* driver media under the subdirectory "examples".

HP VTL Software (VISA)

Application example programs provided with the HP E1312A or HP E1412A Multimeter are written using VTL 3.0 (VISA Transition Language).

VISA (Virtual Instrument Software Architecture) is an I/O library that can be used to create instrument drivers and I/O applications. Application programs written with VTL function calls can use *VXIplug&play* drivers (or SCPI commands) in systems that have the VTL I/O layer. VTL allows you to use software from different vendors together on the same platform. VTL can be used for I/O application development on Microsoft® Windows 3.1©, and is supported on the VXI, GPIB-VXI, and GPIB interfaces. VISA 1.0 provides more VISA functionality and is fully operational on Windows 95© and Windows NT©.

Example Programs

Example programs are provided on the *VXIplug&play* media. These programs have been compiled and tested using Microsoft® Visual C++™ Version 1.51 for the C programs and Microsoft® Visual Basic 3.0.

C Programs

All projects written in C programming language require the following settings to work properly.

Project Type: QuickWin application (.EXE)

Project Files: <source code file name>.C

[drive:]\VXI\PNP\WIN\LIB\MSC\VISA.LIB (Microsoft® compiler)

[drive:]\VXI\PNP\WIN\LIB\BC\VISA.LIB (Borland® compiler)

Memory Model: Options | Project | Compiler | Memory Model ⇒ Large

Directory Paths: Options | Directories

Include File Paths: [drive:]\VXI\PNP\WIN\INCLUDE

Library File Paths: [drive:]\VXI\PNP\WIN\LIB\MSC (Microsoft®)

[drive:]\VXI\PNP\WIN\LIB\BC (Borland®)

Example programs: [drive:]\VXI\PNP\WIN\hpe1412\EXAMPLES

[drive:]\VXI\PNP\WIN\hpe1312\EXAMPLES\C

Visual Basic Programs

All projects written in the Visual Basic programming language require the following settings to work properly.

Project Files: <source code file name>.FRM

[drive:]\VXI\PNP\WIN\INCLUDE\VISA.BAS

Hardware Used

486 IBM compatible computer running Windows 3.1. The computer has an HP 82341 HP-IB interface and HP SICL/Windows 3.1 & Windows/NT for HP-IB software. The VXI modules were loaded in a VXI C-size mainframe using an HP E1406A or B-size mainframe with E1306A Command Module as resource manager connected to the computer via the HP 82341 HP-IB card.

Making Multimeter Measurements

This section provides four programs that demonstrate different ways of making measurements and retrieving the readings. SCPI command sequences for each program are contained in the boxes. The four programs:

1. Use the MEASure command to make a single measurement.
2. Make several externally triggered measurements.
3. Maximize measurement speed on multiple measurements.
4. Maximize measurement accuracy on multiple measurements.

NOTE: Review the section titled "Triggering the Multimeter" just preceding these application examples to fully understand the triggering system.

MEASure Command

The simplest measurement method is using the MEASure command which configures the function to be measured, initiates the measurement(s) and places the reading(s) directly into the output buffer. You then must provide the I/O construct to retrieve the readings and enter them into the computer. One MEASure command will initiate multiple measurements if the trigger count or the sample count is greater than 1. The measurement process stops when the output buffer fills if readings are not retrieved fast enough. The measurement process restarts when there is again room to store readings in the output buffer.

READ? Command

The READ? command requires that you configure the multimeter for the function you want to measure prior to issuing the command. The command initiates the measurement(s) and places the reading(s) directly into the output buffer like the MEASure command. You then must provide the I/O construct to retrieve the readings and enter them into the computer. One READ? command will initiate multiple measurements if the trigger count or the sample count is greater than 1. The measurement process stops when the output buffer fills if readings are not retrieved fast enough. The measurement process restarts when there is room to store readings in the output buffer.

INIT and FETC? Commands

The READ? command is broken down into two operations with the INIT and FETC? commands. The INIT and FETC? commands require that you configure the multimeter for the function you want to measure prior to issuing the commands. The INIT command initiates the measurement(s) and places the reading(s) into the multimeter's RAM memory. This memory will hold a maximum of 512 readings. You use the FETC? command to transfer the readings from memory to the output buffer. You then must provide the I/O construct to retrieve the readings and enter them into the computer. One INIT command will initiate multiple measurements if the trigger count or the sample count is greater than 1. If more than 512 measurements are made, only the last 512 readings are stored. Use the READ? command for more than 512 readings since readings are immediately put into the output buffer and retrieved with an I/O construct you supply. The measurement process stops when the output buffer fills if readings are not retrieved fast enough. The measurement process restarts when there is again room to store readings in the output buffer.

Measurement Format

Readings in the output buffer have the following characteristics:

- Readings sent to the output buffer can consist of two different lengths (bytes or characters) in Real ASCII format:
 $\pm 1.23456E+12$ LF or
 $\pm 1.234567E+12$ LF
- Each measurement is terminated with a Line Feed (LF). The HP-IB End-of-Identify (EOI) signal is sent with the last byte transferred. If multiple measurements are returned, the measurements are separated by commas and EOI is sent only with the last byte. For example:
 $\pm 1.23456E+12$ LF, $\pm 1.234567E+12$ LF, $\pm 1.23456E+12$ LF EOI
- The multimeter's internal memory stores 512 readings maximum.

MEASURE1 Source Code File

Use the MEAS Command to Make a Single Measurement

*RST	<i>reset the multimeter</i>
MEAS:VOLT:DC?	<i>configure dc volts (default settings) and measure</i>
	<i>retrieve the reading from the multimeter</i>
enter statement	<i>enter reading into computer</i>

Comments

- The MEASure command configures the multimeter for the function specified and initiates the measurement. The reading is stored in the output buffer and you must provide the I/O construct to retrieve the reading and enter it into the computer.

MEASURE2 Source Code File

Making Externally Triggered Measurements (multiple triggers/samples)

*RST	<i>reset the multimeter</i>
CONF:VOLT:DC 18	<i>configure for dc volts, expected input = 18V</i>
TRIG:SOUR EXT	<i>set trigger source to external</i>
TRIG:COUN 3	<i>set trigger count to 3</i>
SAMP:COUN 10	<i>set sample count to 10 per trigger</i>
INIT	<i>puts multimeter in wait-for-trigger state</i>
	<i>EXTERNAL triggers occur here to initiate measurements</i>
	<i>measurements are stored in multimeter internal memory</i>
FETC?	<i>transfer measurements from the multimeter internal memory</i>
	<i>to the output buffer and retrieve them with the computer</i>
enter statement	<i>enter reading into computer</i>

Comments

- You must provide a TTL external trigger signal to the HP E1312A or HP E1412A front panel "Trig" input BNC. Measurements are triggered by low pulses of this signal. Each trigger results in 10 readings.
- The CONFigure command configures the multimeter for the function specified. This CONFigure command specifies a range parameter of 18 (expected input is 18V; the multimeter sets a range to accommodate that input which will be 100V). It does not initiate the measurement.

- Trigger source (TRIG:SOUR) is set for an external trigger. A trigger count (TRIG:COUN) of 3 is set; the multimeter will accept three external triggers.
- The sample count (SAMP:COUN) is set for 10 samples per trigger.
- The INITiate command puts the multimeter in the wait-for-trigger state. The trigger source is an "EXternal" hardware trigger. You provide this trigger and input it on the "Ext Trig" BNC connector which initiates the measurement process. This will cause the multimeter to make 30 measurements; 10 samples for each of three triggers.
- The FETCh? command causes the readings to be transferred to the output buffer and you must provide the I/O construct to retrieve the readings and enter them into the computer.

MEASURE3 Source Code File

Maximizing Measurement Speed (no trigger delay, short integration time)

```
*RST                reset the multimeter
CONF:VOLT:DC 18      configure for dc volts, expected input = 18V
CAL:ZERO:AUTO OFF    turn off autozero (makes faster measurements)
TRIG:SOUR IMM        set the trigger source to immediate
TRIG:COUN 3          set trigger count to 3
SAMP:COUN 10          set sample count to 10
INIT                INITiate command puts multimeter in wait-for-trigger state;
                    internal trigger immediately occurs here and measurements
                    are stored in the multimeter's internal memory
FETC?               transfer measurements from the multimeter's internal memory
                    to the output buffer and retrieve them with the computer
enter statement      enter reading into computer
```

Comments

- The CONFigure command configures the multimeter for the function specified. This CONFigure command specifies a range parameter of 18 (expected input is 18V; the multimeter sets a range to accommodate that input which will be 100V). It does not initiate the measurement.
- The autozero function is disabled to speed up the measurement process. See the CALibrate:ZERO:AUTO command in the Command Reference for more information.
- Trigger source (TRIG:SOUR) is set for immediate internal triggers. A trigger count (TRIG:COUN) of 3 is set; the multimeter will accept three triggers.
- The sample count (SAMP:COUN) is set for 10 samples per trigger.
- The INITiate command puts the multimeter in the wait-for-trigger state. The trigger source is "IMMediate" which specifies the internal trigger source. This trigger occurs immediately and causes the measurement process to begin. This will cause the multimeter to make 30 measurements; 10 samples for each of three internal triggers.

- The FETCh? command causes the readings to be transferred to the output buffer and you must provide the I/O construct to retrieve the readings and enter them into the computer.

MEASURE4 Source Code File

Maximizing Accuracy (most accurate resolution, longer integration time)

*RST	<i>reset the multimeter</i>
CONF:VOLT:DC AUTO,MIN	<i>configure for dc volts, autorange, minimum resolution (longest integration time)</i>
TRIG:SOUR EXT	<i>set trigger source to external</i>
TRIG:COUN 2	<i>set trigger count to 2</i>
SAMP:COUN 10	<i>set sample count to 10</i>
READ?	<i>initiate measurements putting them directly into output buffer; retrieve them with the computer</i>
enter statement	<i>enter reading into computer</i>

Comments

- The CONFigure command configures the multimeter for the function specified. This CONFigure command specifies autorange and minimum resolution (the smallest resolution value which is the best resolution). It does not initiate the measurement.
- Specifying a small value for resolution provides the most accurate measurements. This will increase the integration time (NPLCs) and therefore require more time for the measurements.
- Trigger source (TRIG:SOUR) is set for an external trigger. A trigger count (TRIG:COUN) of 2 is set; the multimeter will accept two external triggers.
- The sample count (SAMP:COUN) is set for 10 samples per external trigger.
- The READ? command puts the multimeter in the wait-for-trigger state. When the first external trigger is received, the measurement process begins. This will cause the multimeter to make 10 measurements for the first external trigger, go to the wait-for-trigger state and take 10 measurements for the second external trigger when received.
- The readings are stored in the output buffer and you must provide the I/O construct to retrieve the readings and enter them into the computer.
- This example uses the READ? command. Measurements are initiated with the READ? command which puts the multimeter in the wait-for-trigger state. Measurement occurs when the trigger arrives and readings are subsequently stored directly in the output buffer and must be retrieved by the computer with an I/O construct you supply. An alternative way of initiating measurements is to use the INITiate command as done in the previous example. Measurements are made and stored in the multimeter's internal memory and must be retrieved using the FETCh? command which transfers the readings to the output buffer. You must be careful when using the INITiate and FETCh? commands. Internal memory stores a maximum of 512 readings; the oldest readings exceeding 512 are lost.

Synchronizing the Multimeter With a Switch Module

This program example demonstrates how to synchronize the multimeter with a switch module. For the HP E1412A it uses the TTL triggers from the VXI backplane to trigger the multimeter and advance the channel scan list. The example uses the HP E1476A 64-channel Multiplexer Module but will also work with any HP switch module as long as the channel list is specified properly. Figure 2-1 illustrates the C-size set up. The switch module (multiplexer) and multimeter use the VXI backplane to communicate the trigger and VM Complete signals to each other to synchronize the scan. Figure 2-2 shows the HP E1312A set up using external triggering. B-size command modules do not support VXIbus TTL triggers.

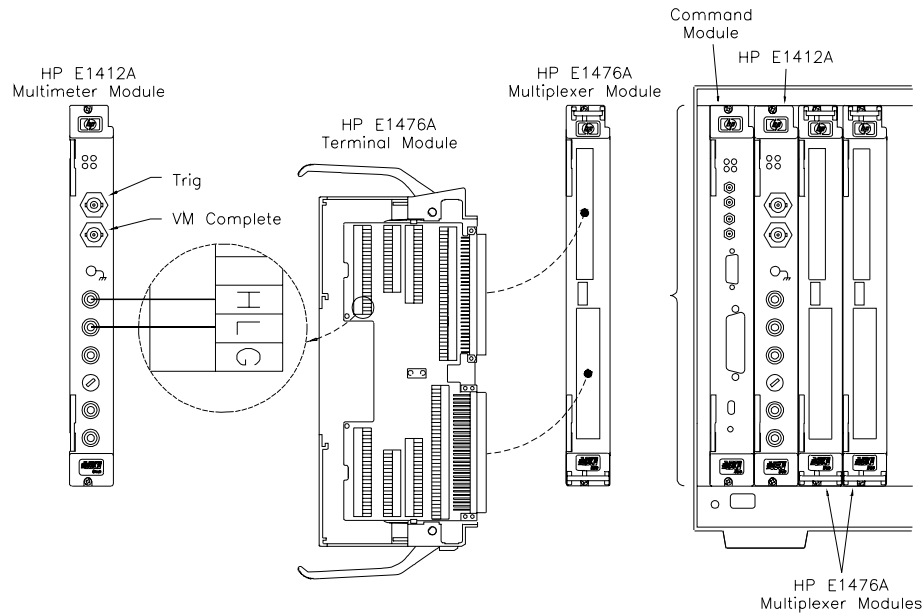


Figure 2-1. HP E1412A Multimeter and Switch Module Synchronization.

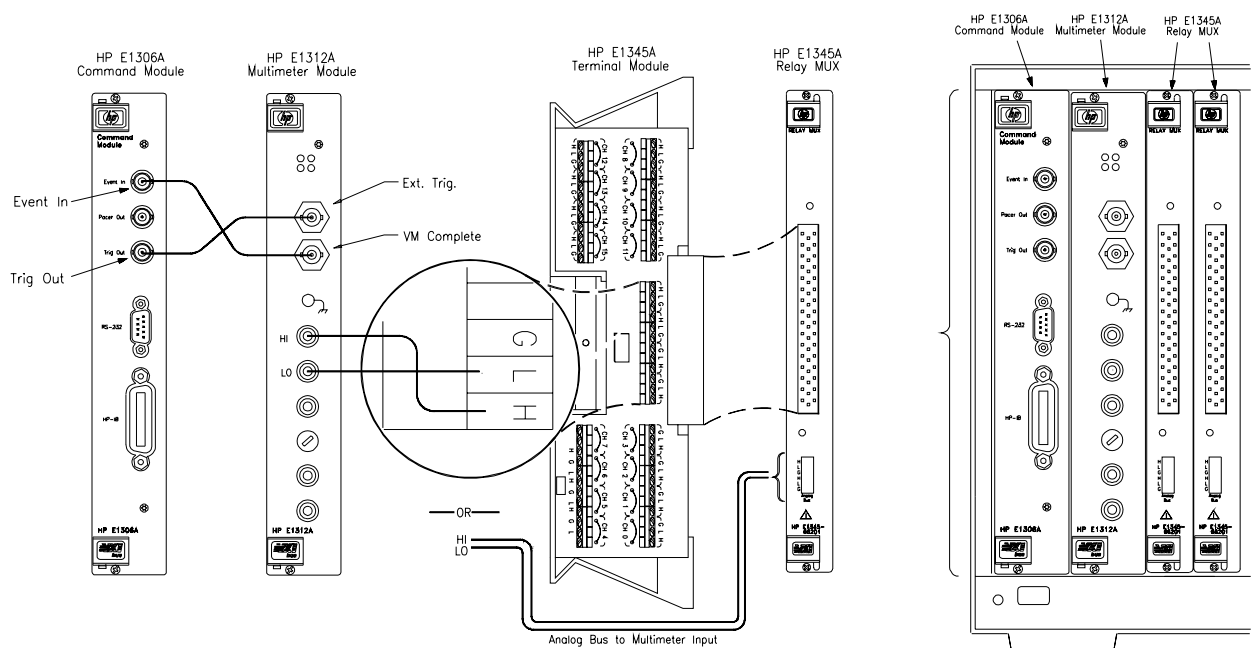


Figure 2-2. HP E1312A Multimeter and Switch Module Synchronization.

This example monitors the switch module's status system. The switch module's status system is shown in Figure 2-3. This example program enables the switch's "Scan Complete" bit to allow it to set the OPR bit in the switch's status byte when the scan is finished. The program repeatedly reads the switch module's status byte until the OPR bit gets set which returns a status byte value of 128. This indicates the switch module has completed all closures in the scan list. The multimeter's FETC? command causes the multimeter to transfer readings to the output buffer after completing the last measurement. Readings are entered into the computer using an I/O construct you provide.

NOTE: This is the HP E1476A switch module's status system. See Figure 2-3 for the HP E1312A/E1412A Multimeter status system.

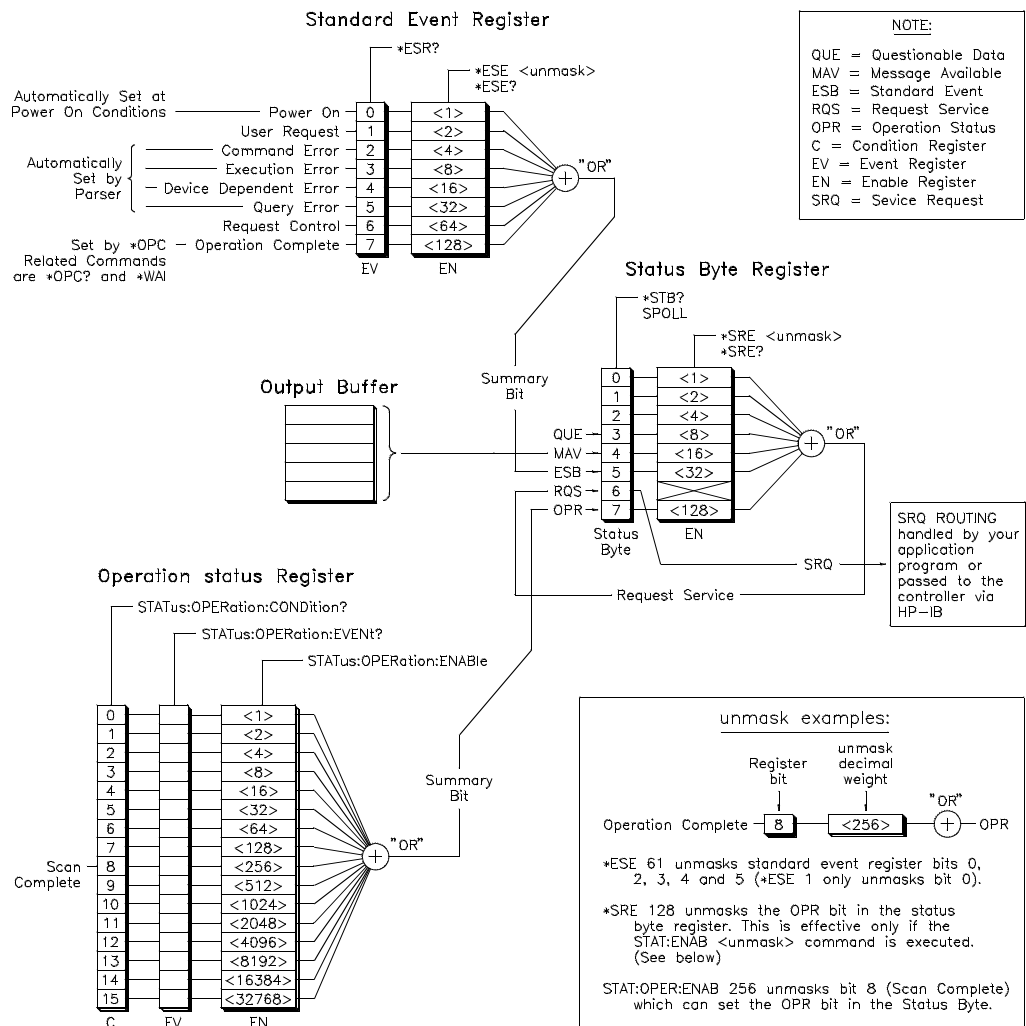


Figure 2-3. HP E1476A Switch Module Status System.

(E1412A) SCAN
Source Code File
(see SCAN1312 example
program for E1312A code
-the E1312A cannot use
TTL triggers)

SCPI command sequences for the program are as follows.

****** Set up the Multimeter ******

```
*RST          reset the multimeter
*CLS          clear the multimeter's status registers
CONF:VOLT 12,MIN  configure for dc volts, 12V input, min res
TRIG:SOUR TTLT2  let switch closure trigger multimeter
TRIG:COUN 8      multimeter will accept 8 triggers
TRIG:DEL 0.01    use a 10 ms delay before each measurement
OUTP:TTLT1:STAT ON output VM Complete to switch via TTLT1
CALC:FUNC AVER    select the math function AVERage
CALC:STAT ON      enable math operations
*OPC?           Wait until above commands are processed
                read the response to the *OPC? command from multimeter
INIT           puts multimeter in the "wait-for-trigger" state;
                trigger source is TTLTrig2 line OUTPut by the switch
```

****** Now set up the switch module ******

```
*RST          reset the switch module
*CLS          clear the switch module's status registers
ABOR          abort any switch operation in progress
STAT:OPER:ENAB 256 enable bit 8 of operation status register
OUTP:TTLT2:STAT ON enable switch closure to trigger multimeter
TRIG:SOUR TTLT1 allow VM Complete to advance the scan
SCAN (@100:107) specify a switch module scan list
*OPC?         Wait until above commands are processed
                read the response to the *OPC? command from switch
INIT          starts scanning by closure of the first channel in the scan list;
                sends output signal to multimeter via TTLTrig2 to trigger
                a measurement; multimeter sends TTLT1 (VM Complete)
                back to switch module to advance scan to the next channel;
                measurements are stored in multimeter internal memeory
```

```
*****
read switch's status byte until all channels are scanned and scan complete
(bit 8 in the operation status register) sets the OPR bit in the status byte
*****
```

retrieve the readings from the multimeter

```
FETC?         transfer measurements from the multimeter internal memory
                to the output buffer and retrieve them with the computer
```

retrieve the AVERage math operation response from the multimeter

```
CALC:AVER:AVER? retrieve the average measurement value
CALC:AVER:MAX?  retrieve the maximum measurement value
CALC:AVER:MIN?  retrieve the minimum measurement value
```

check the multimeter for system errors

```
SYST:ERR?     retrieve the system error response from the multimeter
```

Multimeter Status System Examples

There are two program examples that demonstrate how the HP E1312A and HP E1412A Multimeter status system works. In both programs the status byte is repeatedly read to identify when actions by the Multimeter set the appropriate bit in the status byte. The computer can identify when readings are available by monitoring the status byte and can retrieve readings when they are available.

Figure 2-4 illustrates the HP E1312A and HP E1412A Status system. A Questionable Data Register, an Output Buffer and a Standard Event Register each have a respective status bit in the Status Byte Register. The Output Buffer sets the MAV bit when there is data available such as measurement readings or a response to a SCPI query command. The Questionable Data Register and Standard Event Register require you to "unmask" the bits you want to be OR'd into a summary bit which sets the respective bit in the Status Byte. You must also "unmask" the status bits you want OR'd into a summary bit to set the Service Request bit (SRQ) if you want to generate an interrupt. The B-size HP E1312A requires you unmask any bit with the *SRE command that you want to read with a SPOLL (the E1412A does not require this unmasking). The example programs illustrate this requirement.

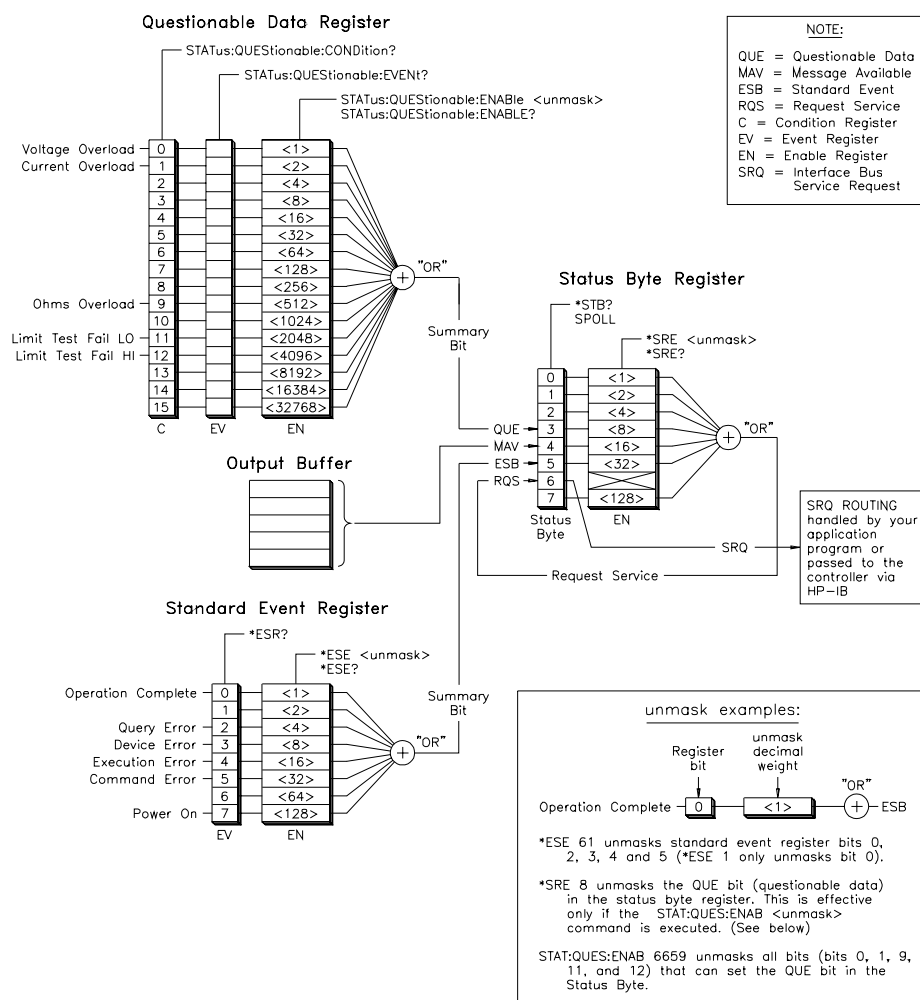


Figure 2-4. HP E1312A/E1412A Multimeter Status System

SYNCHOPC Source Code File

This program has the multimeter take 10 measurements. The Standard Event bit (ESB) in the status byte (see Figure 2-4) is monitored to detect when the operation is complete. Readings are transferred to the output buffer by a FETC? command and retrieved by the computer following the indication that the operation has completed. The Multimeter then calculates the average, minimum and maximum reading.

set up the multimeter

*RST	<i>reset the multimeter</i>
*CLS	<i>clear the multimeter's status registers</i>
*ESE 1	<i>enables bit 0 of the multimeter's standard event register</i>
CONF:VOLT 15	<i>configure for dc volts, expected input of 15V</i>
VOLT:DC:NPLC 10	<i>set number of power line cycles to 10</i>
TRIG:COUN 10	<i>multimeter will accept 10 triggers</i>
TRIG:DEL .01	<i>use a 10 ms delay before <u>each</u> measurement</i>
CALC:FUNC AVER	<i>select the math function AVERage</i>
CALC:STAT ON	<i>enable math operations</i>

*SRE 32 *required for the E1312A to detect the bit in an SPOLL*

INIT *puts multimeter in wait-for-trigger state; trig source is "IMM"; internal trigger occurs "immediately" and measurements are stored in multimeter internal memory*

*OPC *waits for all measurements to complete then sets bit 0 in the standard event register (the operation complete bit)*

Loop

SPOLL - read the multimeter's status byte until bit 5 (ESB) goes high

End Loop

FETC? *transfer measurements from the multimeter internal memory to the output buffer and retrieve them with the computer*

retrieve the AVERage math operation response from the multimeter

CALC:AVER:AVER?	<i>retrieve the average measurement value</i>
CALC:AVER:MAX?	<i>retrieve the maximum measurement value</i>
CALC:AVER:MIN?	<i>retrieve the minimum measurement value</i>

check the multimeter for system errors

SYST:ERR? *retrieve the system error response from the multimeter*

SYNCHMAV Source Code File

This program has the multimeter take 10 measurements just like SYNCHOPC. Readings are transferred to the output buffer by a FETC? command. The Message Available bit (MAV) in the status byte (see Figure 2-4) is monitored to detect when the measurements are complete and the Multimeter has readings in the output buffer. Readings are retrieved by the computer when the MAV bit in the status byte indicates the measurements are complete and readings are available. The Multimeter then calculates the average, minimum and maximum reading.

set up the multimeter

*RST	<i>reset the multimeter</i>
*CLS	<i>clear the multimeter's status registers</i>
CONF:VOLT 15	<i>configure for dc volts, expected input of 15V</i>
VOLT:DC:NPLC 10	<i>set number of power line cycles to 10</i>
TRIG:COUN 10	<i>multimeter will accept 10 triggers</i>
TRIG:DEL .01	<i>use a 10 ms delay before <u>each</u> measurement</i>
CALC:FUNC AVER	<i>select a math function</i>
CALC:STAT ON	<i>enable the math operations</i>
*SRE 16	<i>required by the E1312A to detect MAV bit in SPOLL</i>

INIT *puts multimeter in wait-for-trigger state; trigger source is "IMM"; internal trigger occurs "immediately" and measurements are stored in multimeter internal memory*

FETC? *transfer measurements from the multimeter internal memory to the output buffer and retrieve them with the computer*

Loop

SPOLL - read the multimeter's status byte until bit 4 (MAV) goes high to indicate there is a message available in the output buffer.

End Loop

**** NOTE:** If TRIG:COUN is too big, FETC? can timeout before measurements complete. FETC? expects a response before the timeout interval specified in the program code. Using the previous program detecting the OPC bit is recommended.

retrieve the AVERage math operation response from the multimeter

CALC:AVER:AVER?	<i>retrieve the average measurement value</i>
CALC:AVER:MAX?	<i>retrieve the maximum measurement value</i>
CALC:AVER:MIN?	<i>retrieve the minimum measurement value</i>

check the multimeter for system errors

SYST:ERR? *retrieve the system error response from the multimeter*

LIMITTST Source Code File

This program has the multimeter making measurements continuously until an upper or lower limit is exceeded. The lower test limit is set to 2V; the upper test limit is set to 8V. Questionable data register bits 11 and 12 are unmasked to allow the LO and HI Limit Test Failures to set the QUE bit in the status byte. An input less the 2V or greater than 8V will report a test failure and halt the program.

set up the multimeter

```
*RST          reset the multimeter
*CLS          clear the multimeter's status registers
CONF:VOLT 10  configure for dc volts, 10V range
CALC:STAT ON  enable the math function
CALC:LIM:LOW 2 set lower limit to 2
CALC:LIM:UPP 8 set upper limit to 8
CALC:FUNC LIM  select a math function; set to LIMit
STAT:QUES:ENAB 6144 unmask the limit error bits

*SRE 8        required by the E1312A to detect QUE bit in SPOLL
```

Loop

```
READ?        trigger measurement and place response into the output buffer
```

Enter response into the computer

SPOLL - read the multimeter's status byte until bit 3 (QUE) goes high to indicate there is a Limit Test Failure (HI or LO).

wait 1 second

End Loop

check the multimeter for system errors

```
SYST:ERR?    retrieve the system error response from the multimeter
```

HP VEE Programming Example

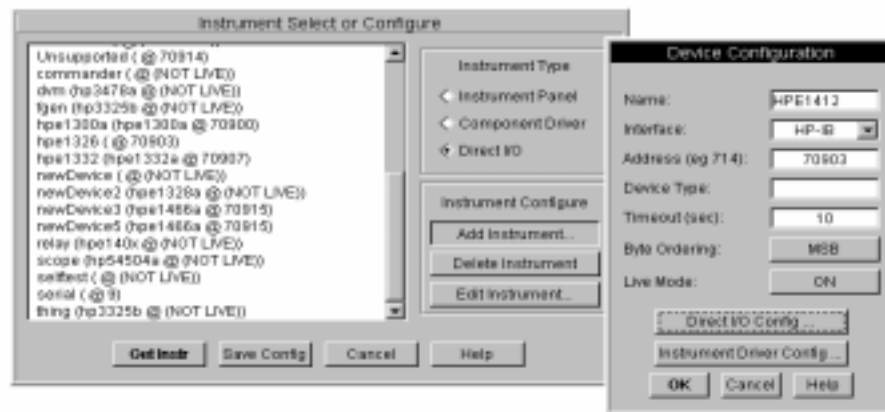
HP VEE is HP's *Visual Engineering Environment*, a graphical programming language for creating test systems and solving engineering problems. This section provides an instrument control example using the "Direct I/O" feature of HP VEE. Direct I/O allows you to directly specify messages to be sent to an instrument and to directly read the information sent back by an instrument. Direct I/O also offers the most efficient I/O performance in HP VEE.

The example provided here synchronizes a measurement scan with a switch module. This is the same example previously discussed in this chapter with programs provided in the C and Visual Basic programming languages.

Device Configuration

You must configure your HP E1312A or HP E1412A Multimeter (and the switch module) before you can communicate with them.

1. Select **I/O ⇒ Instrument...** from the menu bar. The **Instrument Select or Configure** dialog box pops up.
2. Select the **Direct I/O** button from the **Instrument Type** choices. Then select **Add Instrument** from the **Instrument Configure** choices. This selection pops up the **Device Configuration** dialog box.
3. Fill in the **Device Configuration Name**, **Interface**, **Address** and **Timeout**. Set **Byte Ordering** to **MSB** and **Live Mode** to **ON**. Then select **Direct I/O Config...** The **Direct I/O Configuration** dialog box pops up.
4. Verify **Conformance** is set to **IEEE 488** (use default settings for all others).
5. Select **OK** to close both the **Direct I/O** and **Device Configuration** boxes.
6. Select the "name" you put in the name field of the device configuration dialog box now appearing in the instrument list and press the **Get Instr** button.

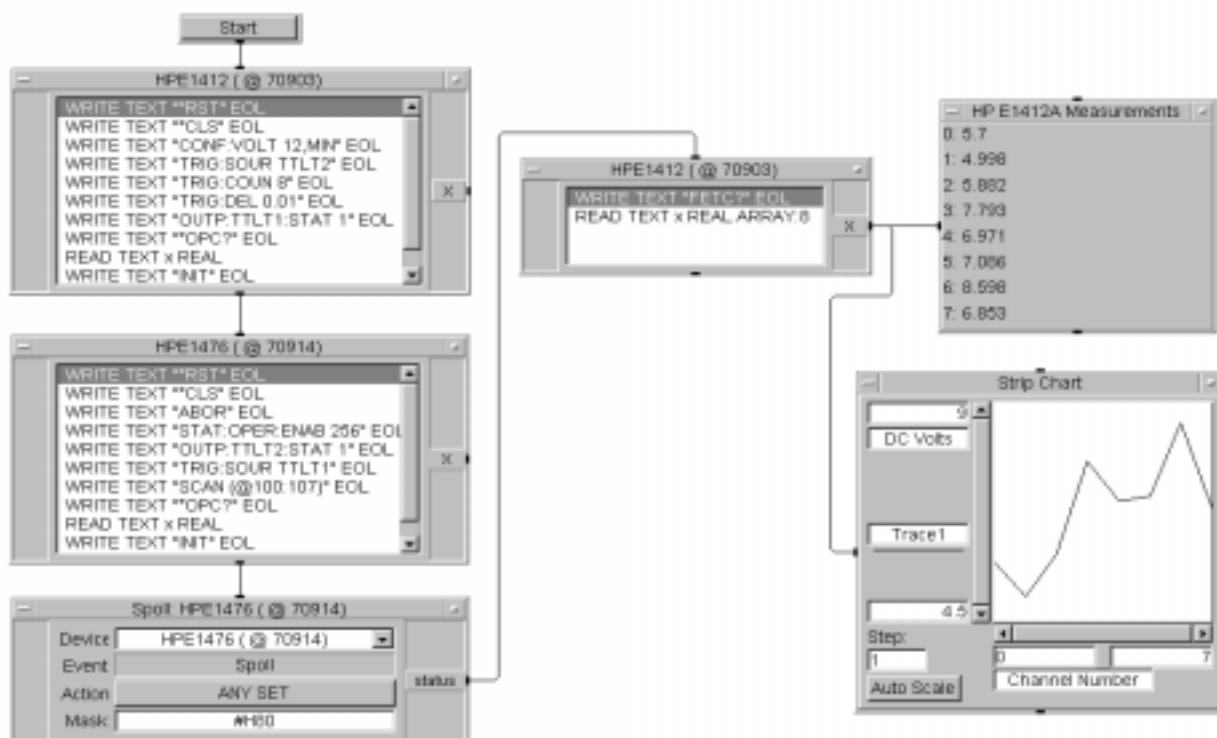


Program Description

The instruments are programmed using Direct I/O objects connected as required by the sequence of SCPI commands. Reading of the HP E1476A status byte is performed using the **I/O | Advanced I/O | Device Event** object **SPOLL** whose action is set to **ANY SET** and its mask set to **#H80**. This mask allows reading only the OPR bit of the status byte (bit 7) which gets set by bit 8 (Scan Complete) from the Operation Status Register when the switch module completes the scan list. Following the detection of scan complete, the readings are retrieved with the Multimeter's **FETCh?** command and sent in an array format to an HP VEE **AlphaNumeric Display** object titled **HP E1412A Measurements**. The readings are also sent to a **Strip Chart Display** object which gives a plot of the measurements.

Strip Chart Object

In parallel with the HP E1412A Measurements AlphaNumeric Display object is a Strip Chart Display object that displays the readings of the eight channels. The Strip Chart has an Auto Scale button to automatically scale the horizontal and vertical axis to best display the measured data. Upper and lower boundary traces could be added to the strip chart's display.



See your HP VEE documentation and on-line help for more detail on test and measurement I/O control. If you are not using HP VEE and are curious about HP's graphical programming language, call your local HP sales office listed in your telephone directory for more information. You can get a free HP VEE Evaluation Kit containing detailed technical information and a demo disk that walks you through many of HP VEE's features and functions. The following brochures provide additional information about HP VEE:

- *HP VEE Visual Engineering Environment*
P/N 5962-9239E
- *HP VEE The Most Productive Language for Test and Measurement*
P/N 5963-9528E
- *HP VEE Visual Engineering Environment Technical Data*
P/N 5091-9554EUS

APPLICATION NOTES

Multimeter Command Reference

Using This Chapter

This chapter describes the Standard Commands for Programmable Instruments (SCPI) and IEEE 488.2 Common (*) commands applicable to the HP E1312A and HP E1412A 6½-Digit Multimeters.

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 like reset, self-test, status byte query, etc. Common commands are four or five characters in length, always begin with the asterisk character (*), and may include one or more parameters. The command keyword is separated from the first parameter by a space character. 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, or 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, 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?
:LFRequency 50|60|MIN|MAX
:LFRequency? [MIN|MAX]
:SECure:CODE <new code>
:SECure:STATe OFF|ON, <code>
:SECure:STATe?
:STRing <quoted string>
:STRing?
:VALue <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 the second level command (CALibration:SECure) and the second level from the third level (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 may use upper or lower case letters and commands of the form 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 "<function>" (e.g., <function> = VOLT:AC)

FUNCTION?

RESistance

:RANGe <range>[MIN]MAX

:RANGe? [MIN]MAX]

The root command SENSE is an implied command. For example, to set the multimeter's function to AC volts, 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.

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 <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 present 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 which 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

Multimeter Range and Resolution Tables

The following tables list the voltage and resistance ranges available for the multimeter. Also shown are the associated resolution values versus aperture time in seconds or integration time in power line cycles (PLCs) for each range.

Table 3-1. DC Voltage Resolution versus Integration Time or Aperture Time

		Integration time in Power Line Cycles (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 μ V	10 μ V
1 V	1.2 V	300 nV	1 μ V	3 μ V	10 μ V	100 μ V
10 V	12V	3 μ V	10 μ V	30 μ V	100 μ V	1 mV
100V	120V	30 μ V	100 μ V	300 μ V	1 mV	10 mV
300V	300V	300 μ V	1 mV	3 mV	10 mV	100 mV

Table 3-2. DC Current Resolution versus Integration Time or Aperture Time

		Integration time in Power Line Cycles (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 μ A
100 mA	120 mA	30 nA	100 nA	300 nA	1 μ A	10 μ A
1A	1.2A	3 nA	1 μ A	3 μ A	10 μ A	100 μ A
3A	3A	900 nA	3 μ A	9 μ A	30 μ A	300 μ A

**Table 3-3. 2-Wire and 4-Wire Resistance
Resolution versus Integration Time or Aperture Time**

		Integration time in Power Line Cycles (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
100Ω	120Ω	30 μΩ	100 μΩ	300 μΩ	1 mΩ	10 mΩ
1 kΩ	1.2 kΩ	300 mΩ	1 mΩ	3 mΩ	10 mΩ	100 mΩ
10 kΩ	12 kΩ	3 mΩ	10 mΩ	30 mΩ	100 mΩ	1Ω
100 kΩ	120 kΩ	30 mΩ	100 mΩ	300 mΩ	1Ω	10Ω
1 MΩ	1.2 MΩ	300 mΩ	1Ω	3Ω	10Ω	100Ω
10 MΩ	12 MΩ	3Ω	10Ω	30Ω	100Ω	1 kΩ
100 MΩ	100 MΩ	30Ω	100Ω	300Ω	1 kΩ	10 kΩ

Table 3-4. AC Voltage: Range versus Resolution

Resolution choices versus range					
RANGE	100 mV	1V	10V	100V	300V
MIN	100 nV	1 μV	10 μV	100 μV	1 mV
power-on & *RST setting	1 μV	10 μV	100 μV	1 mV	10 mV
MAX	10 μV	100 μV	1 mV	10 mV	100 mV

Table 3-5. AC Current: Range versus Resolution

Resolution choices versus range.		
RANGE	1A	3A
MIN	1 μA	3 μA
power-on & *RST setting	10 μA	30 μA
MAX	100 μA	300 μA

SCPI Command Reference

This section describes the Standard Commands for Programmable Instruments (SCPI) for the HP E1312A and E1412A 6½-Digit Multimeters. Commands are listed alphabetically by subsystem and also within each subsystem.

Command Guides

Command guides are printed in the top margin of each page. The left guide indicates the first command listed on that page. The right guide indicates the last command listed on that page. If a single command appears on a page, the left and right guides will be the same.

ABORt

The ABORt command subsystem removes the multimeter from the wait-for-trigger state and places it in the idle state. ABORt is only effective when the trigger source is TRIGger:SOURce BUS.

Subsystem Syntax

ABORt

Example

Aborting a Measurement

```
CONF:VOLT:DC
TRIG:SOUR BUS
INIT
ABOR
```

Function: DC voltage
Trigger source is BUS trigger
Place multimeter in wait-for-trigger state
Abort waiting for a trigger and place multimeter in idle state

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.
- ABORt returns the multimeter to the idle state for TRIGger:SOURce BUS. The "Trigger ignored" error is generated when a Group Execute Trigger (GET) bus command or *TRG common command is executed after an ABORt command (which puts the multimeter into the idle state).
- **Related Commands:** INITiate, TRIGger
- ***RST Condition:** After a a *RST, the multimeter acts as though an ABORt has occurred.

CALCulate

There are five math operations available (NULL, DB, DBM, AVERage and LIMit), 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, 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 math/measurement function combinations allowed. Each “X” 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. *For null and dB measurements, you must turn on the math operation before writing to their math registers.*

	DCV	ACV	DCI	ACI	Ω 2W	Ω 4W	Freq	Per	Ratio
NULL	X	X	X	X	X	X	X	X	
AVERage	X	X	X	X	X	X	X	X	X
DB	X	X							
DBM	X	X							
LIMit	X	X	X	X	X	X	X	X	X

Subsystem Syntax

CALCulate

```
:FUNCTION NULL | DB | DBM | AVERage | LIMit
:FUNCTION?
:STATe OFF|ON
:STATe?
:NULL:OFFSet <value> | MIN | MAX
:NULL:OFFSet? [MIN | MAX]
:DB:REFerence <value> | MIN | MAX
:DB:REFerence? [MIN | MAX]
:DBM:REFerence <value> | MIN | MAX
:DBM:REFerence? [MIN | MAX]
:AVERage:MINimum?
:AVERage:MAXimum?
:AVERage:AVERage?
:AVERage:COUNt?
:LIMit:LOWer <value> | MIN | MAX
:LIMit:LOWer? [MIN | MAX]
:LIMit:UPPer <value> | MIN | MAX
:LIMit:UPPer? [MIN | MAX]
```

:FUNCtion

CALCulate:FUNCtion **NULL|DB|DBM|AVERage|LIMit** selects the math function to be used. One function is enabled at a time with **NULL** the default. The selected function *MUST* be enabled with **CALC:STATe ON**.

Parameter Summary

- **NULL** measurements (also called *relative* measurements) provide a reading which is the difference between a stored null value and the input signal.
- **DB** measurements are the difference between the input signal and a stored relative value, with both values converted to dBm.
- **DBM** operations calculate the power delivered to a resistance referenced to 1 milliwatt.
- **AVERage** measurements store the minimum and maximum readings from a number of measurements. The multimeter records the number of readings taken since the average function was enabled then calculates the average of all the readings. You read these values with **CALC:AVER:MIN?**; **MAX?**; **AVERage?** and **COUNT?**.
- The **LIMit** parameter enables pass/fail testing on the upper and lower limits you specify using the **LIMit:UPPer** and **LIMit:LOWer** commands.
- See the section titled "Math Operations" in Chapter 2, Application Examples, for more detail on the **CALCulate** operations.

Example

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

CALC:FUNC LIM	<i>Set calculate function to limit.</i>
CALC:LIM:LOWer	<i>Set the lower limit to test against.</i>
CALC:LIM:UPPer	<i>Set the upper limit to test against.</i>
CALC:STATe ON	<i>Enable the limit math operation.</i>

FUNCtion?

CALCulate:FUNCtion? queries the multimeter to determine the present math function. Returns **NULL**, **DB**, **DBM**, **AVER**, or **LIM**.

Example

Query what the calculate math function is:

CALC:FUNC?	<i>Query the calculate function.</i>
-------------------	--------------------------------------

:STATe

CALCulate:STATe **OFF | ON** disables or enables the selected math function. The state is stored in volatile memory.

Example

Enable the currently selected calculate math function:

CALC:STAT ON	<i>The selected or default math function is enabled.</i>
---------------------	--

:STATe?

CALCulate:STATe? queries the state of the math function. Returns “0” (OFF) or “1” (ON).

Example

Query whether a math function state is on or off:

CALC:STAT?

Query the state.

:AVERage:MINimum?

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

Example

Query the minimum value found during an AVERage math operation:

CALC:AVER:MIN?

Query the min value.

: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 power is removed, or after the multimeter is reset. The maximum value is stored in volatile memory.

Example

Query the maximum value found during an AVERage math operation:

CALC:AVER:MAX?

Query the max value.

: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 power is removed, or after the multimeter is reset. The average value is stored in volatile memory.

Example

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

CALC:AVER:AVER?

Query the average of all readings.

:AVERage:COUNT?

CALCulate: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 power has been off, or after a remote interface reset. The number of readings taken is stored in volatile memory.

Example

Query the number of readings since the AVERage math operation was enabled:

CALC:COUN?

Query number of readings.

:NULL:OFFSet

CALCulate:NULL:OFFSet <value> | **MIN** | **MAX** stores a null value in the multimeter's Null Register. *You must turn on the math operation e.g., execute CALC:STAT ON before writing to the math register.* You can set the null value to any number between 0 and $\pm 120\%$ of the highest range, for the present function. MIN = -120% of the highest range. MAX = 120% of the highest range. The null value is stored in volatile memory. See the section titled "Math Operations - NULL Function" in Chapter 2 for another way to store the offset value.

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 math operation.

CALC:NULL:OFFS 500

Set null offset to 500.

:NULL:OFFSet?

CALCulate:NULL:OFFSet? [**MIN** | **MAX**] queries the null value.

Example

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

CALC:NULL:OFFS?

Query the null offset value.

:DB:REfERENCE

CALCulate:DB:REfERENCE <value>|**MIN**|**MAX** 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.* You can set the relative value to any number between ± 200 dBm (the MIN and MAX values). The dB reference is stored in volatile memory.

Example

Set the DB reference value:

CALC:STAT ON

Turn on the math operation

CALC:DB:REF 60

Sets DB reference to 60 dBm.

CALC:FUNC DB

Select the DB math operation. You can select the calculate function at any time before or after enabling the calculate state.

:DB:REfERENCE?

CALCulate:DB:REfERENCE? [**MIN** | **MAX**] queries dB reference value.

Example

Query the DB reference value set for the DB math operation:

CALC:DB:REF?

Query the DB reference value.

:DBM:REFeRence

CALCulate:DBM:REFeRence <value> | **MIN** | **MAX** selects the dBm reference value. Choose from: 50, 75, 93, 110, 124, 125, 135, 150, 250, 300, 500, **600 (default)**, 800, 900, 1000, 1200, or 8000 ohms. MIN = 50Ω. MAX = 8000Ω. 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.

Example**Set the DBM reference value:**

CALC:STAT ON
CALC:DBM:REF 135
CALC:FUNC DBM

Turn on the math operation
 Sets DBM reference value to 135.
 Select the DBM math operation.
 You can select the calculate function at any time before or after enabling the calculate state.

:DBM:REFeRence?

CALCulate:DBM:REFeRence? [**MIN** | **MAX**] queries the dBm reference.

Example**Query the DBM reference value set for the DBM math operation:**

CALC:DBM:REF?

Query the DBM reference value.

:LIMit:LOWer

CALCulate:LIMit:LOWer <value> | **MIN** | **MAX** sets the lower limit for limit testing. You can set the value to any number between 0 and ±120% of the highest range, for the present function. MIN = -120% of the highest range. MAX = 120% of the highest range. 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.

Example**Set the lower limit:**

CALC:STAT ON
CALC:LIM:LOW 1000
CALC:FUNC LIM

Turn on the math operation
 Set the lower limit.
 Select the LIMit math operation.
 You can select the calculate function at any time before or after enabling the calculate state.

:LIMit:LOWer?

CALCulate:LIMit:LOWer? [**MIN** | **MAX**] queries the lower limit.

Example**Query the lower limit set for the LIMit math operation:**

CALC:LIM:LOW?

Query the lower limit.

LIMit:UPPer

CALCulate:LIMit:UPPer <value> | MIN | MAX sets the upper limit for limit testing. You can set the value to any number between 0 and $\pm 120\%$ of the highest range, for the present function. MIN = -120% of the highest range. MAX = 120% of the highest range. *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.*

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 can select the calculate function at any time before or after enabling the calculate state.

:LIMit:UPPer?

CALCulate:LIMit:UPPer? [MIN | MAX] queries the upper limit.

Example**Query the upper limit set for the LIMit math operation:**

CALC:LIM:UPP?

Queries the upper limit.

CALibration

The CALibration command subsystem allows you to enter a security code to prevent accidental or unauthorized calibrations of the multimeter. When you first receive your multimeter, it is secured. You must unsecure it by entering the correct security code before you can calibrate the multimeter (see CALibration:SECure:STATE OFF|ON <code> command).

Subsystem Syntax

CALibration
:COUNT?
:LFRrequency 50|60|400
:LFRrequency? [MIN|MAX]
:SECure:CODE <new code>
:SECure:STATE OFF|ON,<code>
:SECure:STATE?
:STRing <quoted string>
:STRing?
:VALue <cal_value>
:VALue?
:ZERO:AUTO ON|OFF
:ZERO:AUTO?

: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.

Comments

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

Example

Querying the number of occurrences of point calibrations:

CAL:COUNT?

Query the calibration count.

:LFRrequency

CALibration:LFRrequency 50 | 60 | 400 sets the line frequency to either 50 Hz or 60 Hz.

Comments

- The wrong 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 line frequency to 50 Hz since 400 is an even multiple of 50.

Default Setting: 60 Hz

***RST** does not change the line frequency setting.

Example

Setting the line frequency to 50 Hz:

CAL:LFR 50

Change the line frequency.

:LFRrequency?

CALibration:LFRrequency? queries the line frequency setting.

Comments

This command returns +50 for line frequency set to 400 because 400 is an even multiple of 50.

Example

Query the line frequency setting:

CAL:LFR?

Query the line frequency.

:SECure:CODE

CALibration:SECure:CODE *<new code>* enters a new calibration security code. To change the security code, first unsecure the multimeter using the old security code with **:SEC:STAT OFF**, *<old code>*. Then, enter the new code. The calibration security code may contain up to 12 characters. The security code is stored in non-volatile memory.

Comments

- The security code is set to "HP_E1412" for C-size (or "HP_E1312" for B-size) when the multimeter is shipped from the factory. The security code is stored in non-volatile memory, and does not change when power has been off or after a remote interface reset.
- The security code *<new code>* can contain up to 12 alphanumeric characters. The first character must be a letter. The remaining characters can be letters or numbers or an underscore. You do not have to use all 12 characters but the first character must be a letter.
- If you forget or lose the active security code, you can disable the security feature by adding a jumper inside the multimeter (see Chapter 5 in the Service Manual). You then enter a new code and remove the jumper.

Example

Enter a new calibration security code:

CAL:SEC:STAT OFF, HP_E1412

Unsecure with the old code.

CAL:SEC:CODE *the_new_code*

*Enter a new calibration code
(a maximum of 12 characters).*

:SECure:STATe

CALibration:SECure:STATe **OFF | ON**, *<code>* unsecures or secures the multimeter for calibration. The calibration code must be the code set by the **CAL:SEC:CODE** command. The state is stored in non-volatile memory.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
OFF ON	boolean	OFF 0 ON 1	none
<i>code</i>	discrete	up to 12 characters set by :SEC:CODE	none

Comments

- You can substitute decimal values for the OFF ("0") and ON ("1") parameters.
- The multimeter calibration is secured when shipped from the factory. The security code is set to "HP_E1412" (or "HP_E1312" for B-size).

*RST does not change the state.

Example

Set the calibration state to unsecured:

CAL:SEC:STAT OFF, HP_E1412

Unsecure multimeter calibration.

:SECure:STATe?

CALibration:SECure:STATe? returns a "1" or "0" to show whether the calibration security state is enabled (1) or disabled (0). The number is sent to the output buffer.

Example

Query the calibration security state:

CAL:SEC:STAT?

Query multimeter calibration security state

enter statement

Enter value into computer.

:STRing

CALibration:STRing <quoted string> allows you to record calibration information about your multimeter while CAL:SEC:STAT is OFF. For example, you can store information such as the last calibration date and/or the next calibration due date. The calibration message can contain up to 40 characters. Characters in excess of 40 are truncated and no error is generated. The string is stored in non-volatile memory.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<quoted string>	discrete	alphanumeric	none

Comments

- The calibration message can contain up to 40 characters.
- Calibration security state must be OFF to store a string.
- The calibration message is stored in non-volatile memory and does not change when power has been off or after a remote interface reset.

Example

Enter calibration information to record the next calibration date:

CAL:STR 'Cal 4/4/YY, Due 10/4/YY'

Enter a calibration message to record the cal date of April 4 and next cal due date as October 4 (YY = year of due date).

:STRing?

CALibration:STRing? queries the calibration message and returns a quoted string (or a null string " " if nothing is present).

Example**Query the calibration message:****CAL:STR?**

enter statement

*Query the calibration message.**Enter value into computer.***:VALue**

CALibration:VALue <cal_value> specifies the value of the known calibration signal used by the calibration procedure. See the HP E1312A and HP E1412A Service Manual, Chapter 5 "Adjustments", for a more detailed description of the multimeter's calibration/adjustment procedures.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<cal_value>	numeric	see service manual	none

Comment***RST** does not affect the calibration value.**Example****Enter the known value for the calibration source signal:****CAL:VAL 10.0***Enter calibration value .***:VALue?****CALibration:VALue?** queries the present calibration value.**Example****Query the calibration value:****CAL:VAL?**

enter statement

*Query the calibration value.**Enter value into computer.***:ZERO:AUTO**

CALibrate:ZERO:AUTO <mode> enables or disables the autozero mode. Auto zero applies to dc voltage, dc current and 2-wire ohms measurements only. 4-wire ohms and dc voltage ratio measurements automatically enable the autozero mode.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
mode	boolean	OFF 0 ON 1 ONCE	none

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)

:ZERO:AUTO?

CALibrate:ZERO:AUTO? queries the autozero mode. Returns "0" (OFF or ONCE) or "1" ON.

CALibration?

CALibration? performs a calibration using the specified calibration value set by the CALibration:VALue command and queries the calibration response to verify a successful calibration.

Comments

- Execution of this command begins the electronic adjustment for the function and range the multimeter is set to. The adjustment is performed based on the value stated in the CAL:VAL command and the multimeter expects that value at the input terminals.
- The command returns "0" to indicate there are no calibration errors and the calibration was performed. A "1" is returned if a calibration error occurs and a calibration is unable to be performed. The error message is reported to the output buffer.
- You must set CALibration:SECure:STaTe OFF <code> to allow a calibration to be performed. This requires that you know the calibration secure code. The secure state enabled prevents unauthorized calibration of the multimeter.

Calibrate the active function and range using the CAL:VALue:**CAL?***Perform the calibration.*

monitor the status byte to detect calibration operation complete

enter statement

Enter cal response into computer to verify the calibration was successful.

CONFigure

The CONFigure command subsystem configures the multimeter to perform the specified measurement with the given range and resolution. CONFigure *does not* make the measurement after setting the configuration. Executing CONFigure is equivalent to setting the multimeter configuration as follows:

Command	Setting
RANGE	As specified (or AUTO).
RESolution	As specified, or 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 ([SENSe:]INP:IMP:AUTO)	Applies to dc voltage and is disabled for all other functions. 10MΩ 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)
VM Complete routing (OUTP:TTLT<n>:STAT)	OFF (all trigger lines; n = 0 - 7)
Math function (CALCulate:STATe)	OFF

After configuring the multimeter, use the INITiate command to place the multimeter in the wait-for-trigger state and store readings in the multimeter's internal memory. Or, use the READ? command to make the measurement and send the readings to the output buffer when the trigger is received.

Subsystem Syntax

CONFigure

```
:CURRent[:DC] [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:CURRent:AC [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:FREQuency [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:FRESistance [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:PERiod [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:RESistance [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
[:VOLTage[:DC]] [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
[:VOLTage[:DC]]:RATio
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:VOLTage:AC [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
```

The CONFigure command RANGE and RESolution parameters are optional. You will get the default range and resolution settings if you do not specify a range or resolution in the command. You will get these default settings even if you set a range or resolution different from the default value prior to executing the CONFigure command. The following table lists the default settings you can expect from the CONFigure command for each function.

Default Settings for CONFigure Command by Function.

FUNCTION	RANGE	RESOLUTION
CURR[:DC]	1A	1 μ A
CURR:AC	1A	10 μ A
FREQ	FREQ:RANG = 3 Hz VOLT:RANG = 10V	30 μ Hz
FRES	1 k Ω	1 m Ω
PER	PER:RANG = 0.333 sec VOLT:RANG = 10V	3.33 μ seconds
RES	1 k Ω	1 m Ω
VOLT[:DC]	10V	10 μ V
VOLT[:DC]:RAT	10V	10 μ V
VOLT:AC	10V	100 μ V

:CURRENT[:DC]

CONFigure:CURRENT[:DC]

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the DC current function and allows you to specify the measurement range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	10mA 100mA 1 A 3 A MIN MAX DEF AUTO	A
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	A

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 autorange and will not accept a *resolution* parameter but will default the integration time to 10 PLC.
- The DEFault option for the *range* parameter will also enable autorange. The DEF option for the *resolution* parameter defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

For *range*: MIN = 10 mA; MAX = 3A

For *resolution*: See Table 1 in this chapter for valid resolution choices for each range.

- To select autorange, specify AUTO or DEF for *range* or do not specify a value for the range and resolution parameters (see next bullet comment). 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 or CONF:CURR:DC DEF,MAX or 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.

Example

Making DC Current Measurements

CONF:CURR 3,MAX

*Function: dc current;
range selected: 3A;
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; send readings to output buffer.

enter statement

Enter readings into computer.

:CURRent:AC

CONFigure:CURRent:AC

[<range>|MIN|MAX|DEF|AUTO|,<resolution>|MIN|MAX|DEF]]

selects the AC current function and allows you to specify the measurement range and resolution. See the range versus resolution table at the beginning of this chapter for valid resolution choices for each ac current range.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	1 A 3 A MIN MAX DEF AUTO	A
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	A

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 DEFault option for the *range* parameter enables autorange.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

For *range*: MIN = 1 A; MAX = 3A

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. See Table 5 in this chapter for resolution choices.

- To select autorange, specify DEF for *range* or do not specify a value for the range and resolution parameters (see next bullet comment). 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 or CONF:CURR:AC DEF,MAX or 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.

Example

Making AC Current Measurements

CONF:CURR:AC 3,MAX

Function: dc current;
range selected: 3A;
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; send readings to output buffer.

enter statement

Enter readings into computer.

:FRESistance**CONFigure:FRESistance**

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the 4-wire ohms function and allows you to specify the measurement range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100Ω 1kΩ 10kΩ 100kΩ 1MΩ 10MΩ 100MΩ MIN MAX DEF AUTO	ohms
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	ohms

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 DEFault option for the *range* parameter enables autorange. The DEFault option for *resolution* defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

For *range*: MIN = 100Ω; MAX =100 MΩ

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 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 the AUTO or DEFault parameter; CONF:FRES DEF,MIN or CONF:FRES DEF,MAX or 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?

Example Making 4-Wire Ohms Measurements**CONF:FRES 1500,MAX***Function: 4-wire ohms;
range selected: 10 kΩ;
MAX resolution: 1Ω***SAMP:COUN 3***Take 3 readings; trigger source
is IMMEDIATE by default.***READ?***Place multimeter in
wait-for-trigger state and make
measurements; send readings to
output buffer.***enter statement***Enter readings into computer.***:RESistance****CONFigure:RESistance****[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]**

selects the 2-wire ohms function and allows you to specify the range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100Ω 1kΩ 10kΩ 100kΩ 1MΩ 10MΩ 100MΩ MIN MAX DEF AUTO	ohms
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	ohms

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 DEFault option for the *range* parameter enables autorange. The DEFault option for *resolution* defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

For *range*: MIN = 100Ω; MAX = 100MΩ

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 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 DEFault for range; CONF:RES DEF,MIN or CONF:RES DEF,MAX or 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 Making 2-Wire Ohms Measurements

CONF:RES 850,MAX

*Function: 2-wire ohms;
range selected: 1 k Ω ;
MAX resolution: 0.1 Ω .*

SAMP:COUN 3

Take 3 readings.

INIT

*Place multimeter in
wait-for-trigger state; store
readings in internal memory;
trigger source is IMMEDIATE by
default.*

FETC?

Place readings in output buffer.

enter statement

Enter readings into computer.

:VOLTage:AC

CONFigure:VOLTage:AC

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the AC-coupled RMS voltage function and allows you to specify the range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	0.1V 1V 10V 100V 300V MIN MAX DEF AUTO	volts
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	volts

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 DEFault option for the *range* parameter enables autorange. The DEFault option for *resolution* defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range*:

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

For *resolution*: See Table 4 for valid resolution choices for each range.

- To select 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 AUTO or DEFault for range; CONF:VOLT:AC DEF,MIN or CONF:VOLT:AC DEF,MAX or 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.

Example Making AC Voltage Measurements

CONF:VOLT:AC 0.54,MAX

Function: AC volts;
range selected: 1A;
MAX resolution: 100 μ A.

SAMP:COUN 3

Take 3 readings; source is IMMEDIATE by default.

READ?

Place multimeter in wait-for-trigger state and make measurements; send readings to output buffer.

enter statement

Enter readings into computer.

[:VOLTage[:DC]]

CONFigure[:VOLTage[:DC]]

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the DC voltage function and allows you to specify the range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100mV 1V 10V 100V 300V MIN MAX DEF AUTO	volts
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	volts

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 DEFault option for the *range* parameter enables autorange. The DEFault option for *resolution* defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum value for *range* and *resolution*:

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

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. See Table 1 in this chapter for valid resolution choices for each range.

- To select 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 AUTO or DEFault for range; CONF:VOLT:DC DEF,MIN or CONF:VOLT:DC DEF,MAX or 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?

Example

Making DC Voltage Measurements

CONF:VOLT 0.825,MAX

*Function: DC voltage;
range selected: 1A;
MAX resolution: 100 µA.*

SAMP:COUN 3

Take 3 readings.

INIT

Place multimeter in wait-for-trigger state; store readings in internal memory; trigger source is IMMEDIATE by default.

FETC?

Place readings in output buffer.

enter statement

Enter readings into computer.

[[:VOLTage[:DC]]
:RATio

CONFigure[:VOLTage[:DC]]:RATio

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

configures the multimeter for dc:dc ratio measurements with the specified range and resolution.

$$DC:DC \text{ RATIO} = \frac{\text{dc signal voltage}}{\text{dc reference voltage}} = \frac{\text{HI and LO input}}{\text{Sense HI and LO input}}$$

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. Autoranging 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.

NOTE

*Autorange on the "Sense" terminals is from 100 mV to 10V range only.
Maximum voltage you can apply to the "Sense" terminals is 10V.*

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i> (HI-LO input)	numeric	100mV 1V 10V 100V 300V MIN MAX DEF AUTO	volts
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	volts

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 DEFault option for the *range* parameter enables autorange. The DEFault option for *resolution* defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

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

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.

:FREQuency**CONFigure:FREQuency**

[<*range*>|MIN|MAX|DEF|AUTO[,<*resolution*>|MIN|MAX|DEF]]

selects the frequency function.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	3E+00	Hz
<i>resolution</i>	numeric	3E-04 3E-05 3E-06	Hz

Comments

- The frequency function uses one "range" for all inputs between 3 Hz and 300 kHz. A frequency measurement returns "0" if no input is applied.

- Range and resolution settings are listed below for the MIN, MAX, DEF and AUTO parameters and the settings after a module reset (*RST).

PARAMETER	RANGE	RESOLUTION
MIN	3E+00	3E-06
MAX	3E+00	3E-04
DEF AUTO and module reset (*RST)	3E+00	3E-05

:PERiod**CONFigure:PERiod**

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the period function and allows you to specify range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	3.3E-01	Sec
<i>resolution</i>	numeric	3.3E-05 3.3E-06 3.3E-07	Sec

Comments

- The period function uses one "range" for all inputs between 0.33 seconds and 3.3 μ Sec. A period measurement will return "0" if no input is applied.
- Range and resolution settings are listed below for the MIN, MAX, DEF and AUTO parameters and the settings after a module reset (*RST).

PARAMETER	RANGE	RESOLUTION
MIN	3.33E-01	3.33E-07
MAX	3.33E-01	3.33E-05
DEF AUTO and module reset (*RST)	3.33E-01	3.33E-06

CONFigure?

The CONFigure? command queries the multimeter to return the configuration set by the most recent CONFigure or MEASure command. It returns a quoted string to the output buffer in the following format:

"<function> <parameter>,<parameter>"

Subsystem Syntax

CONFigure?

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"
"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**Querying the Multimeter Configuration**

dimension string array

Dimension computer array to store string.

CONF:FRES 900,MAX

*Function: 4-wire ohms;
range selected: 1k Ω ;
MAX resolution: 100 m Ω .*

CONF?

Query configuration.

enter statement

Enter string into computer.

String Returned:

"FRES +1.000000E+003,9.999999E-02"

DATA

The multimeter can store up to 512 readings in internal memory. The DATA command allows you to determine how many readings are currently stored.

Subsystem Syntax

DATA
:POINts?

: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.

Comments

- INITiate command uses internal memory to store readings prior to using a FETCh? command. You use the DATA:POINts? command to query the number of readings stored in internal memory to determine the amount of data space to allocate on your computer to receive the data.

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.

Subsystem Syntax

FETCh?

Comments

- 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 (i.e., if INITiate has not been executed), or if settings have been altered since the last FETCh? (i.e., changing function or range), the “Data corrupt or stale” error will be generated.

NOTE: If you don't alter settings, you could "FETCh?" the same data over and over again without error.

- Readings sent to the output buffer can consist of two different lengths (bytes or characters) in Real ASCII format:

**$\pm 1.23456E\pm 12$ LF or
 $\pm 1.234567E\pm 12$ LF**

- Each measurement is terminated with a Line Feed (LF). The HP-IB End-of-Identify (EOI) signal is sent with the last byte transferred. If multiple measurements are returned, the measurements are separated by commas and EOI is sent only with the last byte. For example:
 $\pm 1.23456E\pm 12$ LF, $\pm 1.234567E\pm 12$ LF, $\pm 1.23456E\pm 12$ LF EOI

- The Multimeter's internal memory stores 512 readings maximum.
- Related Commands: CONFigure, INITiate, READ?
- ***RST Condition:** Executing FETCh? after a *RST generates error “Data corrupt or stale” (*RST places the multimeter in the idle state).

Example

Transferring Stored Readings to Output Buffer

dimension array
CONF:VOLT:DC
SAMP:COUN 100
INIT

FETC?
enter statement

*Dimension computer array to store 100 readings.
Function: DC voltage.
100 readings per trigger.
Store readings in internal memory; trigger source is IMMEDIATE by default.
Place readings in output buffer.
Enter readings into computer.*

INITiate

The INITiate command subsystem places the multimeter in the wait-for-trigger state. This command is most commonly used with CONFigure. See the section titled "Triggering the Multimeter" in Chapter 2 for a complete description of the HP E1312A and HP E1412 trigger system which discusses the wait-for-trigger state.

Subsystem Syntax

INITiate
[:IMMediate]

[:IMMediate]

INITiate[:IMMediate] places the multimeter in the wait-for-trigger state. When a trigger is received, readings are placed in multimeter internal memory.

Comments

- 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, the 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, the measurement starts as soon as a trigger is received either from the external BNC connector, the VXIbus backplane (TTLT<n> trigger lines) or a BUS trigger.
- The READ? command executes INITiate implicitly. The MEASure command executes 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

Placing Multimeter in Wait-For-Trigger State

CONF:VOLT:DC
TRIG:SOUR EXT

INIT

FETCh?

INIT

Function: DC voltage.

Trigger source is the external BNC on the multimeter .

Place multimeter in wait-for-trigger state; store readings in internal memory when ext trigger is received.

Place readings in output buffer.

You must re-initiate the wait-for-trigger state after each trigger cycle.

INPut

The INPut command enables or disables the automatic input impedance mode for DC voltage measurements.

Subsystem Syntax

INPut

:IMPedance:AUTO OFF|ON
:IMPedance:AUTO?

: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 M Ω for all DC voltage ranges. This is useful to prevent a change in input impedance, caused by changing ranges, from affecting the measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

<i>mode</i> (Impedance)	AUTO OFF (10 M Ω)	AUTO ON (>10 G Ω)
Range for impedance	All ranges	100 mV, 1V and 10V (other ranges are at 10 M Ω)

Example

Enable Automatic Input Impedance
(use >10 G Ω for 100 mV, 1V and 10V ranges).

INP:IMP:AUTO ON

*Enable automatic input
impedance*

Comments

You can substitute decimal values for the OFF ("0") and ON ("1") parameters.

***RST Conditions:** INP:IMP:AUTO OFF

:IMPedance:AUTO?

INPut:IMPedance:AUTO? returns a number to show whether the automatic input impedance mode is enabled or disabled: "1" = ON, "0" = OFF. The number is sent to the output buffer.

Example

Querying the input impedance mode.

INP:IMP:AUTO ON

Enable automatic input impedance

INP:IMP:AUTO?

Query multimeter to return input impedance mode ("1")

enter statement

Enter value into computer

MEASure

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, or 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 ([SENSe:]INP:IMP:AUTO)	Applies to dc voltage and is disabled for all other functions. 10MΩ 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

Subsystem Syntax

MEASure

```
:CURRent[:DC]?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:CURRent:AC?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:FREQuency?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:FRESistance?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:PERiod?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:RESistance?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
```

```

[:VOLTage[:DC]]?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
[:VOLTage[:DC]]:RATio?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]
:VOLTage:AC?
    [<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

```

:CURRent[:DC]?**MEASure:CURRent[:DC]?**

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the DC current function and allows you to specify the measurement range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	10mA 100mA 1 A 3 A MIN MAX DEF AUTO	A
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	A

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 option for the *range* parameter enables autorange. The DEF option for the *resolution* parameter defaults the integration time to 10 PLC.
- The DEFault option for the *range* parameter will also enable autorange. The DEF option for the *resolution* parameter defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

For *range*: MIN = 10 mA; MAX = 3A

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 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 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 Making DC Current Measurements

MEAS:CURR:DC? .1,MAX

Function: DC current;
range selected: 1A
MAX resolution: 1.0E-05 A

:CURRent:AC?

MEASure:CURRent:AC?

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the AC current function and allows you to specify the measurement range and resolution (see range versus resolution table at start of chapter).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	1 A 3 A MIN MAX DEF AUTO	A
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	A

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 DEFault option for the *range* parameter enables autorange.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

For *range*: MIN = 1A; MAX = 3A

For *resolution*: see the range versus resolution table at the beginning of this chapter for resolution choices.

- To select autorange, specify DEF for *range* or do not specify a value for the parameter. 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 the range parameter as 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?

Example**Making AC Current Measurements****MEAS:CURR:AC? 1,MAX**

Function: AC Current;
range selected: 1A;
MAX resolution: 1.0E-04 A.

:FRESistance?**MEASure:FRESistance?****[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]**

selects the 4-wire ohms function and allows you to specify the measurement range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100Ω 1kΩ 10kΩ 100kΩ 1MΩ 10MΩ 100MΩ MIN MAX DEF AUTO	ohms
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	ohms

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 DEFault option for the *range* parameter enables autorange. The DEF option for the *resolution* parameter defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

For *range*: MIN = 100Ω; MAX =100 MΩ

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 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: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

Making 4-Wire Ohms Measurements

MEAS:FRES? 1500,MAX

Function: 4-wire ohms;
range selected: 10 k Ω ;
MAX resolution: 1 Ω

:RESistance?

MEASure:RESistance?

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the 2-wire ohms function and allows you to specify the range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100 Ω 1k Ω 10k Ω 100k Ω 1M Ω 10M Ω 100M Ω MIN MAX DEF AUTO	ohms
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	ohms

Comments

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

For *range*: MIN = 100 Ω ; MAX = 100M Ω

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 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

Making 2-Wire Ohms Measurements

MEAS:RES? 1320,MAX

Function: 2-wire ohms;
range selected: 10 k Ω ;
MAX resolution: 1.0 Ω .

[:VOLTage[:DC]]?

MEASure[:VOLTage[:DC]]?

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the DC voltage function and allows you to specify the range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100mV 1V 10V 100V 300V MIN MAX DEF AUTO	volts
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	volts

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 DEFault option for the *range* parameter enables autorange. The DEF option for the *resolution* parameter defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

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

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 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?

Example

Making DC Voltage Measurements

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

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

MEAS:VOLT:DC? 0.825,MAX

Function: DC voltage;
range selected: 1V;
MAX resolution: 100 μ V.

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

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

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

configures the multimeter for dc:dc ratio measurements with the specified range and resolution. For ratio measurements, the specified range applies to the signal connected to the HI and LO input terminals. Autoranging is automatically selected for reference voltage measurements on the "Sense" HI and LO terminals with a maximum voltage of 10V.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100mV 1V 10V 100V 300V MIN MAX DEF AUTO	volts
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	volts

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 DEFault option for the *range* parameter enables autorange. The DEF option for the *resolution* parameter defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range* and *resolution*:

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

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 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?

Example Making DC Voltage Ratio Measurements**MEAS:VOLT:DC:RAT? 0.825,MAX**

*Function: DC voltage;
range selected: 1V;
MAX resolution: 100 μ V.*

:VOLTage:AC?**MEASure:VOLTage:AC?****[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]**

selects the AC-coupled RMS voltage function and allows you to specify the range and resolution (see range versus resolution table at start of chapter).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	0.1V 1V 10V 100V 300V MIN MAX DEF AUTO	volts
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX DEF	volts

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 DEFault option for the *range* parameter enables autorange. The DEF option for the *resolution* parameter defaults the integration time to 10 PLC.
- The MIN and MAX parameters select the minimum or maximum values for *range*:

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

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 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: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.

Example Making AC Voltage Measurements**MEAS:VOLT:AC? 0.54,MAX**

*Function: AC volts;
range selected: 1V;
MAX resolution: 100 μ V.*

:FREQuency?**MEASure:FREQuency?**

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the frequency function and uses one range for all inputs between 3 Hz and 300 kHz.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	3E+00	Hz
<i>resolution</i>	numeric	3E-04 3E-05 3E-06	Hz

Comments

- The frequency function uses one "range" for all inputs between 3 Hz and 300 kHz. Querying the range will always return "3E+00". A frequency measurement returns "0" if no input is applied.
- Range and resolution settings are listed below for the MIN, MAX, DEF and AUTO parameters and after a module reset (*RST).

PARAMETER	RANGE	RESOLUTION
MIN	3E+00	3E-06
MAX	3E+00	3E-04
DEF AUTO and *RST	3E+00	3E-05

:PERiod?**MEASure:PERiod?**

[<range>|MIN|MAX|DEF|AUTO[,<resolution>|MIN|MAX|DEF]]

selects the period function and allows you to specify range and resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	3.3E-01	Sec
<i>resolution</i>	numeric	3.3E-05 3.3E-06 3.3E-07	Sec

Comments

- The period function uses one "range" for all inputs between 0.33 seconds and 3.3 μ Sec. A period measurement will return "0" if no input is applied.
- Range and resolution settings are listed below for the MIN, MAX, DEF and AUTO parameters and after a module reset (*RST).

MEASure:PERiod?

MEASure:PERiod?

PARAMETER	RANGE	RESOLUTION
MIN	3.33E-01	3.33E-07
MAX	3.33E-01	3.33E-05
DEF AUTO and *RST	3.33E-01	3.33E-06

OUTPut

The OUTPut command subsystem enables you to route the multimeter's *voltmeter complete* signal to the VXIbus TTL trigger lines.

Subsystem Syntax

OUTPut

:TTLTrg<*n*>[:STATe]<*mode*>

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

:TTLTrg[:STATe]

OUTPut:TTLTrg<*n*>[:STATe] <*mode*> enables or disables routing of the *voltmeter complete* signal to the specified VXIbus trigger line (TTLTrg0 through TTLTrg7) on the backplane P2 connector.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>n</i>	discrete	0 1 2 3 4 5 6 7	none
<i>mode</i>	boolean	OFF 0 ON 1	none

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- The *voltmeter complete* signal is always routed to the multimeter's front panel “VM Complete” BNC connector. When enabled (ON), the OUTPut command also routes *voltmeter complete* to the specified trigger line on connector P2. When disabled (OFF), *voltmeter complete* 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) depends on the aperture time and on the autozero mode as shown below.

Aperture Time	Voltmeter Complete low	
	Autozero ON	Autozero OFF
320 ms (50 Hz)	350 ms	350 μs
267 ms (60 Hz)	370 μs	370 μs
20 ms (50 Hz)	20.5 ms	370 μs
16.7 ms (60 Hz)	17.2 ms	390 μs
2.5 ms (400 Hz)	3.1 ms	430 μs
100 μs	520 μs	250 μs
10 μs		70 μs

- The VXIbus trigger lines are open-collector TTL lines that remain in a non-asserted (high) state until the *voltmeter complete* signal is sent.
- More than one TTL output trigger line can be enabled at one time.
- *RST Condition:** OUTP:TTLTrg OFF

OUTPut:TTLTrg[:STATe]?

OUTPut:TTLTrg[:STATe]?

Example

Routing Voltmeter Complete to Trigger Line

OUTP:TTLT7 ON

Route signal to trigger line 7.

:TTLTrg[:STATe]?

OUTPut:TTLTrg<n>[:STATe]? returns a number to show whether VXIbus trigger line routing of the **voltmeter complete** signal is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example

Querying Voltmeter Complete Destination

OUTP:TTLT7 ON

Route signal to trigger line 7.

OUTP:TTLT7?

Query multimeter to return trigger line mode.

enter statement

Enter value into computer.

READ?

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

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

Subsystem Syntax**READ?****Comments**

- The READ? command is slower than the INITiate command since readings are formatted and sent to the output buffer as they are taken. However, the sample count and trigger count are not limited with READ? since memory is not used.
- This command causes the multimeter to start taking readings as soon as its trigger requirements are met (same as the INIT command).
- Each reading sent to the output buffer is terminated with a Line Feed (*LF*). The HP-IB End-of-Identify (EOI) signal is sent with the last byte transferred. If multiple readings are returned, the readings are separated by commas and EOI is sent only with the last byte.
- The output buffer capacity is 128 bytes. The multimeter remains “busy” with a full buffer until you begin removing readings from it.
- Readings are placed directly in the output buffer and are not stored in internal memory as with an INIT command. With INIT, a FETCh? command is required to transfer readings from internal memory to the output buffer. You may want to use the READ? mode of operation when readings need to be taken at a continuous rate.
- The rate the controller removes the readings from the multimeter needs to match the rate the multimeter puts them into the output buffer to keep from filling the output buffer. The multimeter will quit making measurements until you remove readings from the output buffer and make room in the output buffer for more readings.
- **Related Commands:** CONFigure, FETCh?, INITiate

Example**Transferring Readings Directly to Output Buffer**

dimension array

Dimension computer array to store 100 readings.

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.

enter statement

Enter readings into computer.

SAMPle

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.

Subsystem Syntax

SAMPle

:COUNT <number>|MIN|MAX

:COUNT? [MIN | MAX]

:COUNT

SAMPle:COUNT <number>|MIN|MAX designates the number of readings per trigger.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	1 through 50,000 MIN MAX	none

Comments

- MINimum sets 1 reading per trigger. MAXimum sets 50,000 readings per trigger.
- If MAX or 50,000 is specified for *number*, the command executes without error. When an INIT is executed requiring readings to be stored in internal memory, an “Insufficient memory” error is generated to show that the number of readings exceeds the memory available. However, you can execute READ? which returns the readings to the output buffer and does not use internal memory.
- A number >50,000 returns error -222 "Data out of range".
- CONFigure and MEASure set the sample count to 1.
- ***RST Condition:** SAMP:COUNT 1

Example

Setting the Sample Count

CONF:VOLT:DC

TRIG:SOUR EXT

SAMP:COUNT 10

READ?

enter statement

Function: DC voltage.

Trigger source is external BNC on multimeter front panel.

Specify 10 readings per trigger.

Place multimeter in wait-for-trigger state; make measurement when external trigger is received; send readings to output buffer.

Enter readings into computer.

:COUNT?

SAMPle:COUNT? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present sample count (1 through 50,000) if MINimum or MAXimum is not specified.
- The minimum sample count (1) if MIN is specified.
- The maximum sample count (50,000) if MAX is specified.

Example**Querying the Sample Count**

SAMP:COUN 10

Specify 10 readings per trigger.

SAMP:COUN?

Query multimeter to return sample count.

enter statement

Enter value into computer.

Enter readings into computer.

[SENSe:]

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 re-configuring the multimeter.

- Function, Range and Resolution
- Aperture Time and Number of Power Line Cycles
- Bandwidth
- Autozero

Subsystem Syntax

```
[SENSe:]
FUNction "CURRent:AC"
FUNction "CURRent[:DC]"
FUNction "FREQuency"
FUNction "FREStistance"
FUNction "PERiod"
FUNction "RESistance"
FUNction "VOLTage:AC"
FUNction "VOLTage[:DC]"
FUNction "VOLTage[:DC]:RATio"
FUNction?
CURRent
:AC:RANGe <range> | MIN | MAX
:AC:RANGe? [MIN | MAX]
:AC:RANGe:AUTO OFF | ON
:AC:RANGe:AUTO?
:AC:RESolution <resolution> | MIN | MAX
:AC:RESolution? [MIN | MAX]
[:DC]:APERture .333ms | 3.33ms | 16.7ms | 167ms | 1.67s | MIN | MAX
[:DC]:APERture? [MIN | MAX]
[:DC]:NPLCycles .02 | .2 | 1 | 10 | 100 | MIN | MAX
[:DC]:NPLCycles? [MIN | MAX]
[:DC]:RANGe <range> | MIN | MAX
[:DC]:RANGe? [MIN | MAX]
[:DC]:RANGe:AUTO OFF | ON
[:DC]:RANGe:AUTO?
[:DC]:RESolution <resolution> | MIN | MAX
[:DC]:RESolution? [MIN | MAX]
DETector
:BANDwidth 3 | 20 | 200 | MIN | MAX
:BANDwidth? [MIN | MAX]
FREQuency
:APERture 0.01 | 0.1 | 1 | MIN | MAX
:APERture? [MIN | MAX]
```

[SENSe:]

FREQuency

:VOLTage:RANGe <range> | MIN | MAX

:VOLTage:RANGe? [MIN | MAX]

:VOLTage:RANGe:AUTO OFF | ON

:VOLTage:RANGe:AUTO?

FREStance

:APERture .333ms | 3.33ms | 16.7ms | 167ms | 1.67s | MIN | MAX

:APERture? [MIN | MAX]

:NPLCycles 0.02 | 0.2 | 1 | 10 | 100 | MIN | MAX

:NPLCycles? [MIN | MAX]

:RANGe <range>|MIN | MAX

:RANGe? [MIN | MAX]

:RANGe:AUTO OFF | ON

:RANGe:AUTO?

:RESolution <resolution> | MIN | MAX

:RESolution? [MIN | MAX]

PERiod

:APERture 0.01 | 0.1 | 1 | MIN | MAX

:APERture? [MIN | MAX]

:VOLTage:RANGe <range> | MIN | MAX

:VOLTage:RANGe? [MIN | MAX]

:VOLTage:RANGe:AUTO OFF | ON

:VOLTage:RANGe:AUTO?

RESistance

:APERture .333ms | 3.33ms | 16.7ms | 167ms | 1.67s | MIN | MAX

:APERture? [MIN | MAX]

:NPLCycles 0.02 | 0.2 | 1 | 10 | 100 | MIN | MAX

:NPLCycles? [MIN | MAX]

:RANGe <range> | MIN | MAX

:RANGe? [MIN | MAX]

:RANGe:AUTO OFF | ON

:RANGe:AUTO?

:RESolution <resolution> | MIN | MAX

:RESolution? [MIN | MAX]

VOLTage

:AC:RANGe <range> | MIN | MAX

:AC:RANGe? [MIN | MAX]

:AC:RANGe:AUTO OFF|ON

:AC:RANGe:AUTO?

:AC:RESolution <resolution> | MIN | MAX

:AC:RESolution? [MIN | MAX]

[:DC]:APERture .333ms | 3.33ms | 16.7ms | 167ms | 1.67s | MIN | MAX

[:DC]:APERture? [MIN | MAX]

[:DC]:NPLCycles 0.02 | 0.2 | 1 | 10 | 100 | MIN | MAX

[:DC]:NPLCycles? [MIN | MAX]

[:DC]:RANGe <range> | MIN | MAX

[:DC]:RANGe? [MIN | MAX]

```

[SENSe:]
  VOLTage
    [:DC]:RANGe:AUTO OFF | ON
    [:DC]:RANGe:AUTO?
    [:DC]:RESolution <resolution> | MIN | MAX
    [:DC]:RESolution? [MIN | MAX]
  ZERO
    :AUTO OFF | ONCE | ON
    :AUTO?

```

FUNCTION

[SENSe:]FUNCTION "<function>" selects the measurement function. You can select the functions shown in the following table.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>function</i>	discrete	:CURRent:AC :CURRent[:DC] :FREQuency :FREStance :PERiod :RESistance :VOLTage:AC :VOLTage[:DC] :VOLTage[:DC]:RATio	none

Comments

- ***RST Condition:** SENS:VOLT:DC

Example**Changing Measurement Function**

```

CONF:VOLT
FUNC "FRES"
READ?

```

enter statement

*Function: DC voltage.
Set function to 4-wire resistance.
Place multimeter in
wait-for-trigger state and make
measurement; send reading to
output buffer.
Enter reading into computer.*

FUNCTION?

[SENSe:]FUNCTION? returns one of the following quoted strings to the output buffer:

```

"CURR:AC"
"CURR"
"FREQ"
"FRES"
"PER"
"RES"
"VOLT:AC"

```

“VOLT”
“VOLT:RAT”

Example Querying the Measurement Function

FUNC "FRES"

Function: 4-wire ohms.

FUNC?

Query multimeter to return selected function.

enter statement

Enter quoted string into computer.

CURRent:AC:RANGe

[SENSe:]CURRent:AC:RANGe <*range*> selects the range for AC current measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	1A 3A MIN MAX	amps

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected current. The multimeter then selects the correct range.
- MIN selects the minimum range available with the CURRent:AC:RANGe command: 1A. MAX selects the maximum range available: 3A.
- 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 command.
- The CURR:AC:RANG command overrides the range setting from a previous CONFigure command on the same function.
- ***RST Condition:** CURR:AC:RANG 1

CURRent:AC:RANGe?

[SENSe:]CURRent:AC:RANGe? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present current range selected 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.
- The minimum current range available (1A) if MIN is specified.
- The maximum current range available (3A) if MAX is specified.

Example Querying the AC Current Measurement Range

[SENSe:]CURRent:AC:RANGe :AUTO

[SENSe:]CURRent:AC :RESolution

CURR:AC:RANG 3

Select 3 A range.

CURR:AC:RANG?

Query multimeter to return the present range.

enter statement

Enter value into computer.

**CURRent:AC:RANGe
:AUTO**

[SENSe:]CURRent:AC:RANGe:AUTO <mode> enables or disables the autorange function for AC current measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

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 Commands: CONFigure, :DC:RANGe, RESistance:RANGe
- ***RST Condition:** CURR:AC:RANG:AUTO ON

Example

Disabling AC Current Autoranging

CURR:AC:RANG:AUTO OFF

Disable autorange.

**CURRent:AC:RANGe
:AUTO?**

[SENSe:]CURRent:AC:RANGe:AUTO? returns a number to show whether the AC current autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example

Querying the AC Current Autorange Mode

CURR:AC:RANG:AUTO OFF

Disable autorange.

CURR:AC:RANG:AUTO?

Query multimeter to return autorange mode.

enter statement

Enter value into computer.

**CURRent:AC
:RESolution**

[SENSe:]CURRent:AC:RESolution <resolution> selects the resolution for AC current measurements. See range versus resolution table at the beginning of this chapter.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX	amps

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: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 as the measurement function.
- If autoranging is required, set the resolution using the MIN or MAX parameter.

CURRent:AC
:RESolution?

[SENSe:]CURRent:AC:RESolution? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present current resolution selected if MIN or MAX is not specified.
- The minimum current resolution available if MIN is specified.
- The maximum current resolution available if MAX is specified.

Example

Querying the AC Current Measurement Range

CURR:AC:RES 1E-4

Select 100 μ A resolution

CURR:AC:RES?

Query multimeter to return the present resolution.

enter statement

Enter value into computer.

CURRent[:DC]
:APERture

[SENSe:]CURRent[:DC]:APERture <number> sets the integration time in seconds for dc current measurements. Values are rounded up to the nearest aperture time shown in the following table.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	0.333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX	Seconds

Comments

- MIN sets the aperture time to 0.333 ms. MAX sets the aperture time to 1.66667 seconds (60 Hz) or 2 seconds (50 Hz).

- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7 ms (60 Hz line frequency) sets an integration time of 1 PLC. The corresponding resolution depends on the function and range you select.
- 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.
- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- Related Commands: CALibration:LFRfrequency
- *RST Condition: CURR:DC:APER 0.166667 seconds (60 Hz) or CURR:DC:APER 0.20000 (50 Hz)

Example **Set an aperture time of 16.7 ms**

CURR:APER 16.7E-03

Aperture time is 16.7 ms

CURRent[:DC]:APERture?

[SENSe:]CURRent[:DC]:APERture? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present aperture time in seconds if MIN or MAX is not specified.
- The minimum aperture time available (.333 ms) if MIN is specified.
- The maximum aperture time available (1.67 s @ 60 Hz; 2 s @ 50 Hz) if MAX is specified.

Example **Querying the Aperture Time**

CURR:APER 167E-03

Aperture time is 167 ms

CURR:APER?

Query multimeter to return aperture time

enter statement

Enter value into computer

CURRent[:DC]:NPLC

[SENSe:]CURRent[:DC]:NPLCycles <number> sets the integration time in power line cycles (PLCs). Values are rounded up to the nearest number of PLCs shown in the following table.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	0.02 0.2 1 10 100 MIN MAX	PLCs

[SENSe:]CURREnt[:DC]:NPLC?**[SENSe:]CURREnt[:DC]:RANGe****Comments**

- MINimum selects 0.02 PLCs. MAXimum selects 100 PLCs. Setting the integration time in power line cycles (PLCs) also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 167 ms (60 Hz line frequency) or 200 ms (50 Hz). The corresponding resolution depends on the function and range you select.
- The CURREnt[:DC]:NPLC command overrides the results of previously executed CURREnt:APERture or CURREnt:RESolution command.
- The greater the number of PLCs, the greater the normal mode rejection (and the lower the reading rate).
- Only the 1 PLC, 10 PLC and 100 PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line related noise. Fractional PLC settings of 0.02 and 0.2 do not provide normal mode rejection of power line noise.
- ***RST Condition:** 10 PLC

Example**Setting the DC Current Integration Time in PLCs****CURREnt[:DC]:NPLC 100***Integration time is 100 PLCs.***CURREnt[:DC]:NPLC?**

[SENSe:]CURREnt[:DC]:NPLCycles? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present integration time in PLCs if MINimum or MAXimum is not specified.
- The minimum integration time available (0.02) if MIN is specified.
- The maximum integration time available (100) if MAX is specified.

Example**Querying the DC Current Integration Time****CURREnt[:DC]:NPLC 100***Integration time is 100 PLCs.***CURREnt[:DC]:NPLC?***Query multimeter to return integration time.*

enter statement

*Enter value into computer.***CURREnt[:DC]:RANGe**

[SENSe:]CURREnt[:DC]:RANGe <range> selects the range for DC current measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	0.01A 0.1A 1A 3A MIN MAX	amps

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected current. The multimeter then selects the correct range.

[SENSe:]CURRent[:DC] :RANGe?

[SENSe:]CURRent[:DC]:RANGe :AUTO

- MIN selects the minimum range available with the CURRent:DC:RANGe command: 10 mA. MAX selects the maximum range available: 3 A.
- You must select a range using CURRent:DC:RANGe *before* specifying 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

Example

Setting the DC Current Range to 3A

CURR:DC:RANG 3

DC Current range is 3A.

**CURRent[:DC]
:RANGe?**

[SENSe:]CURRent[:DC]:RANGe? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present current range selected if MIN or MAX is not specified. Only the ranges available with the RANGe command are returned. For example, if CONFigure selects the 100 mA range, 100 mA is the range returned.
- The minimum current range available (10 mA) if MIN is specified.
- The maximum current range available (3 A) if MAX is specified.

Example

Querying the DC Current Measurement Range

CURR:DC:RANG 3

Select 3 A range.

CURR:DC:RANG?

Query multimeter to return the present range.

enter statement

Enter value into computer

**CURRent[:DC]:RANGe
:AUTO**

[SENSe:]CURRent[:DC]:RANGe:AUTO <mode> enables or disables the autorange function for DC current measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

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.

[SENSe:]CURRent[:DC]:RANGe:AUTO?

[SENSe:]CURRent[:DC]:RESolution?

- Related Commands: CONFigure, :AC:RANGe, RESistance:RANGe
- ***RST Condition:** CURR:DC:RANG:AUTO ON

Example **Disabling DC Current Autoranging**

CURR:DC:RANG:AUTO OFF *Disable autorange.*

**CURRent[:DC]:RANGe
:AUTO?**

[SENSe:]CURRent[:DC]:RANGe:AUTO? returns a number to show whether the DC current autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example **Querying the DC Current Autorange Mode**

CURR:DC:RANG:AUTO OFF *Disable autorange.*
CURR:DC:RANG:AUTO? *Query multimeter to return
autorange mode.*
enter statement *Enter value into computer.*

**CURRent[:DC]
:RESolution**

[SENSe:]CURRent[:DC]:RESolution <resolution> selects the resolution for DC current measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
resolution	numeric	resolution MIN MAX	amps

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 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.
- If autoranging is required, set the resolution using the MIN or MAX parameters.
- Changing the resolution also changes the NPLC and APERture setting to the values that correspond with the resolution specified.

**CURRent[:DC]
:RESolution?**

[SENSe:]CURRent[:DC]:RESolution? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present current resolution selected if MIN or MAX is not specified. Only the resolutions available with the RESolution command are returned. For example, if CONFigure selects 10 mA resolution, 10 mA is the resolution returned.

- The minimum current resolution available (1 μ A) if MIN is specified.
- The maximum current resolution available (100 μ A) if MAX is specified.

Example**Querying the DC Current Measurement Range**

CURR:DC:RES 3

Select 3A resolution

CURR:DC:RES?

Query multimeter to return the present resolution.

enter statement

*Enter value into computer.***DETEctor:BANDwidth**

[SENSe:]DETEctor:BANDwidth <bw> 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.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
bw	numeric	3 20 200 MIN MAX	none

- 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 kHz. Specify the lowest frequency expected in the input signal. The multimeter selects the appropriate filter based on the table below.

Comments

- The following table lists the filter frequency range and the settling time for making measurements.

Input Frequency	AC Filter Selected	Settling Time
3 Hz to 300 kHz	Slow filter	1 reading/ 7 seconds
20 Hz to 300 kHz	Medium filter (default)	1 reading/ second
200 Hz to 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 power is removed or after a module reset. The upper limit on all three filters is 300 kHz.
- The slow filter is 3 Hz, the medium filter is 20 Hz and the fast filter is 200 Hz.
- The CONFigure and MEASure commands select the 20 Hz filter.

[SENSe:]DETEctor:BANDwidth?

[SENSe:]FREQuency:VOLTage :RANGe

- ***RST Condition:** DET:BAND 20 (medium filter)

Example

Set the ac Signal Filter for Fast Measurements From 200 Hz to 300 kHz.

DET:BAND 200

Selects the fast filter.

DETEctor:BANDwidth?

[SENSe:]DETEctor:BANDwidth? returns which ac filter has been selected. The value returned is 3, 20 or 200. The value is sent to the output buffer.

Example

Querying the Detector Bandwidth

DET:BAND 200

Select 200 Hz bandwidth (fast filter)

DET:BAND?

Query multimeter to return the detector bandwidth setting

FREQuency:APERture

[SENSe:]FREQuency:APERture <time> selects the aperture time (or gate time) for frequency measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
time	numeric	0.01 0.1 1 MIN MAX	seconds

Comments

- Specify 0.01 (10 ms) for 4 ½ digits, 0.1 (default, 100 ms) for 5 ½ digits or 1 second for 6 ½ digits.
- MIN = 0.01, MAX = 1.
- ***RST Condition:** 0.1 seconds

Example

Set a Frequency Aperture Time of 1 Second.

FREQ:APER 1

Sets aperture time to 1 second

FREQuency
:APERture?

[SENSe:]FREQuency:APERture? [MIN | MAX] queries the aperture time for frequency measurements. The MIN parameter returns the minimum aperture value (0.01); the MAX parameter returns the maximum aperture value (1).

FREQuency:VOLTage
:RANGe

[SENSe:]FREQuency:VOLTage:RANGe <range> selects the voltage range for the signal level of frequency measurements.

[SENSe:]FREQuency:VOLTage :RANGe?

[SENSe:]FREQuency:VOLTage :RANGe:AUTO

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100 mV 1V 10 V 100 V 300 V MIN MAX	volts

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected voltage. The multimeter then selects the correct range.
- MIN selects the minimum range available with the VOLTage :RANGe command: 100 mV. MAX selects the maximum range available: 300 V.
- Specifying a fixed range disables the autorange mode set by the FREQ:VOLT:RANG:AUTO command.
- The FREQ:VOLT:RANG command overrides the range setting from a previous CONFigure:FREQuency command.
- ***RST Condition:** FREQ:VOLT:RANG 10

Example

Set the Voltage Range for Frequency Measurements to 100V.

FREQ:VOLT:RANG 100

Voltage range for frequency measurements is 100V

FREQuency:VOLTage :RANGe?

[SENSe:]FREQuency:VOLTage:RANGe? [MIN | MAX] returns one of the following numbers to the output buffer: 0.1, 1, 10, 100 or 300.

- The present voltage range selected if MIN or MAX is not specified.
- The minimum voltage range available (100 mV) if MIN is specified.
- The maximum voltage range available (300 V) if MAX is specified.

Example

Querying the Measurement Range

FREQ:VOLT:RANG 10

Select 10V range.

FREQ:VOLT:RANG?

Query the present range.

enter statement

Enter value into computer.

FREQuency:VOLTage :RANGe:AUTO

[SENSe:]FREQuency:VOLTage:RANGe:AUTO <mode> enables or disables the autorange function for the signal level of frequency measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

[SENSe:]FREQuency:VOLTage :RANGe:AUTO?

[SENSe:]FREStance:APERture

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:VOLT:RANGe, autoranging is turned OFF.
- Related Commands: CONFigure, PERiod:VOLT:RANGe
- ***RST Condition:** FREQ:VOLT:RANG:AUTO ON

Example

Disabling Autoranging

FREQ:VOLT:RANG:AUTO OFF *Disable autorange.*

FREQuency:VOLTage :RANGe:AUTO?

[SENSe:]FREQuency:VOLTage:RANGe:AUTO? returns a number to show whether the autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example

Querying the Autorange Mode

FREQ:VOLT:RANG:AUTO OFF *Disable autorange.*
FREQ:VOLT:RANG:AUTO? *Query multimeter to return autorange mode.*
enter statement *Enter value into computer.*

FRESistance:APERture

[SENSe:]FRESistance:APERture <number> sets the integration time in seconds for 4-wire resistance measurements. Values are rounded up to the nearest aperture time shown in the following table.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	0.333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX	Seconds

Comments

- MIN sets the aperture time to 0.333 ms. MAX sets the aperture time to 1.66667 seconds (60 Hz) or 2 seconds (50 Hz).
- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7 ms (60 Hz line frequency) sets an integration time of 1 PLC. The corresponding resolution depends on the function and range you select.
- The FRES:APER command overrides the results of previously executed FRES:NPLC and FRES:RES commands. The last command executed has priority.

- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- Related Commands: CALibration:LFRrequency
- *RST Condition: FRES:APER 0.166667 seconds (60 Hz) or FRES:APER 0.20000 (50 Hz)

Example **Set an aperture time of 16.7 ms**

FRES:APER 16.7E-03

Aperture time is 16.7 ms

FRESistance:APERture?

[SENSe:]FRESistance:APERture? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present aperture time in seconds if MIN or MAX is not specified.
- The minimum aperture time available (.333 ms) if MIN is specified.
- The maximum aperture time available (1.67 s @ 60 Hz; 2 s @ 50 Hz) if MAX is specified.

Example **Querying the Aperture Time**

FRES:APER 167E-03

Aperture time is 167 ms

FRES:APER?

Query multimeter to return aperture time

enter statement

Enter value into computer

FRESistance:NPLC

[SENSe:]FRESistance:NPLCycles <number> sets the integration time in number of power line cycles (NPLCs). The NPLC is set to a value from the range of values that can accommodate the <number> you specify. For example, specifying 9 sets the NPLC to 10; specifying 11 sets the NPLC to 100.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	0.02 0.2 1 10 100 MIN MAX	PLCs

Comments

- MINimum selects 0.02 PLCs. MAXimum selects 100 PLCs. Setting the integration time in power line cycles (PLCs) also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 167 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 previously executed FRESistance:APERTure and FRESistance: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 the 1 PLC, 10 PLC and 100 PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line related noise. The 0.02 and 0.2 fractional PLC settings do not provide normal mode rejection of power line related noise.
- ***RST Condition:** 10 PLC

Example **Setting the Integration Time in PLCs**

FRES:NPLC 100

Integration time is 100 PLCs.

FRESistance:NPLC?

[SENSe:]FRESistance:NPLC? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present integration time in PLCs if MINimum or MAXimum is not specified.
- The minimum integration time available (0.02) if MIN is specified.
- The maximum integration time available (100) if MAX is specified.

Example **Querying the Integration Time**

FRES:NPLC 100

Integration time is 100 PLCs.

FRES:NPLC?

Query multimeter to return integration time.

enter statement

Enter value into computer.

FRESistance:RANGe

[SENSe:]FRESistance:RANGe <range> selects the range for 4-wire resistance measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ MIN MAX	ohms

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected resistance. The multimeter then selects the correct range.
- MIN selects the minimum range available with the FRESistance:RANGe command: 100Ω. MAX selects the maximum range available: 100 MΩ.

[SENSe:]FRESistance:RANGe?

[SENSe:]FRESistance:RANGe :AUTO

- You must select a range using FRESistance:RANGe *before* specifying 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 1 k Ω (1E+03)

Example

Set Four-Wire Resistance Range to 10 M Ω .

FRES:RANG 1E+07

4-wire resistance range is 10 M Ω

FRESistance:RANGe?

[SENSe:]FRESistance:RANGe? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present resistance range selected if MIN or MAX is not specified.
- The minimum resistance range available (100 Ω) if MIN is specified.
- The maximum resistance range available (100 M Ω) if MAX is specified.

Example

Querying the Measurement Range

FRES:RANG 100

Select 100 Ω range.

FRES:RANG?

Query multimeter to return the present range.

enter statement

Enter value into computer.

**FRESistance:RANGe
:AUTO**

[SENSe:]FRESistance:RANGe:AUTO <mode> enables or disables the autorange function for 4-wire resistance measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

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.

[SENSe:]FRESistance:RANGe :AUTO?

[SENSe:]FRESistance :RESolution?

Example Put 4-wire Resistance Measurements in the Autorange Mode.

FRES:RANG:AUTO ON

Autorange is turned on for 4-wire ohms measurements

FRESistance:RANGe :AUTO?

[SENSe:]FRESistance:RANGe:AUTO? returns a number to show whether the autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example Querying the Autorange Mode

FRES:RANG:AUTO OFF

Disable autorange.

FRES:RANG:AUTO?

Query multimeter to return autorange mode.

enter statement

Enter value into computer.

FRESistance :RESolution

[SENSe:]FRESistance:RESolution <resolution> selects the resolution for 4-wire resistance measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
resolution	numeric	resolution MIN MAX	ohms

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 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 as the measurement function.
- If autoranging is required, set the resolution using the MIN or MAX parameters or select a specific integration time using FRESistance:NPLCycles.
- ***RST Condition:** FRES:RES 1 mΩ (1E-03)

FRESistance :RESolution?

[SENSe:]FRESistance:RESolution? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present resolution selected if MIN or MAX are not specified. Only the resolution values available on ranges set by the RANGe command are returned.

- The resolution with the smallest value (i.e., the best resolution) for the selected range if MIN is specified.
- The resolution with the largest value (i.e., the worst resolution) for the selected range if MAX is specified.

Example Querying the Resolution

FRES:RES 0.3E-03

*Set resolution to 0.3 mΩ.***FRES:RES?***Query multimeter to return the present resolution.*

enter statement

*Enter value into computer***PERiod:APERture**

[SENSe:]PERiod:APERture <time>[MIN|MAX] sets the integration time in seconds. Values for time are rounded up to the nearest aperture time shown in the following table.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>time</i>	numeric	10 ms 100 ms 1s MIN MAX	seconds

Comments

- MINimum sets the aperture time to 10 ms. MAXimum sets the aperture time to 1 second.
- The fastest aperture time available when autoranging is 100 ms. In order to specify an aperture time of 10 ms, you must select a fixed range.
- Setting the aperture time also sets the resolution. Aperture time of 0.01 sets resolution at 4 1/2 digits, 0.1 set 5 1/2 digits and 1 set 6 1/2 digits.
- *RST Condition: 0.1 (100 ms)

Example Setting the Aperture Time**PER:APER 1E-2***Aperture time is 10 ms.***PERiod:APERture?**

[SENSe:]PERiod:APERture? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present aperture time in seconds if MIN or MAX is not specified.
- The minimum aperture time available (10 ms) if MIN is specified.
- The maximum aperture time available (100 ms) if MAX is specified.

Example Querying the Aperture Time

PER:APER MIN

Aperture time is 10 ms.

[SENSe:]PERiod:VOLTage :RANGe
:RANGe:AUTO

[SENSe:]PERiod:VOLTage

PER:APER?

Query multimeter to return
aperture time.

enter statement

Enter value into computer.

PERiod:VOLTage
:RANGe

[SENSe:]PERiod:VOLTage:RANGe <range> selects the voltage range
for the signal level of period measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
range	numeric	100 mV 1V 10 V 100 V 300 V MIN MAX	volts

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected voltage. The multimeter then selects the correct range.
- MIN selects the minimum range available with the PERiod:VOLTage:RANGe command: 100 mV. MAX selects the maximum range available: 300 V.
- Specifying a fixed range disables the autorange mode set by the PER:VOLT:RANG:AUTO command.
- *RST Condition: PER:VOLT:RANG 10

Example

Set the Voltage Range for Period Measurements to 100 V.

PER:VOLT:RANG 100

Voltage range is 100V

PERiod:VOLTage
:RANGe?

[SENSe:]PERiod:VOLTage:RANGe? [MIN | MAX] returns one of the
following numbers to the output buffer:

- 0.1, 1, 10, 100 or 300 corresponding to the range set.
- MIN returns 0.1.
- MAX returns 300.

Example

Query the Period Voltage Range.

PER:VOLT:RANG?

Query the voltage range for
period measurements

enter statement

Enter response into computer

PERiod:VOLTage
:RANGe:AUTO

[SENSe:]PERiod:VOLTage:RANGe:AUTO <mode> enables or
disables the autorange function for the signal level of period measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

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:VOLT:RANGe, autoranging is turned OFF.
- Related Commands: CONFigure, FREQuency:VOLT:RANGe
- ***RST Condition:** PER:VOLT:RANG:AUTO ON

Example

Disabling Autoranging

PER:VOLT:RANG:AUTO OFF

Disable autorange.

PERiod:VOLTage :RANGe:AUTO?

[SENSe:]PERiod:VOLTage:RANGe:AUTO? returns a number to show whether the autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example

Querying the Autorange Mode

PER:VOLT:RANG:AUTO OFF

Disable autorange.

PER:VOLT:RANG:AUTO?

Query multimeter to return autorange mode.

enter statement

Enter value into computer.

RESistance:APERture

[SENSe:]RESistance:APERture <number> sets the integration time in seconds for 2-wire resistance measurements. Values are rounded up to the nearest aperture time shown in the following table.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	0.333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX	Seconds

Comments

- MIN sets the aperture time to 0.333 ms. MAX sets the aperture time to 1.66667 seconds (60 Hz) or 2 seconds (50 Hz).
- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7 ms (60 Hz line frequency) sets an integration time of 1 PLC.

[SENSe:]RESistance:APERture?

[SENSe:]RESistance:NPLC

The corresponding resolution depends on the function and range you select.

- The RES:APER command overrides the results of previously executed RES:NPLC and RES:RES commands. The last command executed has priority.
- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- Related Commands: CALibration:LFRrequency
- *RST Condition: RES:APER 0.166667 seconds (60 Hz) or RES:APER 0.20000 (50 Hz)

Example **Set an aperture time of 16.7 ms**

RES:APER 16.7E-03

Aperture time is 16.7 ms

RESistance:APERture?

[SENSe:]RESistance:APERture? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present aperture time in seconds if MIN or MAX is not specified.
- The minimum aperture time available (.333 ms) if MIN is specified.
- The maximum aperture time available (1.67 s @ 60 Hz; 2 s @ 50 Hz) if MAX is specified.

Example **Querying the Aperture Time**

RES:APER 167E-03

Aperture time is 167 ms

RES:APER?

Query multimeter to return aperture time

enter statement

Enter value into computer

RESistance:NPLC

[SENSe:]RESistance:NPLCycles <number> sets the integration time in power line cycles (PLCs). The NPLC is set to a value from the range of values that can accommodate the <number> you specify. For example, specifying 11 sets the NPLC to 100.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	0.02 0.2 1 10 100 MIN MAX	PLCs

Comments

- MINimum selects 0.02 PLCs. MAXimum selects 100 PLCs. Setting the integration time in power line cycles (PLCs) also sets the integration time and the resolution. For example, 10 PLCs sets an aperture time of 167 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:RESolution or RESistance:APERture 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 the 1 PLC, 10 PLC and 100 PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line related noise.
- ***RST Condition:** 10 PLC

Example**Setting the Integration Time in PLCs****RES:NPLC 100***Integration time is 100 PLCs.***RESistance:NPLC?**

[SENSe:]RESistance:NPLC? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present integration time in PLCs if MINimum or MAXimum is not specified.
- The minimum integration time available (0.02) if MIN is specified.
- The maximum integration time available (100) if MAX is specified.

Example**Querying the Integration Time****RES:NPLC 100***Integration time is 100 PLCs.***RES:NPLC?***Query multimeter to return integration time.*

enter statement

*Enter value into computer.***RESistance:RANGe**

[SENSe:]RESistance:RANGe <range> selects the range for 2-wire resistance measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ MIN MAX	ohms

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected resistance. The multimeter then selects the correct range.

[SENSe:]RESistance:RANGe?

[SENSe:]RESistance:RANGe :AUTO

- MIN selects the minimum range available with the RESistance:RANGe command: 100Ω. MAX selects the maximum range available: 100 MΩ.
- You must select a range using RESistance:RANGe *before* specifying resolution. Also, in order to specify an aperture time of 10 ms, you must select a fixed range.
- 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:** RES:RANG 1 kΩ

Example

Changing the Range

CONF:RES 1320,MAX

*Function: 2-wire ohms;
range selected: 10 kΩ;
MAX resolution: 1Ω.*

RES:RANG 220

*Range selected: 1 kΩ;
MAX resolution: 0.1Ω.*

READ?

*Place multimeter in
wait-for-trigger state and make
measurements; send readings to
output buffer.*

enter statement

Enter readings into computer.

RESistance:RANGe?

[SENSe:]RESistance:RANGe? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present resistance range selected if MIN or MAX is not specified. Only the ranges available with the RANGe command are returned. For example, if CONFigure selects the 900Ω range, 1 kΩ is the range returned.
- The minimum resistance range available (100Ω) if MIN is specified.
- The maximum resistance range available (100 MΩ) if MAX is specified.

Example

Querying the Measurement Range

RES:RANG 100

Select 100Ω range.

RES:RANG?

*Query multimeter to return the
present range.*

enter statement

Enter value into computer.

RESistance:RANGe :AUTO

[SENSe:]RESistance:RANGe:AUTO <mode> enables or disables the autorange function for resistance measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

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.
- **Related Commands:** CONFigure, RESistance:RANGe
- ***RST Condition:** RES:RANG:AUTO ON

Example

Disabling Autoranging

RES:RANG:AUTO OFF

Disable autorange.

RESistance:RANGe :AUTO?

[SENSe:]RESistance:RANGe:AUTO? returns a number to show whether the autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example

Querying the Autorange Mode

RES:RANG:AUTO OFF

Disable autorange.

RES:RANG:AUTO?

Query multimeter to return autorange mode.

enter statement

Enter value into computer.

RESistance :RESolution

[SENSe:]RESistance:RESolution <resolution> selects the resolution for 2-wire resistance measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX	ohms

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 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.

[SENSe:]RESistance :RESolution?

[SENSe:]VOLTage:AC:RANGe

- If autoranging is required, set the resolution using the MIN or MAX parameters.
- If necessary to achieve the specified resolution, the multimeter will increase the integration time as needed. This command overrides the results of previously executed RESistance:NPLC or RESistance:APERture command (the last command executed has priority).
- The RES:RESolution command overrides the resolution setting from a previous CONFigure:RESistance command.
- **Related Commands:** CONFigure, RESistance:NPLC
- ***RST Condition:** Based on the *RST values for the RESistance:NPLC command.

Example

Changing the Resolution

CONF:RES 1560,MAX

*Function: 2-wire ohms;
range selected: 10 k Ω ;
MAX resolution: 1 Ω*

RES:RES 10E-03

Set resolution to 10 m Ω .

READ?

*Place multimeter in
wait-for-trigger state and make
measurements; send readings to
output buffer.*

enter statement

Enter readings into computer.

RESistance :RESolution?

[SENSe:]RESistance:RESolution? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present resolution selected if MIN or MAX are not specified. Only the resolution values available on ranges set by the RANGe command are returned.
- The resolution with the smallest value (i.e., the best resolution) for the selected range if MIN is specified.
- The resolution with the largest value (i.e., the worst resolution) for the selected range if MAX is specified.

Example

Querying the Resolution

RES:RES 10E-03

Set resolution to 10 m Ω .

RES:RES?

*Query multimeter to return the
present resolution.*

enter statement

Enter value into computer.

VOLTage:AC:RANGe

[SENSe:]VOLTage:AC:RANGe <range> selects the range for AC-coupled RMS voltage measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100 mV 1V 10V 100V 300V MIN MAX	volts

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected voltage. The multimeter then selects the correct range.
- MIN selects the minimum range available with the VOLTage:AC:RANGe command: 100 mV. MAX selects the maximum range available: 300V.
- You must select a range using VOLTage:AC:RANGe *before* specifying resolution.
- Specifying a fixed range disables the autorange mode setting VOLT:AC:RANG:AUTO OFF.
- The VOLT:AC:RANG command overrides the range setting from a previous CONFigure command specifying the same function. With the new range, a new resolution is also selected.
- ***RST Condition:** VOLT:AC:RANG 10V

Example

Changing the Range

CONF:VOLT:AC 01.05,MAX

*Function: AC volts;
range selected: 10V;*

VOLT:AC:RANG 1

Range selected: 1V;

READ?

*Place multimeter in
wait-for-trigger state and make
measurement; send readings to
the output buffer.*

enter statement

Enter readings into computer.

VOLTage:AC:RANGe?

[SENSe:]VOLTage:AC:RANGe? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present voltage range selected if MIN or MAX is not specified. Only the ranges available with the RANGe command are returned. For example, if CONFigure selects the 10V range, 10V is the range returned.
- The minimum voltage range available with the VOLTage:AC:RANGe command (100 mV) if MIN is specified.
- The maximum voltage range available with the VOLTage:AC:RANGe command (300V) if MAX is specified.

Example

Querying the Measurement Range

VOLT:AC:RANG 10

Select 10V range.

[SENSe:]VOLTage:AC:RANGe :AUTO

[SENSe:]VOLTage:AC :RESolution

VOLT:AC:RANG?

Query multimeter to return the present range.

enter statement

Enter value into computer.

**VOLTage:AC:RANGe
:AUTO**

[SENSe:]VOLTage:AC:RANGe:AUTO <mode> enables or disables the autorange function for AC voltage measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
mode	boolean	OFF 0 ON 1	none

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.
- In order to specify an aperture time of 10 μ s, you must select a fixed range (e.g., VOLT:RANG:AUTO OFF).
- **Related Commands:** CONFigure, VOLTage:RANGe
- ***RST Condition:** VOLT:AC:RANG:AUTO ON

Example

Disabling AC Voltage Autoranging

VOLT:AC:RANG:AUTO OFF

Disable autorange.

**VOLTage:AC:RANGe
:AUTO?**

[SENSe:]VOLTage:AC:RANGe:AUTO? returns a number to show whether the AC voltage autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The value is sent to the output buffer.

Example

Querying the Autorange Mode

VOLT:AC:RANG:AUTO OFF

Disable autorange.

VOLT:AC:RANG:AUTO?

Query multimeter to return autorange mode.

enter statement

Enter value into computer.

**VOLTage:AC
:RESolution**

[SENSe:]VOLTage:AC:RESolution <resolution> selects the resolution for AC voltage measurements. See the AC Voltage range versus resolution table at the beginning of this chapter to avoid a settings conflict error when specifying resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX	volts

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 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.
- The VOLT:AC:RES command overrides the resolution setting from a previous CONFigure:VOLT:AC:RES command.
- **Related Commands:** CONFigure, VOLTage:DC:RESolution
- ***RST Condition:** 1E-04

Example

Changing the Resolution

CONF:VOLT:AC 6.25,MAX

*Function: DC volts;
range selected: 10V;
MAX resolution.*

VOLT:AC:RANG 0.95

*Range selected: 1.0V;
MAX resolution: 100 μ V.*

VOLT:AC:RES 10E-06

Set resolution to 10 μ V.

READ?

*Place multimeter in
wait-for-trigger state and make
measurements; send readings to
output buffer.*

VOLTage:AC
:RESolution?

[SENSe:]VOLTage:AC:RESolution? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present resolution selected if MIN or MAX is not specified. Only the resolution values available on ranges set by the RESolution command are returned.
- The resolution with the smallest value (i.e., the best resolution) for the selected range if MIN is specified.
- The resolution with the largest value (i.e., the worst resolution) for the selected range if MAX is specified.

Example

Querying the Resolution

VOLT:AC:RANG 100E-03

Set range to 0.1 volts.

VOLT:AC:RES 1.0E-07

Set resolution to 0.1 μ V.

VOLT:AC:RES?

*Query multimeter to return the
present resolution.*

enter statement

Enter value into computer.

**VOLTage[:DC]
:APERture**

[SENSe:]VOLTage[:DC]:APERture <number> sets the integration time in seconds for dc voltage measurements. Values are rounded up to the nearest aperture time shown in the following table.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	0.333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX	Seconds

Comments

- MIN sets the aperture time to 0.333 ms. MAX sets the aperture time to 1.66667 seconds (60 Hz) or 2 seconds (50 Hz).
- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7 ms (60 Hz line frequency) sets an integration time of 1 PLC. The corresponding resolution depends on the function and range you select.
- The VOLT:APER command overrides the results of previously executed VOLT:NPLC and VOLT:RES commands. The last command executed has priority.
- The greater the aperture time, the greater the normal mode rejection (and the lower the reading rate).
- Related Commands: CALibration:LFRfrequency
- *RST Condition: VOLT:APER 0.166667 seconds (60 Hz) or VOLT:APER 0.20000 (50 Hz)

Example**Set an aperture time of 16.7 ms****VOLT:APER 16.7E-03***Aperture time is 16.7 ms***VOLTage[:DC]
:APERture?**

[SENSe:]VOLTage[:DC]:APERture? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present aperture time in seconds if MIN or MAX is not specified.
- The minimum aperture time available (.333 ms) if MIN is specified.
- The maximum aperture time available (1.67 s @ 60 Hz; 2 s @ 50 Hz) if MAX is specified.

Example**Querying the Aperture Time**

[SENSe:]VOLTage[:DC]:NPLC

[SENSe:]VOLTage[:DC] :NPLC?

VOLT:APER 167E-03

Aperture time is 167 ms

VOLT:APER?

*Query multimeter to return
aperture time*

enter statement

Enter value into computer

VOLTage[:DC]:NPLC

[SENSe:]VOLTage[:DC]:NPLC <number> sets the integration time in power line cycles (PLCs). The NPLC is set to a value from the range of values that can accommodate the <number> specified. 11 sets NPLC to 100.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
number	numeric	0.02 0.2 1 10 100 MIN MAX	PLCs

Comments

- MIN selects 0.02 PLCs. MAX selects 100 PLCs. Setting the integration time in PLCs also sets the aperture time and the resolution. For example, 10 PLCs sets an aperture time of 167 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:DC: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 the 1 PLC, 10 PLC and 100 PLC settings provide normal mode rejection of 50 Hz or 60 Hz power line related noise.
- ***RST Condition:** 10 PLC

Example

Setting the Integration Time in PLCs

VOLT:DC:NPLC 10

Integration time is 10 PLCs.

VOLTage[:DC]
:NPLC?

[SENSe:]VOLTage[:DC]:NPLC? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present integration time in PLCs if MIN or MAX is not specified.
- The minimum integration time available (0.02) if MIN is specified.
- The maximum integration time available (100) if MAX is specified.

Example

Querying the Integration Time

VOLT:DC:NPLC 100

Integration time is 100PLCs.

VOLT:DC:NPLC?

*Query multimeter to return
integration time.*

enter statement

Enter value into computer.

**VOLTage[:DC]
:RANGe**

[SENSe:]VOLTage[:DC]:RANGe <*range*> selects the range for DC voltage measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>range</i>	numeric	100 mV 1V 10V 100V 300V MIN MAX	volts

Comments

- To select a standard measurement range, specify *range* as the input signal's maximum expected voltage. The multimeter then selects the correct range.
- MIN selects the minimum range available with the VOLTage:DC:RANGe command: 100 mV. MAX selects the maximum DC voltage range available: 300V.
- You must select a range using VOLTage:DC:RANGe *before* specifying resolution.
- Specifying a fixed range disables the autorange mode by setting VOLT:DC:RANG:AUTO OFF.
- The VOLT:DC:RANG command overrides the range setting from a previous CONFigure command on the same function.
- ***RST Condition:** VOLT:DC:RANG 300V

Example**Changing the Range**

CONF:VOLT:DC 0.85,MAX

*Function: DC volts;
range selected: 1V;
MAX resolution.*

VOLT:DC:RANG 9

*Range selected 10V;
MAX resolution.*

READ?

*Place multimeter in
wait-for-trigger state and make
measurements; send readings to
output buffer.*

enter statement

Enter readings into computer.

**VOLTage[:DC]
:RANGe?**

[SENSe:]VOLTage[:DC]:RANGe? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present voltage range selected if MIN or MAX are not specified. Only the ranges available with the RANGE command are returned. For example, if CONFigure selects the 1V range, 1.0V is the range returned.
- The minimum voltage range available with the VOLTage:DC:RANGe command (100 mV) if MIN is specified.

[SENSe:]VOLTage[:DC] :RANGe:AUTO

[SENSe:]VOLTage[:DC] :RANGe:AUTO?

- The maximum voltage range available with the VOLTage:DC:RANGe command (300V) if MAX is specified.

Example

Querying the Measurement Range

VOLT:DC:RANG 1.0

Select 1V range.

VOLT:DC:RANG?

Query multimeter to return the present range.

enter statement

Enter value into computer.

**VOLTage[:DC]
:RANGe:AUTO**

[SENSe:]VOLTage[:DC]:RANGe:AUTO <mode> enables or disables the autorange function for DC voltage measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
mode	boolean	OFF 0 ON 1	none

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 μ s, you must select a fixed range (e.g., VOLT:DC:RANG:AUTO OFF).
- **Related Commands:** CONFigure, VOLTage:RANGe
- ***RST Condition:** VOLT:DC:RANG:AUTO ON

Example

Disabling Autoranging

VOLT:DC:RANG:AUTO OFF

Disable autorange.

**VOLTage[:DC]
:RANGe:AUTO?**

[SENSe:]VOLTage[:DC]:RANGe:AUTO? returns a number to show whether the autorange mode is enabled or disabled: “1” = ON, “0” = OFF. The value is sent to the output buffer.

Example

Querying the Autorange Mode

VOLT:DC:RANG:AUTO OFF

Disable autorange.

VOLT:DC:RANG:AUTO?

Query multimeter to return autorange mode.

enter statement

Enter value into computer.

**VOLTage[:DC]
:RESolution**

[SENSe:]VOLTage[:DC]:RESolution <resolution> selects the resolution for DC voltage measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>resolution</i>	numeric	<i>resolution</i> MIN MAX	volts

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 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.
- If autoranging is required, set the resolution using the MIN or MAX parameters or select a specific integration time using VOLTage:DC:NPLC.
- If necessary to achieve the specified resolution, the multimeter will increase the integration time as needed. This command overrides the results of previously executed VOLTage:DC:NPLC commands (the last command executed has priority).
- 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.

Example**Changing the Resolution**

CONF:VOLT:DC 6.25,MAX

*Function: DC volts;
range selected: 10V;
MAX resolution.*

VOLT:DC:RANG 0.95

*Range selected: 1V;
MAX resolution.*

VOLT:DC:RES 3E-07

Set resolution to 0.3 μ V.

READ?

*Place multimeter in
wait-for-trigger state and make
measurements; send readings to
output buffer.*

enter statement

Enter readings into computer.

**VOLTage[:DC]
:RESolution?**

[SENSe:]VOLTage[:DC]:RESolution? [MIN | MAX] returns one of the following numbers to the output buffer.

- The present resolution selected if MIN or MAX is not specified. Only the resolution values available on ranges set by the RANGE command are returned.
- The resolution with the smallest value (i.e., the best resolution) for the selected range if MIN is specified.
- The resolution with the largest value (i.e., the worst resolution) for the selected range if MAX is specified.

Example**Querying the Resolution**

VOLT:DC:RES 1E-03

Set resolution to 1 mV.

VOLT:DC:RES?

Query multimeter to return the present resolution.

enter statement

Enter value into computer.

ZERO:AUTO

[SENSe:]ZERO:AUTO <mode> enables or disables the autozero mode. Auto zero applies to dc voltage, dc current and 2-wire ohms measurements only. 4-wire ohms and dc voltage ratio measurements automatically enable the autozero mode.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1 ONCE	none

Comments

- You can substitute decimal values for the OFF (“0”) and ON (“1”) parameters.
- 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.

[SENSe:]ZERO:AUTO?

[SENSe:]ZERO:AUTO?

- 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.

ZERO:AUTO OFF

Autozero disabled.

ZERO:AUTO?

[SENSe:]ZERO:AUTO? queries the autozero mode. Returns one of the following responses to the output buffer:

- "0" (OFF or ONCE) if autozero is disabled or set for one time.
- "1" ON if autozero is enabled.

Example

Query the Autozero Mode.

ZERO:AUTO?

enter statement

Queries the autozero mode.

Enter response into computer.

STATus

The STATus subsystem reports the bit values of the Questionable Data/Signal Register. It also allows you to unmask the bits you want reported from the Standard Event Register and to read the summary bits from the Status Byte Register.

The Questionable Data/Signal Register group consists of a condition register, and event register and an enable register. The commands in the STATus:QUESTionable subsystem control and monitor these registers.

Subsystem Syntax

```
STATus
:PRESet
:QUESTionable
[:EVENT]?
:CONDition?
:ENABLE <unmask>
:ENABLE?
```

Comments

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.

:PRESet

STATus:PRESet command affects only the enable register by setting all enable register bits to 0. It does not affect either the "status byte" or the "standard event status". PRESet does not clear any of the event registers.

:QUESTionable :CONDition?

STATus:QUESTionable:CONDition? returns a decimal-weighted number representing the bits set in the Questionable Data condition register.

:QUESTionable [:EVENT]?

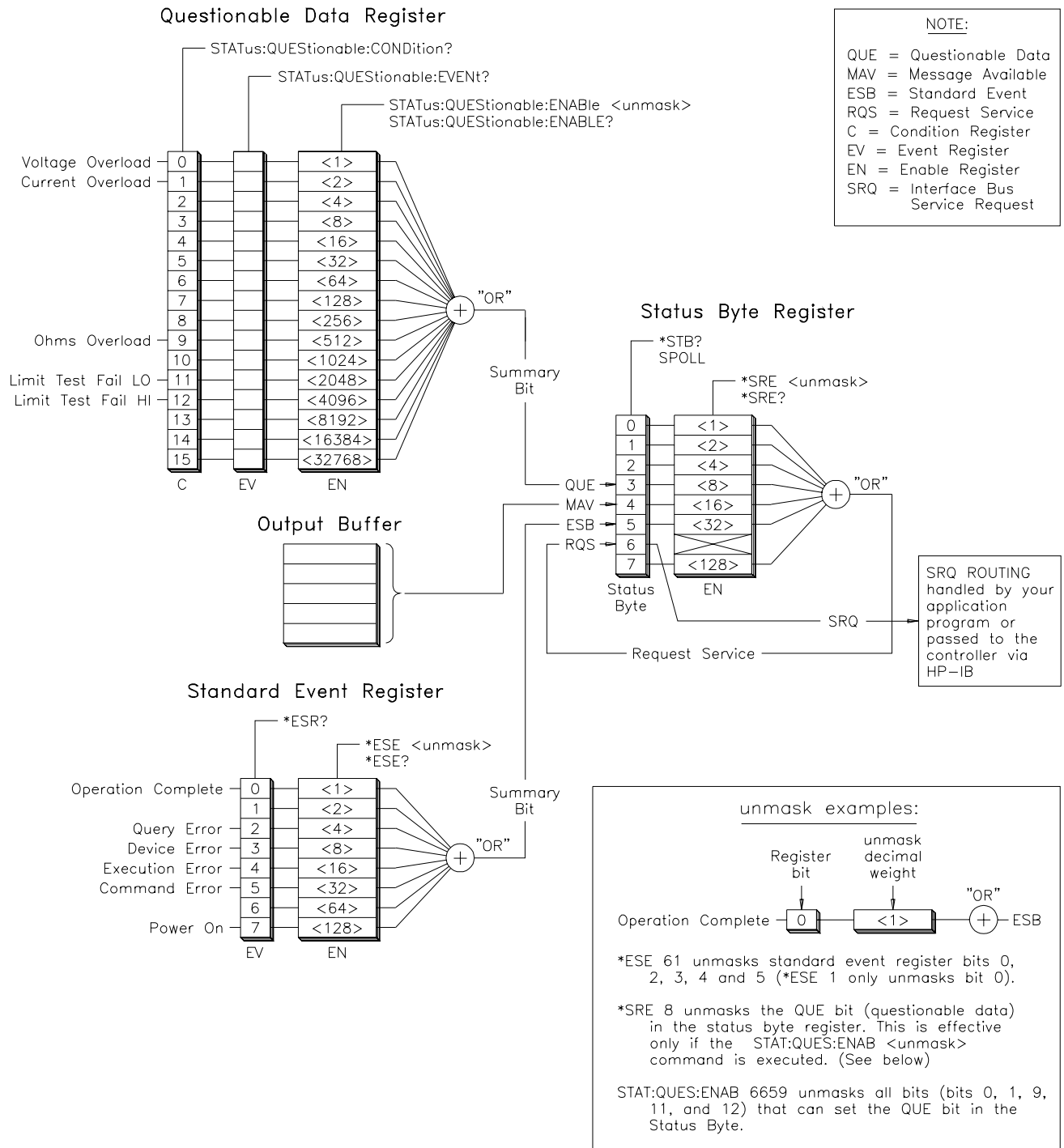
STATus:QUESTionable[:EVENT]? returns a decimal-weighted number representing the bits set in the Questionable Data/Signal Register's event register. This command clears all bits in the event register when executed.

:QUESTionable :ENABLE

STATus:QUESTionable:ENABLE <unmask> 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 true). The event register bits are not reported in the Status Bytes Register unless specifically enabled.

:QUEStionable :ENABLE?

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.



HP E1312A and HP E1412A Status System Register Diagram.

SYSTem

The SYSTem command subsystem returns error numbers and their associated messages from the error queue. You can also query the SCPI version to which this instrument complies.

Subsystem Syntax

SYSTem
:ERRor?
:VERSion?

:ERRor?

SYSTem:ERRor? returns the error numbers and corresponding error messages in the error queue. See Appendix B in this manual for a listing of the error numbers, messages and descriptions.

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.
- The error queue has a maximum capacity of 20 errors. If the queue overflows, the last error is replaced with -350, "Too many errors". No additional errors are accepted by the queue until space becomes available.

Example**Reading the Error Queue**

SYST:ERR?
enter statement

*Query the error queue.
Enter readings into computer.*

:VERSion?**SYSTem:VERSion?**

returns the SCPI version number this instrument complies.

Comments

- The information returned is in the format "YYYY.R" where "YYYY" is the year and "R" is the revision number within that year.

TRIGger

The TRIGger command subsystem controls the behavior of the trigger system. The subsystem can control:

- The number of triggers to occur before the multimeter returns to the idle state (TRIGger:COUNT).
- The delay between trigger and measurement (TRIGger:DElay).
- The source of the trigger (TRIGger:SOURce).

Subsystem Syntax

TRIGger

:COUNT <number> | MIN | MAX | INFinite

:COUNT? [MIN | MAX]

:DElay <seconds> | MIN | MAX

:DElay? [MIN | MAX]

:DElay:AUTO OFF | ON

:DElay:AUTO?

:SOURce BUS | IMMEDIATE | EXTERNAL | TTLTrg0-7

:SOURce?

:COUNT

TRIGger:COUNT <**number**> sets the number of triggers to be issued.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>number</i>	numeric	1 through 50,000 MIN MAX INF	none

Comments

- MIN selects 1 trigger. MAX selects 50,000 triggers.
- If MAX or 50,000 is specified for the *number* parameter, the command will be accepted. If you initiate measurements with an INITiate command, an “Insufficient memory” error occurs to show that this generates too many readings to store in memory. However, you can use the READ? command to return the readings to the output buffer and retrieve them with your controller. The READ? command is a combined INITiate and FETCh? command.
- CONFigure and MEASure set the trigger count to 1.
- ***RST Condition:** TRIG:COUNT 1

Examples

Setting the Trigger Count

CONF:VOLT:DC
TRIG:SOUR EXT

TRIG:COUN 10

READ?

enter statement

Function: DC voltage.

Trigger source is "Trig" BNC on multimeter front panel.

Multimeter will accept 10 external triggers (one measurement is taken with each trigger).

Place multimeter in wait-for-trigger state; make measurement when external trigger is received; send readings to output buffer.

Enter readings into computer.

:COUNT?

TRIGger:COUNT? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present trigger count (1 through 50,000) if MIN or MAX are not specified.
- The minimum trigger count available (1) if MIN is specified.
- The maximum trigger count available (50,000) if MAX is specified.

Example

Querying the Trigger Count

TRIG:COUN 10

TRIG:COUN?

enter statement

Multimeter will accept 10 triggers.

Query multimeter to return trigger count.

Enter value into computer.

:DElay

TRIGger:DElay <seconds> sets the delay time between receipt of the trigger and the start of the measurement. **NOTE: This delay also occurs between each sample when SAMP:COUN > 1.** See "Triggering the Multimeter" in Chapter 2 for a triggering process diagram.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>seconds</i>	numeric	0 through 3600 MIN MAX	seconds

Comments

- MIN selects the minimum delay of 0 seconds for all functions. MAX selects the maximum delay of 3600 seconds for all functions.
- The trigger delay is inserted between the trigger and each measurement.

- If a trigger delay is specified using the TRIG:DEL <period>, TRIGger:DElay:AUTO is turned OFF.
- The multimeter selects an automatic delay if you do not specify a trigger delay (see the TRIG:DEL:AUTO command).
- ***RST Condition:** TRIGger:DElay:AUTO ON

Example Setting the Trigger Delay**TRIG:DEL .002***Wait 2 ms between trigger and start of measurement.***:DElay?**

TRIGger:DElay? [MIN | MAX] returns one of the following numbers to the output buffer:

- The present trigger delay (0 through 3600 seconds) if MIN or MAX is not specified.
- The minimum trigger delay available (0 seconds) if MIN is specified.
- The maximum trigger delay available (3600 seconds) if MAX is specified.

Example Querying the Trigger Delay

TRIG:DEL .002

*Wait 2 ms between trigger and start of measurement.***TRIG:DEL?***Query multimeter to return trigger delay.*

enter statement

*Enter value into computer.***: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 the table on the next page). The trigger delay specifies the period between the trigger signal and the start of the measurement (and between each sample when SAMPLE:COUNt > 1).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>mode</i>	boolean	OFF 0 ON 1	none

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.
- If a trigger delay is specified using the TRIGger:DElay <period> command, TRIG:DEL:AUTO is turned OFF.
- ***RST Condition:** TRIG:DEL:AUTO ON

Example

Disabling Automatic Trigger Delay

TRIG:DEL:AUTO OFF

Disable automatic trigger delay.

Function	Range or Condition	Automatic Trigger Delay	
DCV and DCI	All ranges with Integration Time: NPLC ≥ 1 NPLC < 1	1.5 ms 1.0 ms	
Resistance (2-wire and 4-wire)	Range: 100 Ω 1 k Ω 10 k Ω 100 k Ω 1 M Ω 10 M Ω 100 M Ω	NPLC ≥ 1 1.5 ms 1.5 ms 1.5 ms 1.5 ms 1.5 ms 100 ms 100 ms	NPLC < 1 1.0 ms 1.0 ms 1.0 ms 1.0 ms 1.0 ms 100 ms 100 ms
ACV and ACI	All ranges with AC Filter mode: 3 Hz (Slow) 20 Hz (Medium) 200 Hz (Fast)	7.0 sec 1.0 sec 600 ms	
Frequency and Period	All ranges	1.0 sec	

:DElay:AUTO?

TRIGger:DElay:AUTO? returns a number to show whether the automatic trigger delay mode is on or off: “1” = ON, “0” = OFF. The number is sent to the output buffer.

Example

Querying the Trigger Delay Mode

TRIG:DEL:AUTO OFF

*Disable automatic trigger delay.***TRIG:DEL:AUTO?***Query multimeter to return trigger delay mode.*

enter statement

Enter value into computer.

:SOURce

TRIGger:SOURce <source> configures the trigger system to respond to the specified source. The following sources are available:

- **BUS:** Group Execute Trigger (GET) bus command or *TRG common command.
- **EXT:** The multimeter’s External Trigger BNC connector (triggers on the negative or falling edge of the $\pm 5\text{V}$ TTL input signal).
- **IMMediate:** The trigger system is always true.

- **TTLTrg0 - TTLTrg7:** Trigger source is VXIbus trigger line 0 through 7.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>source</i>	discrete	BUS EXT IMMEDIATE TTLTrg0 through TTLTrg7	none

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" BNC connector as the trigger source. The multimeter triggers on the falling (negative-going) edge of a $\pm 5V$ TTL input signal; (maximum input is +5V to the front panel BNC connector).
- TRIGger:IMMEDIATE causes a trigger to occur immediately provided the multimeter is placed in the wait-for-trigger state using INITiate, READ? or MEAS?.
- When a Group Execute Trigger (GET) bus command or *TRG common command is executed and the multimeter is not in the wait-for-trigger state, the "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

Setting the Sample Source

CONF:VOLT:DC

Function: DC voltage.

TRIG:SOUR EXT

Trigger source is external BNC 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 readings to output buffer.

enter statement

Enter readings into computer.

:SOURce?

TRIGger:SOURce? returns “BUS”, “EXT”, “IMM ” or "TTLTrg0 - 7" to show the present trigger source. The quoted string is sent to the output buffer.

Example**Querying the Trigger Source**

TRIG:SOUR EXT

Trigger source is external BNC on multimeter front panel.

TRIG:SOUR?

Query multimeter to return trigger source setting.

enter statement

Enter quoted string into computer.

IEEE 488.2 Common Command Quick Reference

The table below lists, by functional group, the IEEE 488.2 Common (*) Commands that can be executed by the HP E1312A B-size and HP E1412A C-size 6½-Digit Multimeters. However, commands are listed alphabetically in the following reference. Examples are shown in the reference when the command has parameters or returns a non-trivial response; otherwise, the command string is as shown in the table. For additional information, refer to IEEE Standard 488.2-1987.

Category	Command	Title	Description
System Data	*IDN?	Identification	Returns the identification string of the B- or C-size multimeter which includes the latest inguard and outguard firmware versions. HEWLETT-PACKARD,E1312A,0,A.0x.0x-A.0x.0x HEWLETT-PACKARD,E1412A,0,A.0x.0x-A.0x.0x
Internal Operations	*RST	Reset	Resets the multimeter to: FUNC:VOLT:DC, VOLT:RANG 300V, VOLT:RES 1 mV, RANGE:AUTO ON, NPLC 10, ZERO:AUTO ON, INP:IMP:AUTO OFF, TRIG COUN 1, TRIG:DELAY:AUTO ON, TRIG:SOUR IMM, SAMP:COUN 1. OUTP:TTLT<n>:STAT OFF
Internal Operations	*TST?	Self-Test	Returns "0" if self-test passes. Returns "1" if self-test fails. Use SYST:ERR? to retrieve the error from the multimeter. See "Self-Test Errors" in Appendix B for a complete list of error numbers and their description. Return multimeter to Hewlett-Packard for repair if repair is required.
Synchronization	*OPC *OPC? *WAI	Operation Complete Operation Complete Query Wait to Complete	Operation Complete Command Operation Complete Query Wait-to-Continue Command
Status & Event	*CLS *ESE <unmask> *ESE? *ESR? *SRE <unmask> *SRE? *STB?	Clear Status Event Status Enable Event Status Enable Query Event Status Register Query Service Request Enable Service Request Enable Query Read Status Byte Query	Clear Status Command Standard Event Status Enable Command Standard Event Status Enable Query Standard Event Status Register Query Service Request Enable Command Service Request Enable Query Read Status Byte Query
Bus Operation	*TRG	Bus Trigger	When the multimeter is in the wait-for-trigger state and the trigger source is TRIGger:SOURce BUS, use *TRG to trigger the multimeter.

***CLS**

***CLS** clears the Standard Event Status Register, the Operation Status Register, the Questionable Signal Register, and the error queue. This clears the corresponding summary bits (3, 5, and 7) in the Status Byte Register. ***CLS** does not affect the enable unmask of any of the Status Registers.

Comments

- **Executable when initiated:** Yes
- **Coupled command:** No
- **Related Commands:** STATus:PRESet
- ***RST Condition:** none

***ESE and *ESE?**

***ESE <unmask>** enables (unmasks) one or more event bits of the Standard Event Status Register to be reported in bit 5 (the Standard Event Status Summary Bit) of the Status Byte Register. *unmask* is the sum of the decimal weights of the bits to be enabled allowing these bits to pass through to the summary bit ESB (bit 5 in the status byte).

The query form returns the current enable unmask value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>unmask</i>	numeric	0 through 255	none

A 1 in a bit position enables the corresponding event; a 0 disables it.

Comments

- **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?**

***ESR?** returns the value of the Standard Event Status Register. The register is then cleared (all bits 0).

Comments

- **Executable when initiated:** Yes
- **Coupled command:** No
- ***RST Condition:** none

- **Power-On Condition:** register is cleared

***IDN?**

***IDN?** returns identification information for the HP E1312A B-size or HP E1412A C-size multimeter. The response consists of four fields:

HEWLETT-PACKARD, E1312A, 0, A. 0x. 0x-A. 0x. 0x
(B-size)

HEWLETT-PACKARD, E1412A, 0, A. 0x. 0x-A. 0x. 0x
(C-size)

The first two fields identify this instrument as model number HP E1312A (or HP E1412A) manufactured by Hewlett-Packard. The third field is 0 since the serial number of the multimeter is unknown to the firmware. The last field indicates the revision level of the inguard-outguard firmware.

Note

The firmware revision field will change whenever the firmware is revised. A.01.00-A.01.00 is the initial revision. The first two digits indicate the major revision number and increment when functional changes are made. The last two digits indicate the functional improvement level.

Comments

- **Executable when initiated:** Yes
- **Coupled command:** No
- ***RST Condition:** none
- **Power-On Condition:** register is cleared

***OPC**

***OPC** causes the HP E1312A and HP E1412A 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.

Comments

- **Executable when initiated:** Yes
- **Coupled command:** No
- **Related commands:** *OPC?, *WAI
- ***RST Condition:** none

***OPC?**

***OPC?** causes the HP E1312A and HP E1412A to wait for all pending operations to complete. A single ASCII "1" is then placed in the output queue.

Comments

- **Executable when initiated:** Yes

- **Coupled command:** No
- **Related commands:** *OPC, *WAI
- ***RST Condition:** none

***RST**

***RST** resets the HP E1312A and HP E1412A 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 Registers
- The enable unmask for the Questionable Signal Registers
- Calibration data

Comments

- **Executable when initiated:** Yes
- **Coupled command:** No
- ***RST Condition:** none

***SRE and *SRE?**

***SRE <unmask>** specifies which bits of the Status Byte Register are enabled (unmasked) to generate a 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).

The query form returns the current enable unmask value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i>unmask</i>	numeric	0 through 255	none

A 1 in a bit position enables service request generation when the corresponding Status Byte Register bit is set; a 0 disables it.

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

Enable request on MAV

***STB?**

***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.

Comments

- **Executable when initiated:** Yes
- **Coupled command:** No
- **Related commands:** *SRE
- ***RST Condition:** none

***TST?**

***TST?** causes the HP E1312A and HP E1412A 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 Appendix B, Error Messages, for information on interpreting the error number and description response(s).

The settings for all SCPI commands are unchanged by this command.

Comments

- **Executable when initiated:** No
- **Coupled command:** No
- ***RST Condition:** none

***WAI**

***WAI** causes the HP E1312A and HP E1412A to wait for all pending operations to complete before executing any further commands.

Comments

- **Executable when initiated:** Yes
- **Coupled command:** No
- **Related commands:** *OPC, *OPC?
- ***RST Condition:** none

SCPI Command Quick Reference

The following tables summarize SCPI commands for the HP E1312A B-size and HP E1412A C-size 6½-Digit Multimeters.

Command		Description
ABORt		Place multimeter in idle state.
CALCulate	:FUNCTION NULL DB DBM AVERage LIMit :FUNCTION? :STATe 1 0 ON OFF :STATe? :NULL:OFFSet <value> MIN MAX :NULL:OFFSet? [MIN MAX] :DB:REFeRence <value> MIN MAX :DB:REFeRence? [MIN MAX] :DBM:REFeRence <value> MIN MAX :DBM:REFeRence? [MIN MAX] :AVERage:MINimum? :AVERage:MAXimum? :AVERage:AVERage? :AVERage:COUNT? :LIMit:LOWer <value> MIN MAX :LIMit:LOWer? [MIN MAX] :LIMit:UPPer <value> MIN MAX :LIMit:UPPer? [MIN MAX]	Set math function to calculate. Query math function set. Enable/disable math function state. Query math function state. Set null offset value. Query null offset value. Set dB reference value. Query dB reference value. Set dBm reference value. Query dBm reference value. Query average minimum. Query average maximum. Query average value of the average. Query average count. Set lower limit value. Query lower limit value. Set upper limit value. Query upper limit value.
CALibration	:COUNT? :LFRequency 50 60 400 :LFRequency? :SECure:CODE <new code> :SECure:STATe 1 0 ON OFF, <code> :SECure:STATe? :STRing <quoted string> :STRing? :VALue <cal value> :VALue? :ZERO:AUTO 1 0 ON OFF :ZERO:AUTO?	Query number of cal operations. Sets line reference frequency. Query line reference frequency. Enters a new security code. Enables/disables the security code. Queries the security state. Lets you store info about your calibration. Queries the cal string. Sets the calibration value. Queries the calibration value. Enable/disable autozero mode. Query autozero mode.
CALibration?		Initiates the calibration process using the cal value set by CAL:VALue. The command returns a value to indicate the calibration was successful.

CONFigure	:CURRent:AC [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] :CURRent[:DC] [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] :FREQuency [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] :FRESistance [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] :PERiod [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] :RESistance [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] :VOLTage:AC [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] [:VOLTage[:DC]] [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]] [:VOLTage[:DC]]:RATio [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]]	Configure multimeter for AC current. Configure multimeter for DC current. Configure multimeter for frequency. Configure multimeter for 4-wire ohms. Configure multimeter for period. Configure multimeter for 2-wire ohms. Configure multimeter for AC voltage. Configure multimeter for DC voltage. Configure multimeter for DC voltage ratio.
CONFigure?		Query multimeter configuration.
DATA	:POINTs?	Query number of readings stored in the multimeter's memory.
FEtCh?		Place stored readings in output buffer.
INITiate	[:IMMediate]	Place multimeter in wait-for trigger state.
INPut	:IMPedance:AUTO 1 0 ON OFF :IMPedance:AUTO?	Enable/disable auto impedance mode. Query impedance mode.
MEASure	:CURRent:AC? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] :CURRent[:DC]? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] :FREQuency? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] :FRESistance? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] :PERiod? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] :RESistance? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] :VOLTage:AC? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] [:VOLTage[:DC]]? [<range> MIN MAX DEF AUTO, [,<resolution> MIN MAX DEF]] [:VOLTage[:DC]]:RATio? [<range> MIN MAX DEF AUTO [,<resolution> MIN MAX DEF]]	Make an AC current measurement. Make a DC current measurement. Make a frequency measurement. Make a 4-wire ohms measurement. Make a period measurement. Make a 2-wire ohms measurement. Make an AC voltage measurement. Make a DC voltage measurement. Make a DC voltage ratio measurement.
OUTPut	:TTLTrg0 1 2 3 4 5 6 7 [:STATe] 1 0 ON OFF :TTLTrg0 1 2 3 4 5 6 7 [:STATe]?	Send voltmeter complete to VXIbus trigger lines. Query voltmeter complete destination.
READ?		Place multimeter in wait-for trigger state; place readings in output buffer.
SAMPlE	:COUnT 1-50000 MIN MAX :COUnT? [MIN MAX]	Set number of readings per trigger. Query number of readings per trigger.

[SENSe:]	FUNCTION "function" FUNCTION? CURRent:AC:RANGe <range> MIN MAX CURRent:AC:RANGe? [MIN MAX] CURRent:AC:RANGe:AUTO 1 0 ON OFF CURRent:AC:RANGe:AUTO? CURRent:AC:RESolution <resolution> MIN MAX CURRent:AC:RESolution? [MIN MAX] CURRent[:DC]:APERture .333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX CURRent[:DC]:APERture? [MIN MAX] CURRent[:DC]:NPLCycles <number> MIN MAX CURRent[:DC]:NPLCycles? [MIN MAX] CURRent[:DC]:RANGe <range> MIN MAX CURRent[:DC]:RANGe? [MIN MAX] CURRent[:DC]:RANGe:AUTO 1 0 ON OFF CURRent[:DC]:RANGe:AUTO? CURRent[:DC]:RESolution <resolution> MIN MAX CURRent[:DC]:RESolution? [MIN MAX] DETector:BANDwidth 3 20 200 MIN MAX DETector:BANDwidth? [MIN MAX] FREQuency:APERture 0.01 0.1 1 MIN MAX FREQuency:APERture? [MIN MAX] FREQuency:VOLTage:RANGe <range> MIN MAX FREQuency:VOLTage:RANGe? [MIN MAX] FREQuency:VOLTage:RANGe:AUTO 1 0 ON OFF FREQuency:VOLTage:RANGe:AUTO? FRESistance:APERture .333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX FRESistance:APERture? [MIN MAX] FRESistance:NPLCycles <number> MIN MAX FRESistance:NPLCycles? [MIN MAX] FRESistance:RANGe <range> MIN MAX FRESistance:RANGe? [MIN MAX] FRESistance:RANGe:AUTO 1 0 ON OFF FRESistance:RANGe:AUTO? FRESistance:RESolution <resolution> MIN MAX FRESistance:RESolution? [MIN MAX] PERiod:APERture 0.01 0.1 1 MIN MAX PERiod:APERture? [MIN MAX] PERiod:VOLTage:RANGe <range> MIN MAX PERiod:VOLTage:RANGe? [MIN MAX] PERiod:VOLTage:RANGe:AUTO 1 0 ON OFF PERiod:VOLTage:RANGe:AUTO? RESistance:APERture .333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX RESistance:APERture? [MIN MAX] RESistance:NPLCycles <number> MIN MAX RESistance:NPLCycles? [MIN MAX] RESistance:RANGe <range> MIN MAX RESistance:RANGe? [MIN MAX] RESistance:RANGe:AUTO 1 0 ON OFF RESistance:RANGe:AUTO? RESistance:RESolution <resolution> MIN MAX RESistance:RESolution? [MIN MAX] VOLTage:AC:RANGe <range> MIN MAX VOLTage:AC:RANGe? [MIN MAX] VOLTage:AC:RANGe:AUTO 1 0 ON OFF VOLTage:AC:RANGe:AUTO? VOLTage:AC:RESolution <resolution> MIN MAX VOLTage:AC:RESolution? [MIN MAX]	Select measurement function. Query measurement function. Set range. Query range. Enable/disable autoranging. Query autorange mode. Set resolution. Query resolution. Set the integration time in seconds. Query integration time (seconds). Set integration time in PLCs. Query integration time (PLCs). Set range. Query range. Enable/disable autoranging. Query autorange mode. Set resolution. Query resolution. Set the AC filter. Query AC filter. Set integration time in seconds. Query aperture (integration) time. Select range. Query range. Enable/disable autoranging. Query autorange mode. Set integration time in seconds. Query integration time (seconds). Set integration time in PLCs. Query integration time (PLCs). Select range. Query range. Enable/disable autoranging. Query autorange mode. Specify resolution. Query resolution. Set integration time in seconds. Query integration time (seconds). Select range. Query range. Enable/disable autoranging. Query autorange mode. Set integration time in seconds. Query integration time (seconds). Set integration time in PLCs. Query integration time (PLCs). Set range. Query range. Set autorange mode.. Query autorange mode. Specify resolution. Query resolution. Set range. Query range. Enable/disable autoranging. Query autorange mode. Specify resolution. Query resolution.
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	VOLTage[:DC]:APERture .333ms 3.33ms 16.7ms 167ms 1.67s MIN MAX VOLTage[:DC]:APERture? [MIN MAX] VOLTage[:DC]:NPLC <number> MIN MAX VOLTage[:DC]:NPLC? [MIN MAX] VOLTage[:DC]:RANGe <range> MIN MAX VOLTage[:DC]:RANGe? [MIN MAX] VOLTage[:DC]:RANGe:AUTO 1 0 ON OFF VOLTage[:DC]:RANGe:AUTO? VOLTage[:DC]:RESolution <resolution> MIN MAX VOLTage[:DC]:RESolution? [MIN MAX] ZERO:AUTO 1 0 ON OFF ONCE ZERO:AUTO?	Set integration time in seconds. Query integration time (seconds). Set integration time in PLCs. Query integration time (PLCs). Set range. Query range. Enable/disable autoranging. Query autorange mode. Specify resolution. Query resolution. Enable/disable autozero mode. Query autozero mode.
STATus	:PRESet :QUEStionable[:EVENT]? :QUEStionable:CONDition? :QUEStionable:ENABle <unmask> :QUEStionable:ENABle?	Sets all bits of enable register to "0". Query the questionable event register. Query the questionable condition register. Sets conditions in enable register. Query the questionable enable register.
SYSTem	:ERRor? :VERSion?	Return error number/message from error queue. Return the multimeter's SCPI version.
TRIGger	:COUNt 1-50000 MIN MAX :COUNt? [MIN MAX] :DELay 0-3600 MIN MAX :DELay? [MIN MAX] :DELay:AUTO 1 0 ON OFF :DELay:AUTO? :SOURce BUS EXT IMM TTLTrg0-TTLTrg7 :SOURce?	Set number of triggers or scans. Query trigger count. Set delay between trigger and start of measurement. Query trigger delay. Enable/disable automatic trigger delay. Query automatic trigger delay mode. Specify trigger source. Query trigger source.

HP E1312A and HP E1412A Multimeter Specifications

■ DC Characteristics

Accuracy Specifications $\pm$ (% of reading + % of range) [1]

Function	Range [3]	Test Current or Burden Voltage	24 Hour [2] 23°C $\pm$ 1°C	90 Day 23°C $\pm$ 5°C	1 Year 23°C $\pm$ 5°C	Temperature Coefficient 0°C - 18°C 28°C - 55°C
DC Voltage	100.0000 mV 1.000000 V 10.00000 V 100.0000 V 300.0000 V		0.0030 + 0.0030 0.0020 + 0.0006 0.0015 + 0.0004 0.0020 + 0.0006 0.0020 + 0.0018	0.0040 + 0.0035 0.0030 + 0.0007 0.0020 + 0.0005 0.0035 + 0.0006 0.0035 + 0.0030	0.0050 + 0.0035 0.0040 + 0.0007 0.0035 + 0.0005 0.0045 + 0.0006 0.0045 + 0.0030	0.0005 + 0.0005 0.0005 + 0.0001 0.0005 + 0.0001 0.0005 + 0.0001 0.0005 + 0.0003
Resistance [4]	100.0000 Ω 1.000000 k Ω 10.00000 k Ω 100.0000 k Ω 1.000000 M Ω 10.00000 M Ω 100.0000 M Ω	1 mA 1 mA 100 μ A 10 μ A 5 μ A 500 nA 500 nA 10 M Ω	0.0030 + 0.0030 0.0020 + 0.0005 0.0020 + 0.0005 0.0020 + 0.0005 0.0020 + 0.0010 0.0150 + 0.0010 0.3000 + 0.0100	0.0080 + 0.0040 0.0080 + 0.0010 0.0080 + 0.0010 0.0080 + 0.0010 0.0080 + 0.0010 0.0350 + 0.0010 0.8000 + 0.0100	0.0100 + 0.0040 0.0100 + 0.0010 0.0100 + 0.0010 0.0100 + 0.0010 0.0100 + 0.0010 0.0540 + 0.0010 0.8000 + 0.0100	0.0006 + 0.0005 0.0006 + 0.0001 0.0006 + 0.0001 0.0006 + 0.0001 0.0010 + 0.0002 0.0030 + 0.0004 0.1500 + 0.0002
DC Current	10.00000 mA 100.0000 mA 1.000000 A 3.000000 A	<0.1V <0.6V <1V <2V	0.0050 + 0.0100 0.0100 + 0.0040 0.1000 + 0.0060 0.7000 + 0.0200	0.0500 + 0.0200 0.0500 + 0.0050 0.1300 + 0.0100 0.7200 + 0.0200	0.0700 + 0.0200 0.0700 + 0.0050 0.1500 + 0.0100 0.7200 + 0.0200	0.0050 + 0.0020 0.0060 + 0.0005 0.0060 + 0.0010 0.0060 + 0.0020
DC:DC Ratio	100 mV to 300V		(Input Accuracy) + (Reference Accuracy) Input Accuracy = accuracy specification for the HI-LO input signal. Reference Accuracy = accuracy specification for HI-LO reference input signal (Sense HI-LO input terminals). NOTE: Autorange is used for the reference signal regardless of the range set for the HI-LO input signal. The 10V range is the highest range available for the reference signal and the highest range the multimeter will autorange to for measuring the reference signal.			

■ DC Characteristics (continued)

Measuring Characteristics

DC Voltage

Measurement Method: Continuously integrating, multi-slope III A/D converter.

A/D Linearity: 0.0002% of reading + 0.0001% of range

Input Resistance:

0.1V, 1V, 10V ranges Selectable 10 M Ω or >10G Ω

100V, 300V ranges 10 M Ω $\pm$ 1%

Input Bias Current: <30 pA at 25 °C

Input Terminals: Copper alloy

Input Protection: 300V on all ranges

Resistance

Measurement Method: Selectable 4-wire or 2-wire ohms. Current source referenced to LO input.

Max. Lead Resistance: 10% of range per lead for 100 Ω and 1 k Ω ranges. 1 k Ω per lead on all (4-wire ohms) other ranges.

Input Protection: 300V on all ranges

DC Current

Shunt Resistor: 0.1 Ω for 1A and 3A. 5 Ω for 10 mA and 100 mA

Input Protection: Externally accessible 3.15A, 250V, Class H fuse
(see note at the bottom of the AC Measuring Characteristics page describing class H fuses)

DC:DC Ratio

Measurement Method: Input HI-LO/Reference HI-LO (Reference = Ω 4W Sense terminals)

Input HI-LO 100 mV to 300V ranges

Reference HI-LO 100 mV to 10V ranges (autoranged)

Input to Reference Reference LO to Input LO voltage <2V

Reference HI to Input LO voltage <12V

Measurement Noise Rejection

DC CMRR: 140 dB [5]

Integration Time

Normal Mode Rejection [6]

60 Hz (50 Hz)

100 PLC, 1.67s (2s) 60 dB [7]

10 PLC, 167 ms (200 ms) 60 dB [7]

1 PLC, 16.7 ms (20 ms) 60 dB [7]

<1 PLC 0 dB

[1] Specifications are for 1-hour warm-up at an integration time of 100 PLCs.

[2] Relative to calibration standards.

[3] 20% overrange on all ranges, except 300 Vdc and 3A range which have 1% overrange.

[4] Specifications are for 4-wire ohms function, or 2-wire ohms using Math Null. Without Math Null, add 0.2 Ω additional error in 2-wire ohms function.

■ DC Characteristics (continued)

Operating Characteristics [8]

Function	PLCs	Digits	Readings/sec	Additional Noise Error
DCV, DCI and Resistance	100	6.5	0.6 (0.5) [8]	0% of range
	10	6.5	6 (5) [8]	0% of range
	1	5.5	60 (50) [8]	0.001% of range [9]
	0.2	5.5	300	0.001% of range [9]
	0.02	4.5	1000	0.01% of range [9]

System Speeds [10]

Function Change	30/sec
Range Change	65/sec
Autorange Time	<30 ms
Max. Internal Trigger Rate	1000/sec
Max. External Trigger Rate to Memory	1000/sec

Additional Error with Autozero OFF

Following instrument warm-up at calibration temperature $\pm 1^{\circ}\text{C}$ and <10 minutes:

100 mV - 100V ranges: add (0.0002% range additional error +5 μV). 300V range: add 0.0006% range.

Settling Considerations

Reading settling times are affected by source impedance, cable dielectric characteristics and input signal changes.

Measurement Considerations

HP recommends the use of Teflon® or other high-impedance, low-dielectric absorption wire insulation for these measurements. 1

[5] For 1 k Ω unbalance in LO lead.

[6] For power-line frequency $\pm 0.1\%$.

[7] For power-line frequency $\pm 1\%$, subtract 20 dB; for $\pm 3\%$, subtract 30 dB.

[8] Readings speeds for 60 Hz and (50 Hz) operation, Autozero OFF.

[9] For 300V and 3A ranges: use 0.003% range for 5.5 digits and 0.030% range for 4.5 digits;
For all ranges: add 20 μV for DC volts, 4 μA for DC current or 20 m Ω for resistance.

[10] Speeds are for 0.02 PLC integration time, Delay 0 and Autozero OFF. Includes measurement and data transfer over the VXI backplane.

1 Teflon is a registered trademark of E.I. duPont deNemours and Co.

■ AC Characteristics

Accuracy Specifications $\pm$ (% of reading + % of range) [1]

Function	Range [3]	Frequency	24 Hour [2] 23°C ± 1°C	90 Day 23°C ± 5°C	1 Year 23°C ± 5°C	Temperature Coefficient 0°C - 18°C 28°C - 55°C
True RMS AC Voltage [4]	100.0000 mV	3 Hz-5 Hz	1.00 + 0.03	1.00 + 0.04	1.00 + 0.04	0.100 + 0.004
		5 Hz-10 Hz	0.35 + 0.03	0.35 + 0.04	0.35 + 0.04	0.035 + 0.004
		10 Hz-20 kHz	0.04 + 0.03	0.05 + 0.04	0.06 + 0.04	0.005 + 0.004
		20 kHz-50 kHz	0.10 + 0.05	0.11 + 0.05	0.12 + 0.05	0.011 + 0.005
		50 kHz-100 kHz	0.55 + 0.08	0.60 + 0.08	0.60 + 0.08	0.060 + 0.008
		100 kHz-300 kHz	5.00 + 0.50	5.00 + 0.50	5.00 + 0.50	0.200 + 0.020
	1.000000 V to 100.000V [12]	3 Hz-5 Hz	1.00 + 0.02	1.00 + 0.03	1.00 + 0.03	0.100 + 0.003
		5 Hz-10 Hz	0.35 + 0.02	0.35 + 0.03	0.35 + 0.03	0.035 + 0.003
		10 Hz-20 kHz	0.04 + 0.02	0.05 + 0.03	0.06 + 0.03	0.005 + 0.003
		20 kHz-50 kHz	0.10 + 0.04	0.11 + 0.05	0.12 + 0.05	0.011 + 0.005
		50 kHz-100 kHz	0.55 + 0.08	0.60 + 0.08	0.60 + 0.08	0.060 + 0.008
		100 kHz-300 kHz	5.00 + 0.50	5.00 + 0.50	5.00 + 0.50	0.200 + 0.020
300.000V [12]	3 Hz-5 Hz	1.00 + 0.06	1.00 + 0.09	1.00 + 0.09	0.100 + 0.009	
	5 Hz-10 Hz	0.35 + 0.06	0.35 + 0.09	0.35 + 0.09	0.035 + 0.009	
	10 Hz-20 kHz	0.04 + 0.06	0.05 + 0.09	0.06 + 0.09	0.005 + 0.009	
	20 kHz-50 kHz	0.10 + 0.12	0.11 + 0.15	0.12 + 0.15	0.011 + 0.015	
	50 kHz-100 kHz [5]	0.55 + 0.24	0.60 + 0.24	0.60 + 0.24	0.060 + 0.024	
	100 kHz-300 kHz [5]	5.00 + 1.50	5.00 + 1.50	5.00 + 1.50	0.200 + 0.060	
True RMS AC Current [4]	1.000000 A	3 Hz-5 Hz	1.05 + 0.04	1.05 + 0.04	1.05 + 0.04	0.100 + 0.006
		5 Hz-10 Hz	0.35 + 0.04	0.35 + 0.04	0.35 + 0.04	0.035 + 0.006
		10 Hz-1 kHz	0.15 + 0.04	0.15 + 0.04	0.15 + 0.04	0.015 + 0.006
		1 kHz-5 kHz	0.40 + 0.04	0.40 + 0.04	0.40 + 0.04	0.015 + 0.006
	3.00000 A	3 Hz-5 Hz	1.70 + 0.06	1.70 + 0.06	1.70 + 0.06	0.100 + 0.006
		5 Hz-10 Hz	0.95 + 0.06	0.95 + 0.06	0.95 + 0.06	0.035 + 0.006
		10 Hz-1 kHz	0.75 + 0.06	0.75 + 0.06	0.75 + 0.06	0.015 + 0.006
		1 kHz-5kHz	1.00 + 0.06	1.00 + 0.06	1.00 + 0.06	0.015 + 0.006
Additional Low Frequency Errors (% of reading)				Additional Crest Factor Errors (non-sinewave) [6]		
Frequency	AC Filter			Crest Factor	Error (% or reading)	
	3 Hz	20 Hz	200 Hz			
10 Hz-20 Hz	0	0.74	--	1-2	0.05%	
20 Hz-40 Hz	0	0.22	--	2-3	0.15%	
40 Hz-100 Hz	0	0.06	0.73	3-4	0.30%	
100 Hz-200 Hz	0	0.01	0.22	4-5	0.40%	
200 Hz-1 kHz	0	0	0.18	NOTE: Crest Factor is not specified for non sinewave inputs <100 Hz using the slow (3 Hz) AC filter. See note [6].		
>1 kHz	0	0	0			

■ AC Characteristics (continued)

Measuring Characteristics

Measurement Noise Rejection [7]

AC CMRR 70 dB

True RMS AC Voltage

Measurement Method: AC-coupled True RMS - measures the ac component of the input with up to 300 Vdc of bias on any range (max AC + DC = 300 Vrms).

Crest Factor: Maximum 5:1 at full scale

AC Filter Bandwidths: 3 Hz-300 kHz (Slow filter)
20 Hz-300 kHz (Medium filter)
200 Hz-300 kHz (Fast filter)

Input Impedance: 1 M Ω $\pm$ 2%, in parallel with 100 pF

Input Protection: 300 Vrms all ranges

True RMS AC Current

Measurement Method: Direct coupled to the fuse and shunt. AC-coupled True RMS measurement (measures the ac component only).

Shunt Resistor: 0.1 Ω for 1A and 3A ranges

Burden Voltage: 1A range: <1 Vrms
3A range: < 2 Vrms

Input Protection: Externally accessible 3.15A, 250V, Class H fuse

Class H fuses are fuses with a high interrupt rating which defines a fuse's ability to *safely* interrupt and clear short circuits. Replace the fuse with HP part number 2110-0957, (3.15A, 250V, 5.0 mm diameter, 20.0 mm long) or use Cooper Industries Inc. fuse part number GDA-3.15.

■ AC Characteristics (continued)

Operating Characteristics

Function	Digits	Readings/sec	AC Filter
ACV and ACI	6 1/2	1 (per 7 seconds) [8]	Slow (3 Hz) (7 sec settling time)
	6 1/2	1 [8]	Medium (20 Hz)
	6 1/2	1.6 [8],[9]	Fast (200 Hz)
	6 1/2	50 [10]	Fast (200 Hz)

System Speeds [10], [11]

Function or Range Change	5/sec
Autorange Time	<0.8 sec
ASCII readings to HP-IB	50/sec
Max. Internal Trigger Rate	50/sec
Max. External Trigger Rate to Memory	50/sec

[1] Specifications are for 1-hour warm-up at 100 PLC integration time, 3 Hz (Slow) ac filter, sinewave input.

[2] Relative to calibration standards.

[3] 20% overrange on all AC ranges, except 300V and 3A ranges which have 1% overrange.

[4] Values in the AC Characteristics Accuracy Specifications table are for *sinewave inputs* >5% of range (>15% of range for 300 VAC). For smaller inputs, add an additional error to the value in the table as follows:

Function	Range	Additional Error Specifications to % Range Table Value for sinewave inputs:			
		1% to 5% of range		3% to 15% of range	
		<50 kHz	>50 kHz	<50 kHz	>50 kHz
True RMS AC Voltage	100mV to 100V	add 0.1 to % of range	add 0.13 to % of range		
	300V			add 0.3 to % of range	add 0.4 to % of range
True RMS AC Current	1A and 3A	add 0.1 to % of range			

[5] 300 Vac range limited to 50 kHz. For frequencies >50 kHz, signals must be $<1.5 \times 10^7$ Volt-Hz.

[6] For frequencies below 100 Hz, 3 Hz (Slow) AC filter specified for sinewave input only.

[7] For 1 k Ω unbalance in LO lead.

[8] Maximum reading rates for 0.01% of ac step additional error. Additional settling delay required when input dc level varies.

[9] For External Trigger or remote operation using default settling delay (Delay Auto).

[10] Maximum useful limit with default settling delays defeated.

[11] Speeds are for 0.02 PLC integration time, Delay 0, and 200 Hz (Fast) ac filter.

[12] 100Vac and 300Vac ranges may latch up the module or system mainframe if you drive the LO terminal with a high voltage, high frequency input. Only drive the HI terminal when measuring ac voltages.

■ Frequency and Period Characteristics

Accuracy Specifications $\pm$ (% of reading) [1] [4]

Function	Range [3]	Frequency	24 Hour [2] 23°C $\pm$ 1°C	90 Day 23°C $\pm$ 5°C	1 Year 23°C $\pm$ 5°C	Temperature Coefficient 0°C - 18°C 28°C - 55°C
Frequency, Period	100 mV to 300V	3 Hz - 5 Hz	0.10	0.10	0.10	0.005
		5 Hz - 10 Hz	0.05	0.05	0.05	0.005
		10 Hz - 40 Hz	0.03	0.03	0.03	0.001
		40 Hz - 300 kHz	0.006	0.01	0.01	0.001

Additional Low-Frequency Errors (% of reading) [4]

Frequency	Integration Time (number PLCs)		
	100 & 10	1 & 0.2	0.02
3 Hz-5 Hz	0	0.12	0.12
5 Hz-10 Hz	0	0.17	0.17
10 Hz-40 Hz	0	0.2	0.2
40 Hz-100 Hz	0	0.06	0.21
100 Hz-300 Hz	0	0.03	0.21
300 Hz-1 kHz	0	0.01	0.07
>1 kHz	0	0	0.02

■ Frequency and Period Characteristics (continued)

Measuring Characteristics

Frequency and Period

Measurement Method:	Reciprocal-counting technique. AC-coupled input using the ac voltage measurement function.
Voltage Ranges:	100 mV rms full scale to 300V rms. Auto or manual ranges.
Gate Time:	10 ms, 100 ms or 1 second.

Settling Considerations

Errors will occur when attempting to measure the frequency or period of an input following a dc offset voltage change. The input blocking RC time constant must be allowed to adequately settle (up to 1 second) before the most accurate measurements are possible.

Measurement Considerations

All frequency counters are susceptible to error when measuring low-voltage, low-frequency signals. Shielding inputs from external noise pickup is critical for minimizing measurement errors.

Operating Characteristics [5]

Function	Integration Time	Readings/second
Frequency, Period	100	1
	1	9.8
	0.02	80

System Speeds [5]

Configuration Rates	14/sec
Autorange Time	<0.6 sec
Max. Internal Trigger Rate	80/sec
Max. External Trigger Rate to Memory	80/sec

[1] Specifications are for 1-hour warm-up at 100 PLC integration time.

[2] Relative to calibration standards.

[3] 20% overrange on all ranges, except 300 Vac range which has 1% overrange.

[4] Input >100 mV. For 10 mV input, multiply % of reading error x10.

[5] Speeds are for 0.02 PLC integration time, Delay 0 and 200 Hz (Fast) ac filter.

■ General Specifications

Overvoltage Category 1 (1500V peak max impulse)

HP E1312A and E1412A Available Power (Amps):

+5V:	I _{pm} (maximum peak current):	0.20A
	I _{dm} (maximum dynamic current):	0.10A
+12V:	I _{pm} (maximum peak current):	0.70A
	I _{dm} (maximum dynamic current):	0.06A

Cooling /Slot: Average Watts/Slot: 9.40
 deltaP mm H₂O: 0.05
 Air Flow liters/s: 0.80

Operating Environment: 0°C to 55°C

65% Relative Humidity to 40°C

NOTE: Recalibration may be required after exposure to humidity levels >65%.

Storage Environment: -40°C to 70°C

State Storage Memory: Power-off state automatically saved

Warm-up Time: 1 hour

Programming Language: SCPI-1993, IEEE-488.2

The HP E1312A is factory calibrated in a mainframe with a nominal 12°C rise above ambient.

To Calculate Total Measurement Error

Each specification includes correction factors which account for errors present due to operational limitations of the multimeter. This section explains these errors and shows how to apply them to your measurements. Refer to the section titled “Interpreting Multimeter Specifications” following this section to get a better understanding of the terminology used and to help you interpret the multimeter’s specifications.

The multimeter’s accuracy specifications are expressed in the form: (% of reading + % of range). In addition to the reading error and range error, you may need to add additional errors for certain operating conditions. Check the list below to make sure you include *all* measurement errors for a given function. Also, make sure you apply the conditions as described in the footnotes on the specification pages.

- If you are operating the multimeter outside the $23^{\circ}\text{C}\pm 5^{\circ}\text{C}$ temperature range specified, apply an additional *temperature coefficient error*.
- For dc voltage, dc current, and resistance measurements, you may need to apply an additional *reading speed error* or *autozero OFF error*.
- For ac voltage and ac current measurements, you may need to apply an additional *low frequency error* or *crest factor error*.

Understanding the “% of reading” Error

The *reading error* compensates for inaccuracies that result from the function and range you select, as well as the input signal level. The reading error varies according to the input level on the selected range. This error is expressed in percent of reading. The following table shows the reading error applied to the multimeter’s 24-hour dc voltage specification.

Range	Input Level	Reading Error (% of reading)	Reading error Voltage
10 Vdc	10 Vdc	0.0015	$\leq 150\ \mu\text{V}$
10 Vdc	1 Vdc	0.0015	$\leq 15\ \mu\text{V}$
10 Vdc	0.1 Vdc	0.0015	$\leq 1.5\ \mu\text{V}$

Understanding the “% of range” Error

The *range error* compensates for inaccuracies that result from the function and range you select. The range error contributes a constant error, expressed as a percent of range, *independent* of the input signal level. The following table shows the range error applied to the multimeter’s 24-hour dc voltage specification.

Range	Input Level	Range Error (% of range)	Range Error Voltage
10 Vdc	10 Vdc	0.0004	≤40 μV
10 Vdc	1 Vdc	0.0004	≤40 μV
10 Vdc	0.1 Vdc	0.0004	≤40 μV

Total Measurement Error

To compute the total measurement error, add the reading error and range error. You can then convert the total measurement error to a “percent of input” error or a “ppm (part-per- million) of input” error as shown below.

$$\% \text{ of input error} = \frac{\text{Total Measurement Error}}{\text{Input Signal Level}} \times 100$$

$$\text{ppm of input error} = \frac{\text{Total Measurement Error}}{\text{Input Signal Level}} \times 1,000,000$$

Error Example

Assume that a 5 Vdc signal is input to the multimeter on the 10 Vdc range. Compute the total measurement error using the 90-day accuracy specifications: ±(0.0020% of reading + 0.0005% of range).

$$\text{Reading error} = 0.0020\% \times 5 \text{ Vdc} = 100 \mu\text{V}$$

$$\text{Range error} = 0.0005\% \times 10 \text{ Vdc} = 50 \mu\text{V}$$

$$\begin{aligned} \text{Total error} &= 100 \mu\text{V} + 50 \mu\text{V} \\ &= \pm 150 \mu\text{V} \\ &= \pm 0.0030\% \text{ of } 5 \text{ Vdc} \\ &= \pm 30 \text{ ppm of } 5 \text{ Vdc} \end{aligned}$$

Interpreting Multimeter Specifications

This section is provided to give you a better understanding of the terminology used and will help you interpret the multimeter's specifications.

Number of Digits and Overrange

The “number of digits” specification is the most fundamental, and sometimes, the most confusing characteristic of a multimeter. The number of digits is equal to the maximum number of “9’s” the multimeter can measure or display. This indicates the number of *full digits*. Most multimeters have the ability to overrange and add a partial or “ $\frac{1}{2}$ ” digit.

For example, the HP E1412A can measure 9.9999 Vdc on the 10 V range. This represents six full digits of resolution. The multimeter can also overrange on the 10 V range and measure up to a maximum of 12.00000 Vdc. This corresponds to a $6\frac{1}{2}$ -digit measurement with 20% overrange capability.

Sensitivity

Sensitivity is the minimum level that the multimeter can detect for a given measurement. Sensitivity defines the ability of the multimeter to respond to small changes in the input level. For example, suppose you are monitoring a 1 mVdc signal and you want to adjust the level to within ± 1 mV. To be able to respond to an adjustment this small, this measurement would require a multimeter with a sensitivity of at least 1 μ V. You could use a $6\frac{1}{2}$ -digit multimeter if it has a 1 Vdc or smaller range. You could also use a $4\frac{1}{2}$ -digit multimeter with a 10 mVdc range.

Note that the smallest value that can be measured is different from the sensitivity for ac voltage and ac current measurements. For the HP E1412A, these functions are specified to measure down to 1% of the selected range. For example, the multimeter can measure down to 1 mVac on the 100 mVac range.

Resolution

Resolution is the numeric ratio of the maximum measureable value divided by the minimum measureable value on a selected range. Resolution is often expressed in percent, parts-per-million (ppm), counts, or bits. For example, a $6\frac{1}{2}$ -digit multimeter with 20% overrange capability can make a measurement with up to 1,200,000 counts of resolution. This corresponds to about 0.0001% (1 ppm) of full scale, or 21 bits including the sign bit. All four specifications are equivalent.

Accuracy

Accuracy is a measure of the “exactness” to which the multimeter’s measurement uncertainty can be determined *relative to* the calibration reference used. Absolute accuracy includes the multimeter’s relative accuracy specification plus the known error of the calibration reference relative to national standards (such as the U.S. National Institute of Standards and Technology). To be meaningful, the accuracy specifications must

be accompanied with the conditions under which they are valid. These conditions should include temperature, humidity, and time.

There is no standard convention among multimeter manufacturers for the confidence limits at which specifications are set. The table below shows the probability of non-conformance for *each specification* with the given assumptions.

Specification Criteria	Probability of Failure
Mean $\pm$ 2 sigma	4.5%
Mean $\pm$ 3 sigma	0.3%
Mean $\pm$ 4 sigma	0.006%

Variations in performance from reading to reading, and instrument to instrument, decrease for increasing number of sigma for a given specification. This means that you can achieve greater actual measurement precision for a specific accuracy specification number. The HP E1412A is designed and tested to meet performance better than mean $\pm$ 4 sigma of the published accuracy specifications.

Transfer Accuracy

Transfer accuracy refers to the error introduced by the multimeter due to noise and short-term drift. This error becomes apparent when comparing two nearly-equal signals for the purpose of “transferring” the known accuracy of one device to the other.

24-Hour Accuracy

The 24-hour accuracy specification indicates the multimeter’s relative accuracy over its full measurement range for short time intervals and within a stable environment. Short-term accuracy is usually specified for a 24-hour period and for a $\pm 1^{\circ}\text{C}$ temperature range.

90-Day and 1-Year Accuracy

These long-term accuracy specifications are valid for a $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ temperature range. These specifications include the initial calibration errors plus the multimeter’s long-term drift errors.

Temperature Coefficients

Accuracy is usually specified for a $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ temperature range. This is a common temperature range for many operating environments. You must add additional temperature coefficient errors to the accuracy specification if you are operating the multimeter outside a $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ temperature range.

Configuring for Highest Accuracy Measurements

The measurement configurations shown below assume that the multimeter is in its power-on or reset state. It is also assumed that manual ranging is enabled to ensure proper full scale range selection.

DC Voltage, DC Current, and Resistance Measurements:

- Set the resolution to 6 digits Fast (integration time of 10 PLC). You can use the 6 digits slow mode (integration time of 100 PLC) for further noise reduction.
- Set the input resistance to greater than 10 G Ω (for the 100 mV, 1 V, and 10 V ranges) for the best dc voltage accuracy.
- Use 4-wire ohms for the best resistance accuracy.
- Use Math Null to null the test cable resistance for 2-wire ohms, and to remove interconnection offset for dc voltage measurements.

AC Voltage and AC Current Measurements:

- Set the resolution to 6 digits (integration time of 100 PLC).
- Select the slow ac filter (3 Hz to 300 kHz).

Frequency and Period Measurements:

- Set the resolution to 6 digits (aperture time of 1 second).

HP E1312A and HP E1412A Multimeter Error Messages

The following sections describe the types of errors the HP E1312A and HP E1412A report; Execution Errors, Self-Test Errors and Calibration Errors. 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

The wrong parameter type was found in the command string. You may have specified a number where a string was expected, or vice versa. Example: **TRIG:COUN '150' or TRIG:COUN A**

-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 this command. Example:

SAMP:COUN

-112 Program mnemonic too long

A command header was received which contained more than the maximum 12 characters allowed. Example: ***CONFIGURATION:VOLT:DC***

A `<code>` 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: ***TRIG: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 Numeric overflow

A numeric parameter was found whose exponent was larger than 32,000.

Example: ***TRIG:COUN 1E34000***

-124 Too many digits

A numeric parameter was found whose mantissa contained more than 255 digits, excluding leading zeros.

-128 Numeric data not allowed

A numeric parameter was found but a character string was expected. Check the list of parameters to verify you have used a correct 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 which 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 but 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'**

-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

A Group Execute Trigger (GET) or ***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 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**

You turned math on (**CALC:STAT ON**) and then changed to a math operation that was not valid with the present measurement function. For example, dB measurements are not allowed with 2-wire ohms. 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** and **DISPlay:TEXT** commands.

-224 Illegal parameter value

A discrete parameter was received which was 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) or **SAMP:COUN ON** (ON is not a valid choice).

-230 Data stale

A **FETCh?** command was received but internal reading memory was empty. The reading retrieved may be invalid or settings have changed since the data was taken.

-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. *See also "Self-Test Errors," following this section.*

-350 Too many errors

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 power has been off, or after a ***CLS** (clear status) command has been executed.

-410 Query INTERRUPTED

A command was received which 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 power has been off, or after a ***RST** (reset) command has been executed.

-420 Query UNTERMINATED

The multimeter was addressed to talk (i.e., to send data over the interface) but a command has not been received which 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.

-430 Query DEADLOCKED

A command was received which 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.

Self-Test Errors The following errors indicate failures that may occur during a self-test. The error message provides a description of the failure. Refer to the *HP E1312A* and *HP E1412A Service Manual* for more information.

- 602** RAM read/write failed
- 603** A/D sync stuck
- 604** A/D slope convergence failed
- 605** Cannot calibrate rundown gain
- 606** Rundown gain out of range
- 607** Rundown too noisy
- 609** DC gain x1 failed
- 610** DC gain x10 failed
- 611** DC gain x100 failed
- 612** Ohms 500 nA source failed
- 613** Ohms 5 uA source failed
- 614** DC 300V zero failed
- 615** Ohms 10 uA source failed
- 616** DC current sense failed
- 617** Ohms 100 uA source failed
- 618** DC high voltage attenuator failed
- 619** Ohms 1 mA source failed
- 620** AC rms zero failed
- 621** AC rms full scale failed

622 Frequency counter failed

623 Cannot calibrate precharge

625 I/O processor does not respond

626 I/O processor failed self-test

Calibration Errors The following errors indicate failures that may occur during a calibration. The most common errors have descriptions here. Refer to the *HP E1312A and HP E1412A Service Manual* for more information on the other errors.

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 which contained more than 12 characters.

705 Cal aborted

A calibration in progress is aborted when you send a device clear to the multimeter.

706 Cal value out of range

The specified calibration value (**CAL : VALue**) is invalid for the present 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, continuity, diode, ratio, or on the 100 M Ω 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**
- 724 Extended resistance self cal failed**
- 725 500V DC correction out of range**
- 730 Precharge DAC convergence failed**
- 731 A/D turnover correction out of range**
- 732 AC flatness DAC convergence failed**
- 733 AC low frequency convergence failed**
- 734 AC low frequency correction out of range**
- 735 AC rms converter noise correction out of range**
- 736 AC rms 100th scale linearity correction out of range**
- 740 Cal checksum failed, secure state**
- 741 Cal checksum failed, string data**
- 742 Cal checksum failed, DCV corrections**
- 743 Cal checksum failed, DCI corrections**
- 744 Cal checksum failed, RES corrections**
- 745 Cal checksum failed, FRES corrections**
- 746 Cal checksum failed, AC corrections**
- 747 Cal checksum failed, HP-IB address**
- 748 Cal checksum failed, internal data**

Measurement Speed and Accuracy Tradeoffs

The HP E1312A and HP E1412A Multimeters were designed so the default mode of operation will deliver high accuracy readings with a minimum of programming effort. However, many applications require high-speed measurements. This appendix discusses two topics: 1) 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 set-up and 2) how to increase measurement speed where reduced reading accuracy is acceptable.

HP E1312A/E1412A Special Function and Range Commands (Non-SCPI)

The HP E1312A and HP E1412A Multimeter have special function and range commands for DCV, DCI, 2-wire resistance (RES) and four-wire resistance (FRES) shown in the following table. ACV, ACI, frequency or period functions are not supported with these special commands.

Table C-1. Special Function and Range Commands.

	RANGE						
FUNCTION	R1	R2	R3	R4	R5	R6	R7
F1 (DCV)	0.1V	1V	10V	100V	300V	INVALID RANGES	
F2 (DCI)	0.01A	0.1A	1A	3A	WILL RETURN "Out of range" ERROR		
F3 (RES)	100Ω	1KΩ	10KΩ	100KΩ	1MΩ	10MΩ	100MΩ
F4 (FRES)	100Ω	1KΩ	10KΩ	100KΩ	1MΩ	10MΩ	100MΩ

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 10V, sending the range command R2 changes the DCV range to 1V 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 then R2 sets the range to 1KΩ. Sending F1 returns the function to DCV and to the range and state it was last set prior to the F3 command.

Table C-2 shows equivalent [SENSe:] commands for the special commands.

Speed Advantage Using the Special Non-SCPI Commands (F1-F4 and R1-R7)

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. 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.

Table C-2. Special Commands and Their Equivalent SENSe Command.

Speed Advantage	Special Command	Equivalent [SENSe:] SCPI command
approximate 3 mS advantage with special command	F1	[SENSe:]FUNC "VOLT[:DC]"
	F2	[SENSe:]FUNC "CURR[:DC]"
	F3	[SENSe:]FUNC "RES"
	F4	[SENSe:]FUNC "FRES"
The special range command affects the currently configured function.		
approximate 5 mS advantage with special 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 1000 [SENSe:]FRES:RANG 1000
	R3	[SENSe:]VOLT[:DC]:RANG 10 [SENSe:]CURR[:DC]:RANG 1 [SENSe:]RES:RANG 10000 [SENSe:]FRES:RANG 10000
	R4	[SENSe:]VOLT[:DC]:RANG 100 [SENSe:]CURR[:DC]:RANG 3 [SENSe:]RES:RANG 1E5 [SENSe:]FRES:RANG 1E5
	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

HP E1312A/E1412A 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:]<function>: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 Chapter 3, Command Reference, Tables 3-1, 3-2, and 3-3.

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 Funtion	HP E1312A/E1412 Power-on State	HP E1312A/E1412 *RST State
F1	10V (R3), NPLC = 10	300V (R5), NPLC = 10
F2	1A (R3), NPLC = 10	1A (R3), NPLC = 10
F3	1 k Ω (R2), NPLC = 10	1 k Ω (R2), NPLC = 10
F4	1 k Ω (R2), NPLC = 10	1 k Ω (R2), NPLC = 10

NOTE

Refer to Tables 3-1, 3-2 and 3-3 in Chapter 3, 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).

Resolution Example

Assume the power-on state where the multimeter function is DC Voltage, 10V range, with an NPLC setting of 10 PLCs providing 10 μ V resolution (see Chapter 3, Table 3-1). Use the special range command R5 to change the DC Voltage range to 300V. The NPLC setting remains at 10 PLCs providing a resolution of 1 mV (see Chapter 3, Table 3-1).

Use the special function command F3 to change the function to 2-Wire Resistance. The range goes to the resistance power-on state (1 k Ω 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 m Ω .

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.

General Guidelines for Increasing Measurement Speed

The following guidelines show how to increase measurement speed, which in some cases, will reduce the accuracy of the measurement. Some of the guidelines will not affect accuracy but simply make taking measurements more efficient. Be aware that these guidelines also increase the complexity of the program.

- 1. Avoid function changes.
- 2. Avoid aperture changes when making frequency or period measurements.
- 3. Minimize the number of command/response sessions.
- 4. Set autozeroing to ONCE or OFF.
- 5. Turn auto ranging OFF.
- 6. Decrease the NPLC setting for DCV, DCI, 2-wire and 4-wire resistance measurements.
- 7. Store the readings in the HP E1312A or E1412A internal memory instead of sending them directly to the computer.

Note

Only items 4, 5 and 6 may reduce the accuracy of a measurement. The rest of the guidelines involve additional work by the system programmers.

Avoid Function Changes

The HP E1312A and HP E1412A Multimeter takes time to switch between the various functions because the hardware must be re-configured for the new function. Organize your program so all measurements on a function are done at the same time.

Avoid Aperture Changes

Changing aperture times for frequency or period measurements takes a significant amount of time. The easiest way to avoid aperture changes is to directly specify the aperture time. This requires that you not use the MEASure command and that you not specify the optional *<resolution>* parameter in a CONFigure command.

Minimize the Number of Command / Response Sessions

Minimizing the number of command/response sessions involves programming the multimeter to pace itself, rather than the computer pacing the multimeter. Use the external trigger mode when measuring signals routed to the multimeter from a switch module.

The EXTERNAL TRIGGER input can be used to start a scan from an external signal. The HP E1406 Command Module "Clk out" is a convenient source for an external signal. A potential problem exists whereby an external trigger arrives before the multimeter is ready to start a new scan causing the trigger to be missed and no error message generated. Send a *OPC? command to the multimeter after setting up the multimeter and prior to initiating the switch module to eliminate this problem.

Set Autozeroing to ONCE or OFF

Autozeroing causes the A/D to alternately measure its internal zero and the external signal. Autozeroing improves reading accuracy; however, it reduces reading speed by $\frac{1}{2}$.

CAL:ZERO:AUTO ON	----The zero will be measured before each measurement.
CAL:ZERO:AUTO OFF	---- No new zero readings will be made.
CAL:ZERO:AUTO ONCE	---- Does one Autozeroing operation when the command is received and also sets the mode to autozeroing OFF.

The zero may vary over time, especially as the room temperature varies. Noticeable changes can be expected over many minutes or hours. However, over a few seconds the changes should be very small.

Turn Auto Ranging OFF

Turning auto ranging OFF makes the HP E1312A and HP E1412A take all measurements on a fixed range which results in fast and predictable measurement times.

Auto ranging is turned OFF when a numeric value or MIN | MAX is specified for the <range> parameter of the CONFIGure, MEASure, [SENSe:]RESistance:RANGe, [SENSe:]VOLTage:RANGe, or [SENSe:]VOLTage:AC:RANGe command. Auto ranging is directly controlled by the [SENSe:]VOLTage:RANGe:AUTO ON | OFF, [SENSe:]VOLTage:AC:RANGe:AUTO ON | OFF, or [SENSe:]RESistance:RANGe:AUTO ON | OFF command .

You can query the HP E1312A or HP E1412A auto range status for a particular function by the following commands:

```
[SENSe:]CURREnt[:DC]:RANGe:AUTO?  
[SENSe:]CURREnt:AC:RANGe:AUTO?  
[SENSe:]FREQuency:VOLTage:RANGe:AUTO?  
[SENSe:]FREStance:RANGe:AUTO?  
[SENSe:]PERiod:VOLTage:RANGe:AUTO?  
[SENSe:]RESistance:RANGe:AUTO?  
[SENSe:]VOLTage[:DC]:RANGe:AUTO?  
[SENSe:]VOLTage:AC:RANGe:AUTO?  
[SENSe:]RESistance:RANGe:AUTO?
```

Decrease Aperture Time or NPLCs

The aperture time or NPLCs (number of power line cycles) is the amount of time that the input signal is integrated. The smaller the aperture time or NPLCs, the faster the readings are taken.

A disadvantage to faster aperture times or smaller NPLC settings is increased noise will be present in the measured values. The most common source of noise is from AC power sources.

The magnitude of noise from AC power sources in most cases is many milli-volts. If the signal being measured is large enough, then the noise may not be significant. However, noise becomes a factor if the signal being measured is in the micro-volt range.

Setting the Resolution

The aperture time or NPLC is set as a result of specifying the *<resolution>* parameter in the MEASure or CONFigure command, or by directly setting it with the [SENSe:]FREQuency:APERture or [SENSe:]PERiod:APERture command or [SENSe:]function:NPLC commands.

Store the Readings in Multimeter RAM Instead of Sending them Directly to the Computer

There is a major difference between INIT::FETCh? and READ? after a CONFigure command.

INIT::FETCh?

When the INITiate command is sent to the HP E1312A or HP E1412A, the multimeter will store up to 512 readings in Multimeter RAM. For example:

```
CONF:VOLT:DC  
SAMP:COUN 200  
INIT      ! Stores 200 readings in RAM  
FETC?    ! Transfers readings to output buffer
```

The HP E1312A or HP E1412A then takes the readings as soon as its trigger conditions have been satisfied and stores them in internal memory (RAM). For example, if the trigger source is IMMEDIATE, the readings are started once INITiate is executed. If the trigger source is EXT, then the readings are started when an external trigger is received.

The FETCh? command causes the readings that have been stored in the multimeter RAM to be placed in the multimeter's output buffer so they can be retrieved and sent over the HP-IB bus (or other I/O interface such as VXLink). No readings are output until all readings have been taken and stored in internal memory (RAM). This results in a burst-then-transfer mode of operation.

The multimeter can store a maximum of 512 readings in its internal memory.

READ? The READ? command does not store readings in internal memory (RAM) like the INITiate command does. for example:

```
CONF:VOLT:DC
SAMP:COUN 200
READ?      ! Takes 200 readings and puts them in the output buffer
```

The READ? command causes the HP E1312A and HP E1412A multimeter to start taking readings as soon as the trigger requirements have been met. For example, if the trigger source is IMMEDIATE, the readings are started immediately. If the trigger source is EXT, then the readings are started when an external trigger is received. The multimeter immediately places those readings in the multimeter's output buffer so they can be retrieved via the HP-IB bus (or other I/O interface such as VXLink) by the controller. If the controller cannot take the readings from the output buffer fast enough, the multimeter will suspend taking measurements until there is room to place the readings in the output buffer. You can have a variable reading rate if your controller is busy doing other tasks instead of emptying the output buffer to make room for more readings.

- *CLS, 161-162
- *ESE, 161-162
- *ESE?, 161-162
- *ESR?, 161-162
- *IDN?, 161, 163
- *OPC, 161, 163
- *OPC?, 161, 163
- *RST, 161, 164
- *SRE, 161, 164
- *SRE?, 161, 164
- *STB?, 161, 165
- *TRG, 44, 159, 161
- *TST?, 161, 165
- *WAI, 161, 165

2-wire ohms measurements, 26

4-wire ohms measurements, 26

A

abbreviated commands, 67

ABORt subsystem

 ABORt, 71

ac signal filters, 34

ac voltage

 loading errors, 32

 measurements, 90, 108

address switch

 location, 13

 setting, 13

APERture

 increasing measurement speed, 197

 SENSe:CURRent[:DC]:APERture, 121

 SENSe:FREQuency:APERture, 127

 SENSe:FRESistance:APERture, 129

 SENSe:PERiod:APERture, 134

 SENSe:RESistance:APERture, 136

 SENSe:VOLTage[:DC]:APERture, 145

aperture time

 changing, 197

 decreasing, 199

 increasing measurement speed, 199

 querying, 134, 137

 setting, 121, 129, 134, 136, 145, 199

Application Examples, 51

autorange

 enabling, 120, 124, 128, 132, 135, 139, 143, 148

 increasing measurement speed, 198

 querying, 120, 125, 129, 133, 136, 140, 143, 148

 setting the, 198

autozero, 29, 37

 disabling, 81, 150, 198

 enabling, 81, 150, 198

 increasing measurement speed, 198

 one time (ONCE), 150

 querying, 81, 151

B

backplane trigger lines, 44

bandwidth

 ac signal filters, 35, 126

 SENSe:DETEctor:BANDwidth, 126

 setting, ac filter, 126

BNC connector, external trigger, 158-159

boolean parameters, 68

burden voltage, 29

burden voltage errors, 34

BUS trigger, 46, 158-159

C

CALCulate

 average reading, 74

 count (number of readings), 74

 dB reference, 75

 dBm reference, 76

 limits, 76

 maximum reading, 74

 minimum reading, 74

 offset null, 75

CALCulate subsystem, 72-77

 CALCulate:AVERage:AVERage?, 74

 CALCulate:AVERage:COUNT?, 74

 CALCulate:AVERage:MAXimum?, 74

 CALCulate:AVERage:MINimum?, 74

 CALCulate:DB:REFerence, 75

 CALCulate:DB:REFerence?, 75

 CALCulate:DBM:REFerence, 76

 CALCulate:DBM:REFerence?, 76

- CALCulate:FUNction, 73
- CALCulate:FUNction?, 73
- CALCulate:LIMit:LOWer, 76
- CALCulate:LIMit:LOWer?, 76
- CALCulate:LIMit:UPPer, 77
- CALCulate:LIMit:UPPer?, 77
- CALCulate:NULL:OFFSet, 75
- CALCulate:NULL:OFFSet?, 75
- CALCulate:STATe, 73
- CALCulate:STATe?, 74
- calibration
 - errors, 191
- calibration security code
 - changing, 79
 - disabling, 79
 - enabling, 79
- CALibration subsystem, 78
 - CALibration:COUNt?, 78
 - CALibration:LFRequency, 78
 - CALibration:LFRequency?, 79
 - CALibration:SECure:CODE, 79
 - CALibration:SECure:STATe, 79
 - CALibration:SECure:STATe?, 80
 - CALibration:STRing, 80
 - CALibration:STRing?, 80
 - CALibration:VALue, 81
 - CALibration:VALue?, 81
 - CALibration:ZERO:AUTO, 81
 - CALibration:ZERO:AUTO?, 82
 - CALibration?, 83
- capacity, output buffer, 97, 113
- Certification, 5
- clearing the multimeter
 - error queue, 154
- *CLS, 161-162
- command reference, 66-169
 - ABORt subsystem, 71
 - CALCulate subsystem, 72-77
 - CALibration subsystem, 78
 - common (*) commands, 161-165
 - CONFigure subsystem, 84-87, 89-91, 93-94
 - CONFigure? subsystem, 95
 - DATA subsystem, 96
 - FETCh? subsystem, 97
 - INITiate subsystem, 98
 - INPut subsystem, 99-100
 - MEASure subsystem, 101-109
 - OUTPut subsystem, 111-112
 - READ? subsystem, 113
 - SAMPlE subsystem, 114-115
 - SCPI commands, 71
 - SENSe subsystem, 116-132, 135, 138-139, 141-142, 144, 146-151
 - SENSe: subsystem, 132-141, 143
 - STATus subsystem, 152-153
 - SYSTem subsystem, 154
 - TRIGger subsystem, 155-160
- command separator, 67
- command subsystems, description, 66-169
- command types, 66
- command/response sessions, 197
- commands
 - abbreviated, 67
 - alphabetical listing, 66-169
 - common command format, 66
 - FETCh?, info on measurement speed, 199
 - implied, 67
 - INITiate, increasing measurement speed, 199
 - linking, 68
 - low-level, 84, 101
 - parameter types, 68
 - quick reference, 166-169
 - READ?, info on measurement speed, 200
 - SCPI command format, 66
 - separators, 67
 - special non-SCPI, 194
 - upper case vs. lower case, 67
- Comment Sheet, Reader, reply, 10
- common (*) command
 - *CLS, 161-162
 - *ESE, 161-162
 - *ESE?, 161-162
 - *ESR?, 161-162
 - *IDN?, 161, 163
 - *OPC, 161, 163
 - *OPC?, 161, 163
 - *RST, 161, 164
 - *SRE, 161, 164
 - *SRE?, 161, 164
 - *STB?, 161, 165
 - *TRG, 46, 159, 161
 - *TST?, 161, 165
 - *WAI, 161, 165
- format, 66
- reference, 161-165
- Common Command Reference, 161-165
- common mode errors, 33
- common mode rejection (CMR), 24
- CONFigure subsystem, 84-91, 93-94
 - CONFigure:VOLTage, 91, 93
 - CONFigure:CURREnt:AC, 86
 - CONFigure:CURREnt[:DC], 85
 - CONFigure:FREQuency, 93
 - CONFigure:FRESistance, 88

- CONFigure:PERiod, 94
- CONFigure:RESistance, 89-90
- CONFigure:VOLTage:AC, 90
- CONFigure:VOLTage[:DC], 91
- CONFigure:VOLTage[:DC]:RATio, 92
- CONFigure? subsystem, 95
 - CONFigure?, 95
- Conformity, Declaration of, 7-8
- count
 - sample, 50
 - SAMPlE:COUNt, 50, 114
 - trigger, 47
 - TRIGger:COUNt, 155
- crest factor error, 31, 179

D

- data points, 96
- DATA subsystem, 96
 - DATA:POINt?, 96
- dB measurements, 40
- dBm measurements, 41
- dc current
 - measurement errors, 29
- dc voltage
 - loading errors, 23
 - measurements, 91, 106
 - ratio measurements, 93, 107
- Declaration of Conformity, 7-8
- delay, trigger
 - added for function change, 50
 - added for range change, 49
 - defaults, 49
 - inserting, 48
 - querying, 50
 - table of trigger default times, 49
- delays, settling time, 28
- dielectric absorption, 28
- digits, number of, 12, 35, 181
- discrete parameters, 68
- dynamic addressing, 13

E

- enabling
 - autorange, 120, 124, 128, 132, 135, 139, 143, 148
 - autozero, 81, 198
- error messages
 - calibration errors, 191
 - execution errors, 184
 - self-test errors, 189
- error queue

- capacity, 154
- clearing, 154
- reading, 154
- error, crest factor, 179
- ERRor, see SYSTem subsystem, 154
- errors
 - burden voltage, 34
 - common mode, 33
 - crest factor, 31
 - field wiring resistance, 26
 - leakage current, 23
 - temperature coefficient, 179
 - thermal EMF, 22
- *ESE, 161-162
- *ESR?, 161-162

Example programs

- HP VEE programming example, 63
- making a single measurement, 53
- making external trigger measurements, 53
- maximizing accuracy, 55
- maximizing measurement speed, 54
- monitoring for limit test failure, 62
- monitoring for message available (MAV bit), 61
- monitoring for operation complete (OPC bit), 60
- status system example, 59
- synchronizing with a switch module, 56, 58
- using math operations, 58
- visual engineering environment (VEE), 63
- hardware used, 51
- external trigger, 158-159
 - Trig input requirement, 45
 - VM Complete output signal, 45

F

- FETCh? subsystem, 97
 - see also DATA:POINt? command, 199
- FETCh?, 97
 - using to increase measurement speed, 199
- field wiring resistance, 26
- filters
 - ac signal, 34-35
 - for ac current measurements, 126
 - for ac voltage measurements, 126
 - settling time, 35
 - slow, medium and fast, 34-35, 126
- format
 - common command, 66
 - SCPI command, 66
- four-wire
 - ohms measurements, 26, 88, 104
- frequency measurements, 93, 109

- function
 - querying, 118
 - selecting, 118
 - SENSe:FUNcTion, 118
- function changes, 197
 - increasing measurement speed, 196
 - increasing measurement speed, 194, 197
- Function commands, special, 194
- functional connections, measurement, 16

G

- General information, 12
- graphical programming example
 - HP VEE, 63
- ground loop noise, 25
- Group Execute Trigger, 44, 159

H

- HP-IB trigger, 44

I

- idle state (trigger system), 43
- *IDN?, 161, 163
- IEEE 488.2 Common Commands, 161-165
- IMMediate trigger source, 158-159
- impedance, input, 99
- implied commands, 67
- increasing aperture time, 199
- increasing measurement speed, 194-201
- indicators, front panel, 15
- induced voltages, 25
- Initial operation, 20
- INITiate subsystem, 98
 - INITiate[:IMMediate], 98
 - using to increase measurement speed, 199
- input bias current, 23
- INPut subsystem, 99-100
 - INPut:IMPedance:AUTO, 99
 - INPut:IMPedance:AUTO?, 100
- input terminals, 15
- integration time, 24, 36
 - querying, 123, 131, 138, 146
 - setting, 122, 130, 137, 146
- internal memory, capacity, 96
- internal triggering, 46
- interrupt priority, 14

L

- leakage current errors, 23
- LIMit function, 42, 73, 76-77
- limit testing
 - setting upper and lower limits, 42, 76-77
- line frequency reference
 - setting, 14, 78
- linking commands, 68
- loading errors
 - ac voltage, 32
 - dc voltage, 23
- low-level commands, 84, 101

M

- magnetic loops
 - noise, 25
- Math Operations, 39
 - AVERage Function, 39
 - dB Measurements, 40
 - dBm Measurements, 41
 - LIMit Tests, 42
 - NULL (relative) Function, 39
- MEASure subsystem, 101-109
 - MEASure:?, 101
 - MEASure:CURREnt:AC?, 103
 - MEASure:CURREnt[:DC]?, 102
 - MEASure:FREQuency?, 109
 - MEASure:FRESistance?, 104
 - MEASure:PERiod?, 109
 - MEASure:RESistance?, 105
 - MEASure:VOLTage:AC?, 108
 - MEASure:VOLTage[:DC]:RATio?, 107
 - MEASure:VOLTage[:DC]?, 106
- measurement connections, 22
- measurement errors, 179
- measurement function
 - querying, 118
 - selecting, 118
- measurement speed tradeoffs, 194-201
- measurement speed, increasing
 - guidelines, 197
- Measurement Tutorial, 22
- measurement, ac, below full scale, 32
- measurements
 - 2-wire ohms, 89-90, 105-106
 - 4-wire ohms, 88, 104
 - AC voltage, 90, 108
 - dB, 40
 - dBm, 41
 - dc voltage, 91, 106
 - DC voltage ratio, 93, 107
 - frequency, 93, 109

- PERiod, 94, 109
- Measurment Configuration, 34
- multimeter
 - command/response sessions, 197
 - error queue, 154
 - function changes, 197

N

- noise
 - ground loop, 25
 - magnetic loops, 25
 - power-line voltage, 24
- noise pickup, 23
- noise rejection, 24
- normal mode rejection, 37
- normal mode rejection (NMR), 24
- NPLC
 - increasing measurement speed, 199
 - querying, 123, 131, 138, 146
 - resolution, 36
 - SENSe:CURRent[:DC]:NPLC, 122
 - SENSe:FRESistance:NPLC, 130
 - SENSe:RESistance:NPLC, 137
 - SENSe:VOLTage[:DC]:NPLC, 146
 - setting, 122, 130, 137, 146, 199
- NPLC, number of power line cycles, 36
- NULL (relative) function, 39
- null offset
 - storing, 40
- number of digits, 181
- number of digits versus PLC, 12
- numeric parameters, 68

O

- offset voltage, 25
- *OPC, 161, 163
- optional parameters, 68
- output buffer
 - capacity, 97
- output buffer capacity, 113
- OUTPut subsystem, 111-112
 - OUTPut:TTLTrg:STATe, 111
 - OUTPut:TTLTrg:STATe?, 112
- overload errors, 32
- overload indication, 38

P

- parameters
 - boolean, 68

- discrete, 68
- numeric, 68
- optional, 68
- types of, 68
- parts-per-million, 181
- period measurements, 94, 109
- power dissipation effects, 28
- power line cycles, 24
- power-line noise
 - rejecting, 24
- Printing History, 6
- programming the multimeter, 20

Q

- querying
 - aperture time, 122, 127, 130, 134, 137, 145
 - autorange, 120, 125, 129, 133, 136, 140, 143, 148
 - autozero mode, 82, 151
 - function, 118
 - integration time, 123, 131, 138, 146
 - line frequency reference, 79
 - measurement function, 118
 - range, 119, 124, 128, 132, 135, 139, 142, 147
 - resolution, 121, 125, 133, 141, 144, 150
 - sample count, 50, 115
 - trigger count, 47, 156
 - trigger delay, 50, 157-158
 - trigger source, 45, 160
- quick reference
 - IEEE 488.2 Common Commands, 161-165
 - SCPI commands, 166-169

R

- range
 - increasing measurement speed, 194
 - querying, 119, 124, 128, 132, 135, 139, 142, 147
 - setting, 119, 123, 127, 131, 135, 138, 141, 147
 - special non-SCPI commands, 194
- Ranging, 38
- ratio measurements, DC voltage, 93
- READ?, 113, 200
- READ? subsystem, 113
- Reader Comment Sheet, 10
- reading the error queue, 154
- readings per trigger
 - querying, 115
 - setting, 114
- readings, number of, 50
- reciprocal counting technique, 34
- relative value, dB

- storing, 41
- resistance measurements, 26
- resistance measurements, errors in high, 28
- resistance, input, 35
- Resolution, 181
 - 4 1/2, 5 1/2 or 6 1/2 digits, 35
 - NPLC, 35
 - number of digits, 35
 - number of power line cycles, 35
 - querying, 121, 125, 133, 141, 144, 150
 - setting, 120, 125, 133, 140, 143, 149, 199
 - using special non-SCPI commands, 196
- *RST, 161, 164

S

- Safety Warnings, 6
- sample count, 50
 - checking, 50
 - querying, 50
 - setting, 50
- SAMPLE subsystem, 114-115
 - SAMPLE:COUNt, 114
 - SAMPLE:COUNt?, 115
- SCPI command reference, 71, 166-169
- SCPI commands
 - abbreviated, 67
 - command format, 66
 - implied, 67
 - linking with common (*) commands, 68
 - parameters, 68
 - quick reference, 166-169
 - specifying, 20
- security code, calibration
 - changing, 79
 - disabling, 79
 - enabling, 79
- selecting
 - function (SENSe:FUNCTION), 118
 - measurement function, 118
 - trigger source, 158-159
- self-test errors, 189
- SENSe subsystem, 116-151
 - SENSe:CURRent:AC:RANGe, 119
 - SENSe:CURRent:AC:RANGe:AUTO, 120
 - SENSe:CURRent:AC:RANGe:AUTO?, 120
 - SENSe:CURRent:AC:RANGe?, 119
 - SENSe:CURRent:AC:RESolution, 120
 - SENSe:CURRent:AC:RESolution?, 121
 - SENSe:CURRent[:DC]:APERture, 121
 - SENSe:CURRent[:DC]:APERture?, 122
 - SENSe:CURRent[:DC]:NPLC, 122

- SENSe:CURRent[:DC]:NPLC?, 123
- SENSe:CURRent[:DC]:RANGe, 123
- SENSe:CURRent[:DC]:RANGe:AUTO, 124
- SENSe:CURRent[:DC]:RANGe:AUTO?, 125
- SENSe:CURRent[:DC]:RANGe?, 124
- SENSe:CURRent[:DC]:RESolution, 125
- SENSe:CURRent[:DC]:RESolution?, 125
- SENSe:DETEctor:BANDwidth, 126-127
- SENSe:FREQuency:APERture, 127
- SENSe:FREQuency:APERture?, 127
- SENSe:FREQuency:VOLTag:e:RANGe, 127
- SENSe:FREQuency:VOLTag:e:RANGe:AUTO, 128
- SENSe:FREQuency:VOLTag:e:RANGe:AUTO?, 129
- SENSe:FREQuency:VOLTag:e:RANGe?, 128
- SENSe:FRESistance:APERture, 129
- SENSe:FRESistance:APERture?, 130
- SENSe:FRESistance:NPLC, 130
- SENSe:FRESistance:NPLC?, 131
- SENSe:FRESistance:RANGe, 131
- SENSe:FRESistance:RANGe:AUTO, 132
- SENSe:FRESistance:RANGe:AUTO?, 133
- SENSe:FRESistance:RANGe?, 132
- SENSe:FRESistance:RESolution, 133
- SENSe:FRESistance:RESolution?, 133
- SENSe:FUNCTION, 118
- SENSe:FUNCTION?, 118
- SENSe:PERiod:APERture, 134
- SENSe:PERiod:APERture?, 134
- SENSe:PERiod:VOLTag:e:RANGe, 135
- SENSe:PERiod:VOLTag:e:RANGe:AUTO, 135
- SENSe:PERiod:VOLTag:e:RANGe:AUTO?, 136
- SENSe:PERiod:VOLTag:e:RANGe?, 135
- SENSe:RESistance:APERture, 136
- SENSe:RESistance:APERture?, 137
- SENSe:RESistance:NPLC, 137
- SENSe:RESistance:NPLC?, 138
- SENSe:RESistance:RANGe, 138
- SENSe:RESistance:RANGe:AUTO, 139
- SENSe:RESistance:RANGe:AUTO?, 140
- SENSe:RESistance:RANGe?, 139
- SENSe:RESistance:RESolution, 140
- SENSe:RESistance:RESolution?, 141
- SENSe:VOLTag:e:AC:RANGe, 141
- SENSe:VOLTag:e:AC:RANGe:AUTO, 143
- SENSe:VOLTag:e:AC:RANGe:AUTO?, 143
- SENSe:VOLTag:e:AC:RANGe?, 142
- SENSe:VOLTag:e:AC:RESolution, 143
- SENSe:VOLTag:e:AC:RESolution?, 144
- SENSe:VOLTag[:DC]:APERture, 145
- SENSe:VOLTag[:DC]:APERture?, 145
- SENSe:VOLTag[:DC]:NPLC, 146
- SENSe:VOLTag[:DC]:NPLC?, 146

- SENSe:VOLTage[:DC]:RANGe, 147
- SENSe:VOLTage[:DC]:RANGe:AUTO, 148
- SENSe:VOLTage[:DC]:RANGe:AUTO?, 148
- SENSe:VOLTage[:DC]:RANGe?, 147
- SENSe:VOLTage[:DC]:RESolution, 149
- SENSe:VOLTage[:DC]:RESolution?, 150
- SENSe:ZERO:AUTO, 150
- SENSe:ZERO:AUTO?, 151
- sensitivity, 181
- setting
 - aperture time, 121, 127, 129, 134, 136, 145, 199
 - autorange, 198
 - bandwidth, ac filter, 126
 - integration time, 121-122, 129-130, 136-137, 145-146
 - line frequency reference, 14
 - NPLCs, 199
 - range, 119, 123, 127, 131, 135, 138, 141, 147
 - readings per trigger, 114
 - resolution, 120, 125, 133, 140, 143, 149, 199
 - trigger count, 155
 - trigger delay, 156
- settling delays, 28
- settling time, 28
 - ac signal filters, 35, 126
- SICL, Standard Instrument Control Language, 12
- source
 - trigger, 44, 158
- Specifications, 170-183
 - AC, 173-175
 - DC, 170-172
 - Frequency, 176-177
 - General, 178
 - Period, 176-177
- *SRE, 161, 164
- Standard Commands for Programmable Instrument
 - SCPI, 12, 66
- STATus subsystem, 152-153
 - STATus:PRESet, 152
 - STATus:QUEStionable:CONDition?, 152
 - STATus:QUEStionable:ENABle, 152
 - STATus:QUEStionable:ENABle?, 153
 - STATus:QUEStionable[:EVENT]?, 152
- *STB?, 161, 165
- SYSTem subsystem, 154
 - SYSTem:ERRor?, 154
 - SYSTem:VERSion?, 154

T

- temperature coefficient error, 179
- temperature coefficient errors, 32
- tempture coefficient, 182

- terminals
 - input, 15
- thermal EMF errors, 22
- transfer accuracy, 182
- transfer readings to output buffer, 97
- *TRG, 159, 161
- trigger
 - count, querying, 47, 156
 - count, setting, 47, 155
 - delay, querying, 50
 - delay, setting, 48
 - sample count, querying, 50
 - sample count, setting, 50
 - source, querying, 45
 - source, selecting, 44
- trigger count, 47
 - querying, 47
- trigger delay
 - querying, 50, 157-158
 - setting, 48, 156
- trigger lines (TTLTrg0-TTLTrg7), 44
- trigger source, 44
 - BUS, 44, 46
 - EXTeRnal, 44-45
 - IMMediate, 44, 46
 - querying, 45, 160
 - selecting, 158-159
 - TTL VXIbus triggers (TTLTrg0-TTLTrg7), 44
- TRIGger subsystem, 155-160
 - TRIGger:COUNt, 47, 155
 - TRIGger:COUNt?, 47, 156
 - TRIGger:DELAy, 48, 156
 - TRIGger:DELAy:AUTO, 157
 - TRIGger:DELAy:AUTO?, 158
 - TRIGger:DELAy?, 50, 157
 - TRIGger:SOURce, 44, 158-159
 - TRIGger:SOURce?, 45, 160
- trigger system
 - diagram, 43
 - idle state, 43
 - Trig input requirement, 45-46
 - VM Complete output signal, 45-46
 - wait-for-trigger state, 43, 46
- triggering the multimeter, 43
- true RMS, 30
- *TST?, 161, 165
- *TST? (self-test), 161
- TTL VXIbus triggers (TTLTrg0-TTLTrg7), 158-159
- TTLTrg, (OUTPut:TTLTrg:STATe), 111
- TTLTrg, (TRIGger:SOURce TTLTrg), 158
- twisted-pair connections, 25
- two-wire

ohms measurements, 89-90, 105-106
two-wire resistance, 26

V

VEE, Visual Engineering Environment, 63
Virtual Instrument software Architecture, VIS
 VISA, Virtual Instrument Software Architectur, 12
VISA software, 51
VM Complete output signal, 45-46
VXIbus trigger lines (TTLTRG0-TTLTRG7), 44

W

*WAI, 161, 165
wait-for-trigger state, 43, 46
WARNINGS, 6
Warranty, 5

Z

ZERO (autozero)
 CALibration:ZERO:AUTO, 81
 CALibration:ZERO:AUTO?, 82
 SENSe:ZERO:AUTO, 150
 SENSe:ZERO:AUTO?, 151