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Edition 4



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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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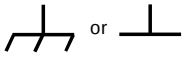
Safety Symbols



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.



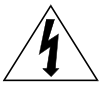
Frame or chassis ground terminal—typically connects to the equipment's metal frame.



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.

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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: VXI 6½-Digit Multimeter

Model Number: HP 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

EMC: CISPR 11:1990/EN55011 (1991): Group1 Class A
IEC 801-2:1991/EN50082-1 (1992): 4kVCD, 8kVAD
IEC 801-3:1984/EN50082-1 (1992): 3 V/m
IEC 801-4:1988/EN50082-1 (1992): 1kV Power Line
.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 configuration in an HP B-Size VXI mainframe.

May 8, 1996

Jim White, QA Manager

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HP E1412A Declaration of Conformity

according to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name: Hewlett-Packard Company
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Manufacturer's Address: 815 14th Street S.W.
Loveland, Colorado 80537

declares, that the product:

Product Name: VXI 6½-Digit Multimeter

Model Number: HP 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
IEC 801-2:1991/EN50082-1 (1992): 4kVCD, 8kVAD
IEC 801-3:1984/EN50082-1 (1992): 3 V/m
IEC 801-4:1988/EN50082-1 (1992): 1kV Power Line
.5kV Signal Lines

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Tested in a typical configuration in an HP C-Size VXI mainframe.



July 31, 1995

Jim White, QA Manager

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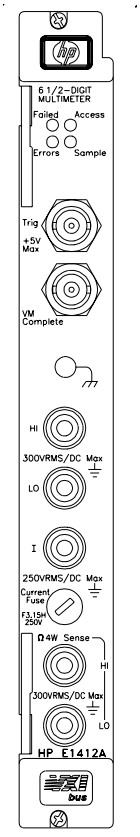
Chapter 1
HP E1312A and HP E1412A Multimeter Module Setup

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 is ***not*** recommended for use in the HP E1300A or HP E1301A B-size mainframe.
- 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 4½-digits for fast measurements to 6½-digits for more accuracy. Resolution is set by specifying the integration time in number of power line cycles (NPLCs) or corresponding aperture time. Table 1-1 shows the correlation between NPLCs and resolution.

Table 1-1. Resolution of Power Line Cycles

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

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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 HP E1406A as the VXIbus resource manager with SCPI commands, the multimeter's address switch value must be a multiple of 8.

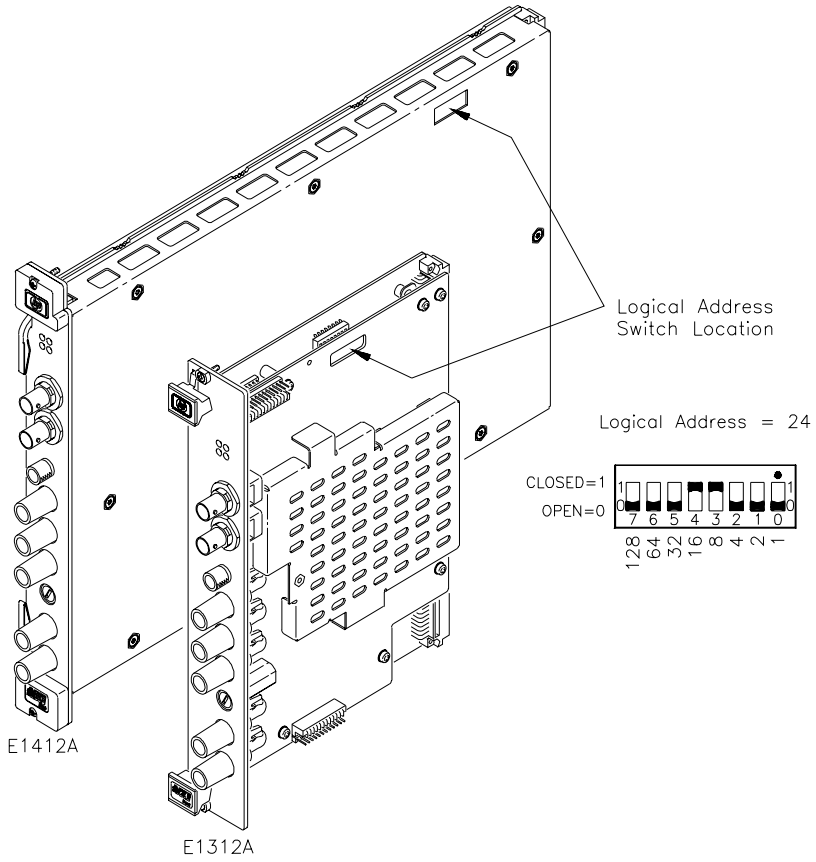


Figure 1-1. Setting the Logical Address

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Interrupt Priority

The HP E1312A and HP E1412A Multimeters 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 HP 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:LFRequency 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:LFRequency? will return **+50** after executing CAL:LFR 400 to set the line frequency reference to 400 Hz.

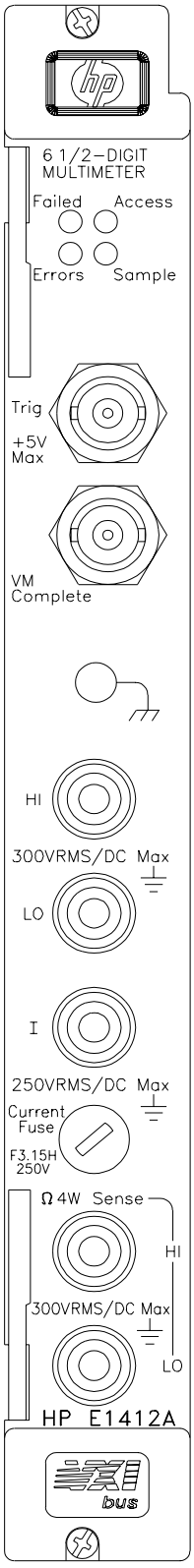
The line frequency reference setting is also useful when the device being measured operates at a different frequency than the multimeter. For example, if the multimeter has a power line frequency reference of 60 Hz and the device being measured has a power line frequency of 50 Hz, maximum NMR is achieved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

```
CAL:LFR 50
```

Checking the Line Frequency Reference

The CALibration:LFRequency? 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.

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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

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Use Banana Plugs to connect field wiring to the input terminals of the Multimeter.

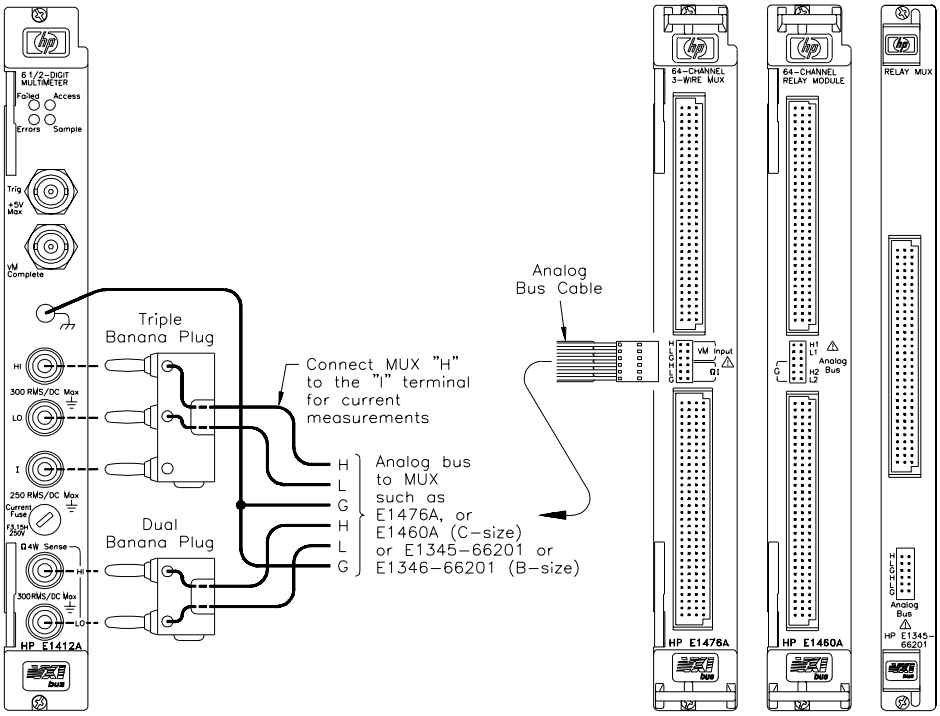


Figure 1-3. Switch Module Analog Bus Connections

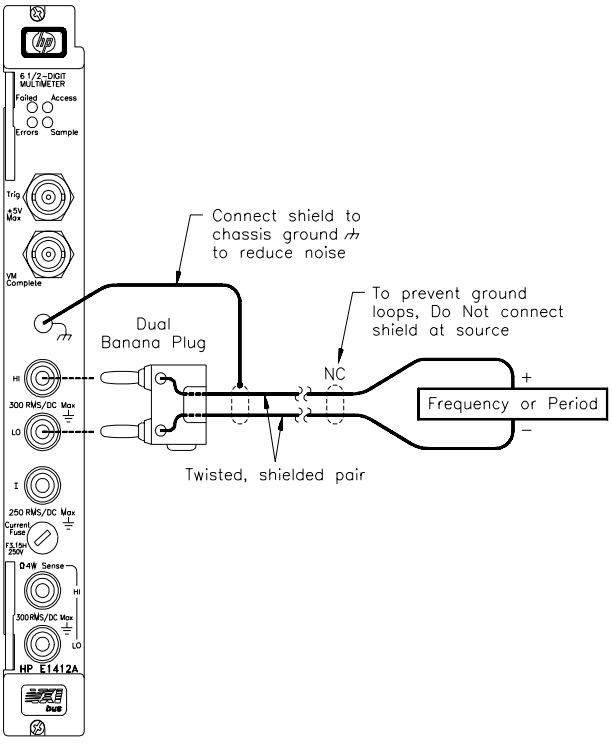


Figure 1-4. Frequency or Period Measurement Connections

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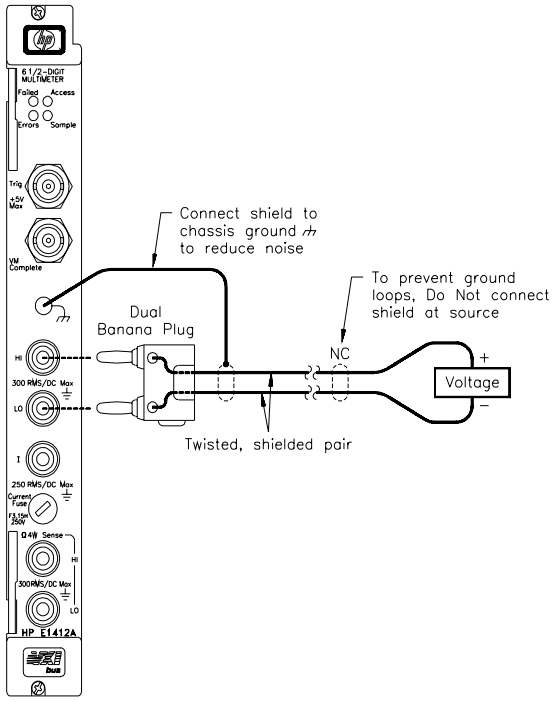


Figure 1-5. Voltage Measurement Connections

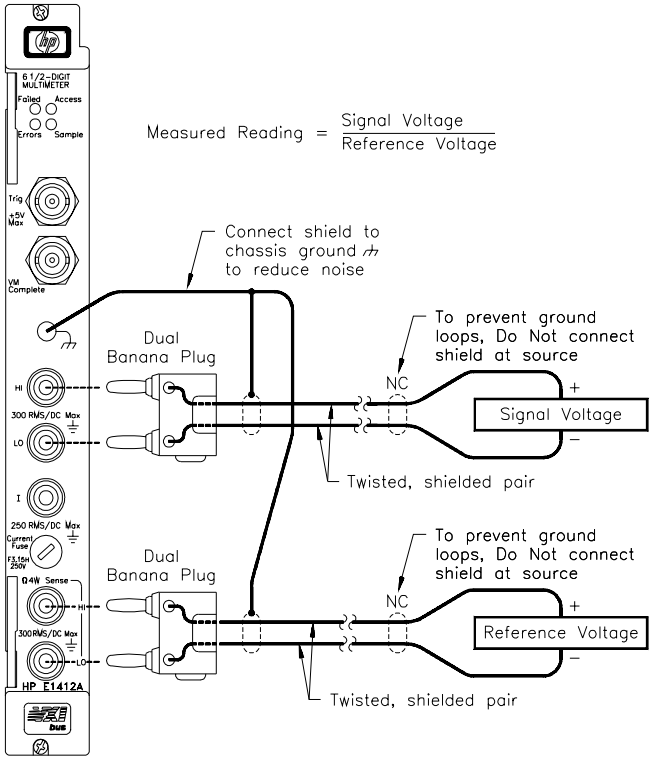


Figure 1-6. Voltage Ratio (Vdc) Measurement Connections

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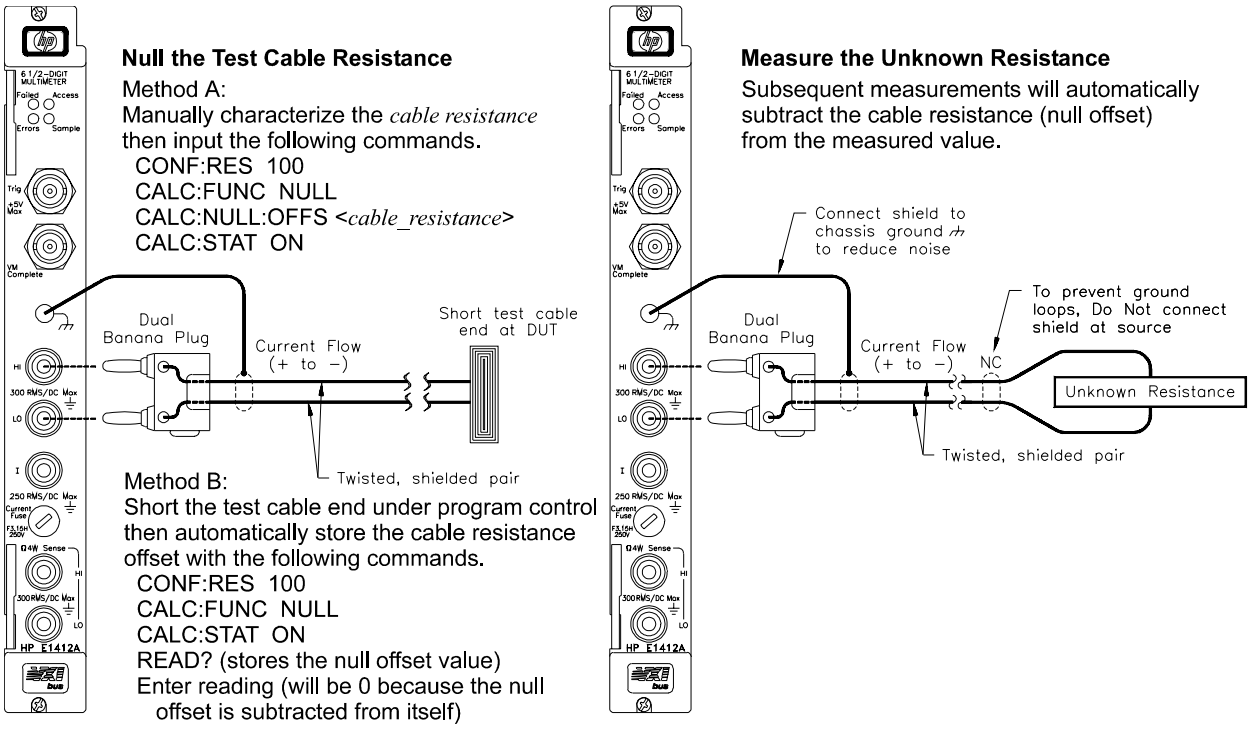


Figure 1-7. 2-Wire Ohms Measurement Connections

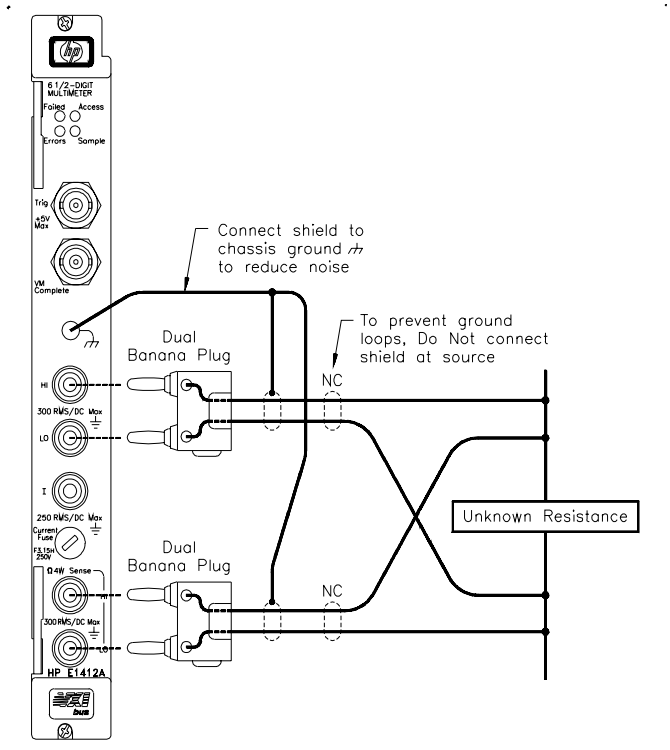


Figure 1-8. 4-Wire Ohms Measurement Connections

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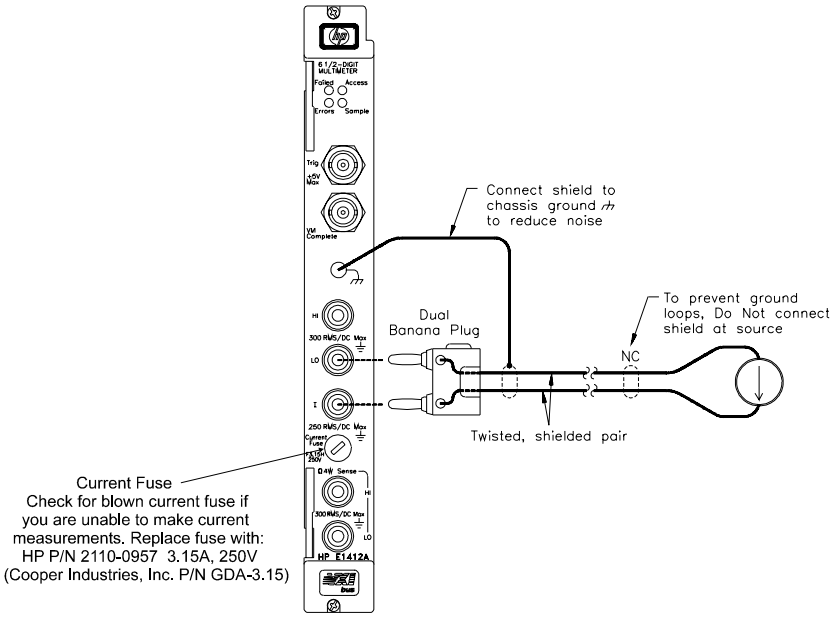


Figure 1-9. Current Measurement Connections

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 VXI*plug&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 *HP 75000 Series C 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.

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```
#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;
}
```


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Notes:

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Chapter 2
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 HP 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. Table 2-1 shows common thermoelectric voltages for connections between dissimilar metals.

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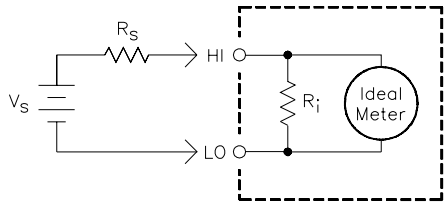
Table 2-1. Thermoelectric Voltages

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

The 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.



V_S = ideal DUT voltage

R_S = DUT source resistance

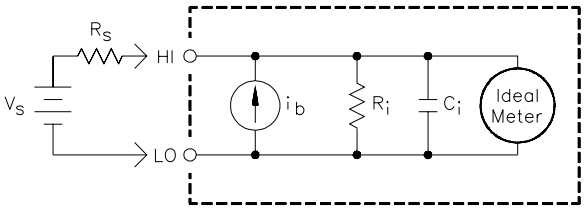
R_i = multimeter input resistance (10 MΩ or >10 GΩ)

$$\text{Error (\%)} = \frac{100 \times R_S}{R_S + R_i}$$

To reduce the effects of loading errors, and to minimize noise pickup, you can set the multimeter's input resistance to greater than 10 GΩ for the 100 mVdc, 1 Vdc, and 10 Vdc ranges. The input resistance is maintained at 10 MΩ 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 GΩ). 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 (×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 kΩ, or when the multimeter's operating temperature is significantly greater than 30°C.



i_b = multimeter bias current

R_S = DUT source resistance

C_i = multimeter input capacitance

Error (v) ≅ $i_b \times R_S$

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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.

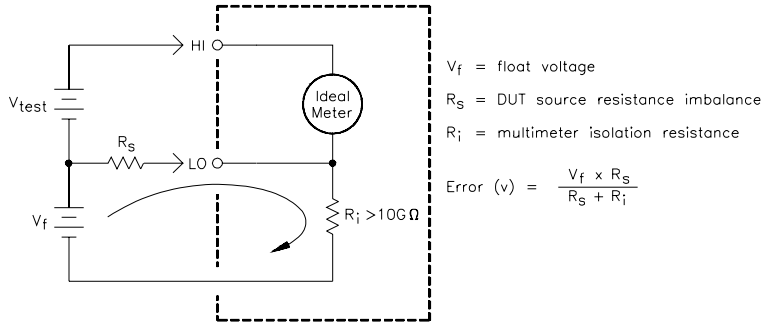
The HP E1312A and HP E1412A provide three A/D integration times (1, 10 and 100 PLCs) to reject power line frequency noise (and power-line frequency harmonics). Power line frequency defaults to 60 Hz unless you specifically set it to 50 Hz with the CAL:LFR command. The multimeter determines the proper integration time based on which power line frequency is set. Table 2-2 shows the noise rejection achieved with various configurations. Select a longer integration time for better resolution and increased noise rejection.

Table 2-2. Noise Rejection

Power Line Cycles (PLCs)	Integration Time 60 Hz	(50 Hz)	NMR
0.02	400 µs	(400 µs)	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.



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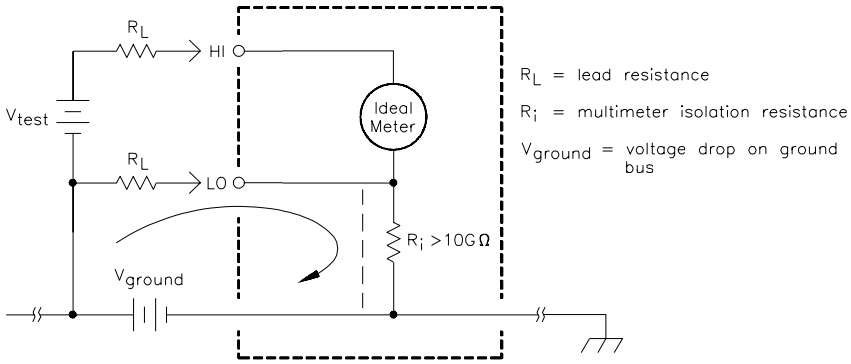
Noise Caused by Magnetic Loops

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.



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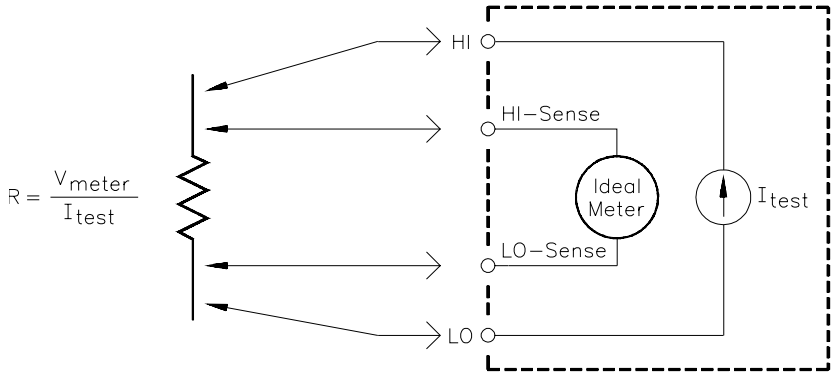
Resistance Measurements

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.



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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).

The following program shows SCPI examples used 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.
```


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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. Table 2-3 shows several examples.

Table 2-3. DUT Power Dissipation

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

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 200pF of combined cable and device capacitance. This is particularly important if you are measuring resistances above 100kΩ. Settling due to RC time constant effects can be quite long. Some precision resistors and multi-function calibrators use large parallel capacitors (1000pF to 0.1µF) 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 1MΩ resistance in humid conditions.

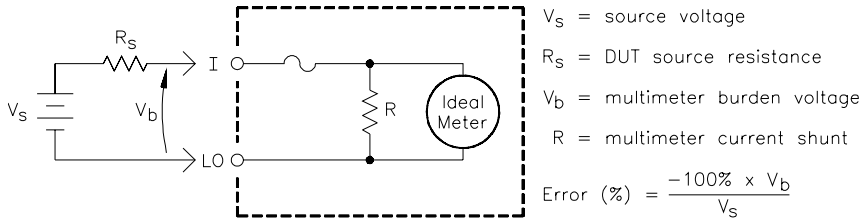
Making High-Speed DC and Resistance Measurements

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

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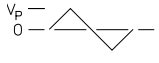
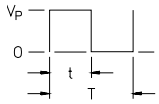
DC Current Measurement Errors

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

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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:

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

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

C.F. = signal's crest factor
f = signal's fundamental frequency
BW = multimeter's -3 dB bandwidth
(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: ±(0.05% + 0.03%).

Total Error = 0.08% + 0.15% + 1.4% = 1.6%

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Loading Errors (ac volts)

In the ac voltage function, the input of the HP E1312A and HP E1412A appears as a 1MΩ resistance in parallel with 100pF of capacitance. The cabling that you use to connect signals to the multimeter will also add additional capacitance and loading.

For low frequencies where $(f \times R_S) \leq 15(10^6)\Omega \bullet Hz$::

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

For any frequency:

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

R_s = source resistance
f = input frequency
C_{in} = input capacitance (100pF) plus cable capacitance

AC Measurements Below Full Scale

You can make the most accurate ac measurements when the multimeter is at full scale of the selected range. Autoranging occurs at ≤10% and ≥120% of full scale. This enables you to measure some inputs at full scale on one range and 10% of full scale on the next higher range (e.g., 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.

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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.

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

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) on page 27).

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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.

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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.

Table 2-4. AC Signal Filters

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 36 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 MΩ for all dc voltage ranges to minimize noise pickup. You can set the input resistance to greater than 10 GΩ 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.

Table 2-5. DC Voltage Input Resistance

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

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Resolution

Resolution is expressed in terms of number of digits the multimeter can measure. You can set the resolution to 4½, 5½ or 6½-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. Table 2-6 illustrates the correlation between Number of Power Line Cycles and Resolution. See the tables beginning on page 70 for detailed cross-reference of function ranges to resolution as a function of NPLCs or Aperture Time.

Table 2-6. Resolution of Power Line Cycles

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

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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 beginning on page 70. 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 4½-digits, 100 mS for 5½-digits or 1 second for 6½-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*>

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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 3Hz and 300kHz for the frequency and period functions. The multimeter determines an internal resolution based on a 3Hz signal. If you query the range, the multimeter will respond with **"3Hz"**. Frequency and period measurements return **"0"** with no input signal applied.
- The specified range applies to the signal connected to the Input terminals for ratio measurements. Autoranging is automatically selected for reference voltage measurements on the Sense terminals.
- You can set the range using any of the following commands:

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

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Math Operations (CALCulate Subsystem)

This sections 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, “Multimeter Command Reference”. There are two steps to initiating a math operation.

1. Select the desired math function:
   CALCulate:FUNCtion AVERage|DB|DBM|LIMit|NULL
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	*Selects the average function.*
CALCulate:STATe OFF|ON	*Activates the average function.*
Take measurements here.	
CALCulate:AVERage:MINimum?	*Read the minimum value.*
CALCulate:AVERage:MAXimum?	*Read the maximum value.*
CALCulate:AVERage:AVERage?	*Read the average value.*
CALCulate:AVERage:COUNt?	*Read the number of measurements.*

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.
- The null value is adjustable and you can set it to any value between 0 and ±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.

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Two Ways to Store the NULL Offset Value

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

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

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.

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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              Set math function to DB.
CALCulate:STATe  ON                 Enable math operation.
CALCulate:DB:REFerence  <value>     Store a dB reference value.
```

dBm Measurements

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

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

- 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 nonvolatile 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             Set math function to DBm.
CALCulate:STATe  ON                 Enable math operation.
CALCulate:DBM:REFerence  <value>    Store a dBm reference.
```


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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 ±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 Figure 3-1 on page 154. 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).

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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 will 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.

Figure 2-1 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.

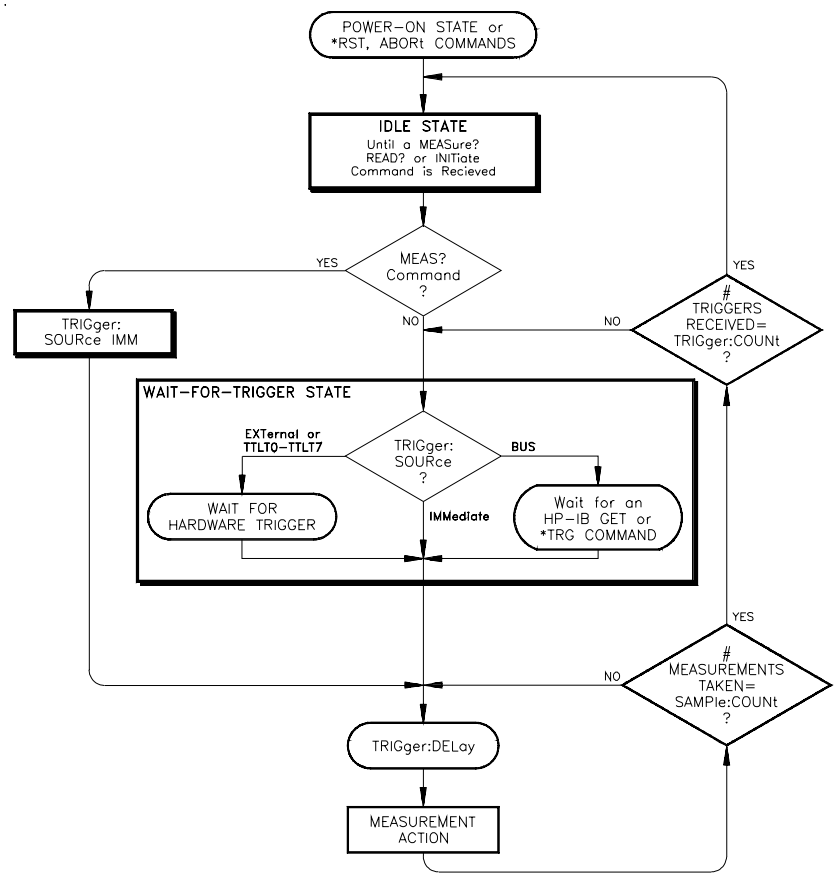


Figure 2-1. Multimeter Triggering Flow Chart

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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 MEASure command always uses an immediate trigger (see the flow chart in Figure 2-1 on page 45).

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, HP 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 >1µs, +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, HP 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.

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Checking the Trigger Source

The TRIGger:SOURce? command returns **"BUS"**, **"EXT"**, **"IMM"**, or **"TTLT*n*"** to show the present trigger source. The string is sent to the output buffer.

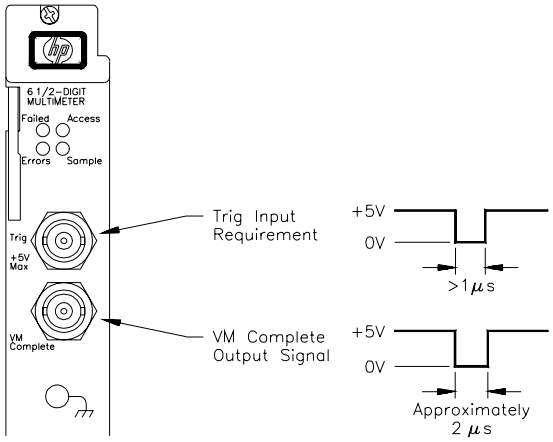
Note

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 1µs. 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 in Figure 2-1 on page 45.

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Bus Triggering

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

- Use the *TRG command from the HP-IB 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
```

Note TRIG:SOUR BUS is not implemented on B-size resource managers, such as the HP E1306A Command Module or the HP E1300A/E1301A B-size Mainframes.

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.

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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          Dimension computer array.
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 (one
                         measurement is taken per trigger).
READ?                    Place multimeter in wait-for-trigger state; make
                         measurements when external trigger is received; send
                         readings to output buffer.
timeout may occur        May require INIT, monitor the status byte for
                         completion (standard event bit 0), FETC? to transfer
                         readings to the output buffer (vs. READ?).
enter statement          Enter readings into computer.
```

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 1µs 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          Dimension computer array.
CONF:VOLT:DC             Function: DC voltag.e
TRIG:SOUR EXT            Trigger source is external BNC on multimeter front
                         panel.
TRIG:COUN  5             Multimeter will accept 5 external triggers (one
                         measurement is taken per trigger).
SAMP:COUN  4             Take 4 measurements for each trigger.
TRIG:DEL 2               Wait 2 seconds between trigger and start of first
                         measurement and each subsequent measurement till
                         sample count reached.
READ?                    Place multimeter in wait-for-trigger state; make
                         measurements when external triggers are received;
                         send readings to output buffer.
timeout may occur        May require INIT, monitor the status byte for
                         completion (standard event bit 0), FETC? to transfer
                         readings to the output buffer (vs. READ?).
enter statement          Enter readings into computer.
```


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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 in Figure 2-1 on page 45).

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

Table 2-7. Default Trigger Delays

Default Trigger Delays for DC Voltage and DC Current (all ranges):	
Integration Time	**Trigger Delay**
NPLC ≥1	1.5ms
NPLC <1	1.0ms

Default Trigger Delays for 2-Wire and 4-Wire Resistance:		
Range	**Trigger Delay (For NPLC ≥1)**	**Trigger Delay (For NPLC <1)**
100Ω	1.5ms	1.0ms
1kΩ	1.5ms	1.0ms
10kΩ	1.5ms	1.0ms
100kΩ	1.5ms	1.0ms
1MΩ	1.5ms	10ms
10MΩ	100ms	100ms
100MΩ	100ms	100ms

Default Trigger Delays for AC Voltage and AC Current (all ranges):	
AC Filter	**Trigger Delay**
3Hz - 300kHz filter	7.0sec
20Hz - 300kHz filter	1.0sec
200Hz - 300kHz filter	600ms

Default Trigger Delay for Frequency and Period:
1.0s

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Querying the Delay Time

The TRIGger:DELay? [MINimum|MAXimum] command returns one of the following numbers to the output buffer:

- The present trigger delay (1µs through 3600 seconds) if MIN or MAX is not specified.
- The minimum trigger delay available (1µs) 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          Dimension computer array.
CONF:VOLT:DC             Function: DC voltage.
TRIG:SOUR EXT            Trigger source is external BNC on multimeter front
                         panel.
SAMP:COUN 10             Specify 10 readings per trigger.
READ?                    Place multimeter in wait-for-trigger state; make
                         measurements when external trigger is received; send
                         readings to output buffer.
timeout may occur        May require INIT, monitor the status byte for
                         completion (standard event bit 0), FETC? to transfer
                         readings to the output buffer (vs. READ?).
enter statement          Enter readings into computer.
```

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.

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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, "Multimeter 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 VXI*plug&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 VXI*plug&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 VXI*plug&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:]\VXIPNP\WIN\LIB\MSC\VISA.LIB (Microsoft compiler)
[drive:]\VXIPNP\WIN\LIB\BC\VISA.LIB (Borland compiler)
Memory Model: Options | Project | Compiler | Memory Model ⇒ Large

Directory Paths: Options | Directories
Include File Paths: [drive:]\VXIPNP\WIN\INCLUDE
Library File Paths: [drive:]\VXIPNP\WIN\LIB\MSC (Microsoft)
[drive:]\VXIPNP\WIN\LIB\BC (Borland)
Example Programs: [drive:]\DSCPI\e1412 (on driver CD)
[drive:]\DSCPI\e1312 (on driver CD)

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:]\VXIPNP\WIN\INCLUDE\VISA.BAS

Note

If using Windows 3.1, change "spc" to "cps" in the Memory I/O Operations section of VISA.BAS

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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 and 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 HP 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” beginning on page 45 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.

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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:
  ±1.23456E±12 *LF or*
  ±1.234567E±12 *LF*
- Each measurement is terminated with a Line Feed (*LF*). The HP-IB End-or-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:
  ±1.23456E±12 *LF*,±1.234567E±12 *LF*,±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                  Reset the multimeter.
MEAS:VOLT:DC?         Configure dc volts (default settings) and measure
                      retrieve the reading from the multimeter.
enter statement       Enter reading into computer
```

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                  Reset the multimeter.
CONF:VOLT:DC  18      Configure for dc volts, expected input = 18V.
TRIG:SOUR  EXT        Set trigger source to external.
TRIG:COUN  3          Set trigger count to 3.
SAMP:COUN  10         Set sample count to 10 per trigger.
INIT                  Puts multimeter in wait-for-trigger state. EXTernal
                      triggers occur here to initiate measurements.
                      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.
enter statement       Enter reading into computer.
```

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 18 V; the multimeter sets a range to accommodate that input which will be 100 V). It does not initiate the measurement.

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- 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 18 V; the multimeter sets a range to accommodate that input which will be 100 V). 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.

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MEASURE4 Source Code File

Maximizing Accuracy (most accurate resolution, longer integration time)

```
*RST                          Reset the multimeter.
CONF:VOLT:DC  AUTO,MIN        Configure for dc volts, autorange, minimum
                              resolution (longest integration time).
TRIG:SOUR  EXT                Set trigger source to external.
TRIG:COUN  2                  Set trigger count to 2.
SAMP:COUN  10                 Set sample count to 10.
READ?                         Initiate measurements putting them directly
                              into output buffer; 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 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.

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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 2-2 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.

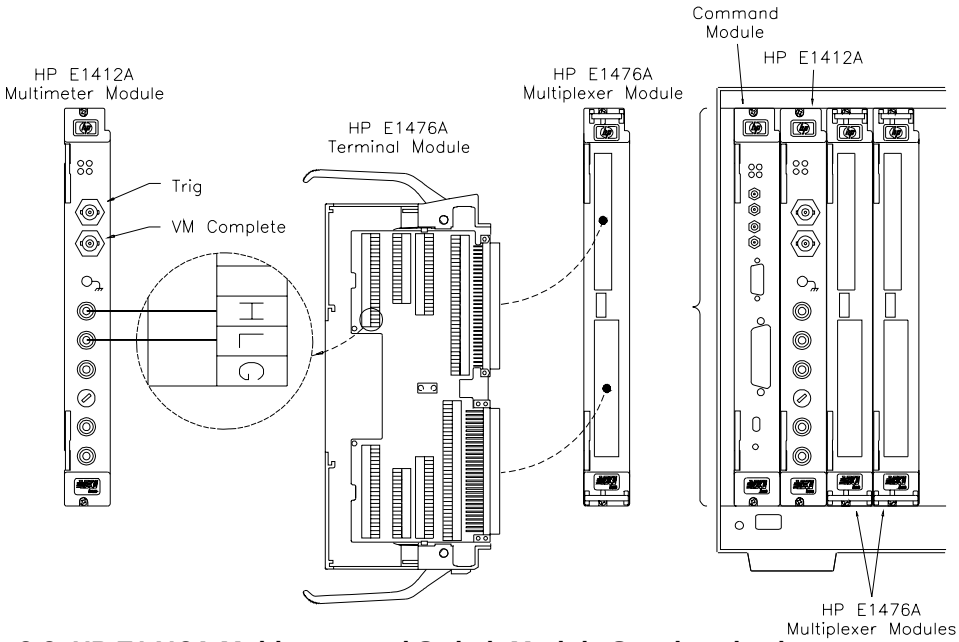


Figure 2-2. HP E1412A Multimeter and Switch Module Synchronization

Figure 2-3 shows the HP E1312A set up using external triggering. B-size command modules do not support VXIbus TTL triggers.

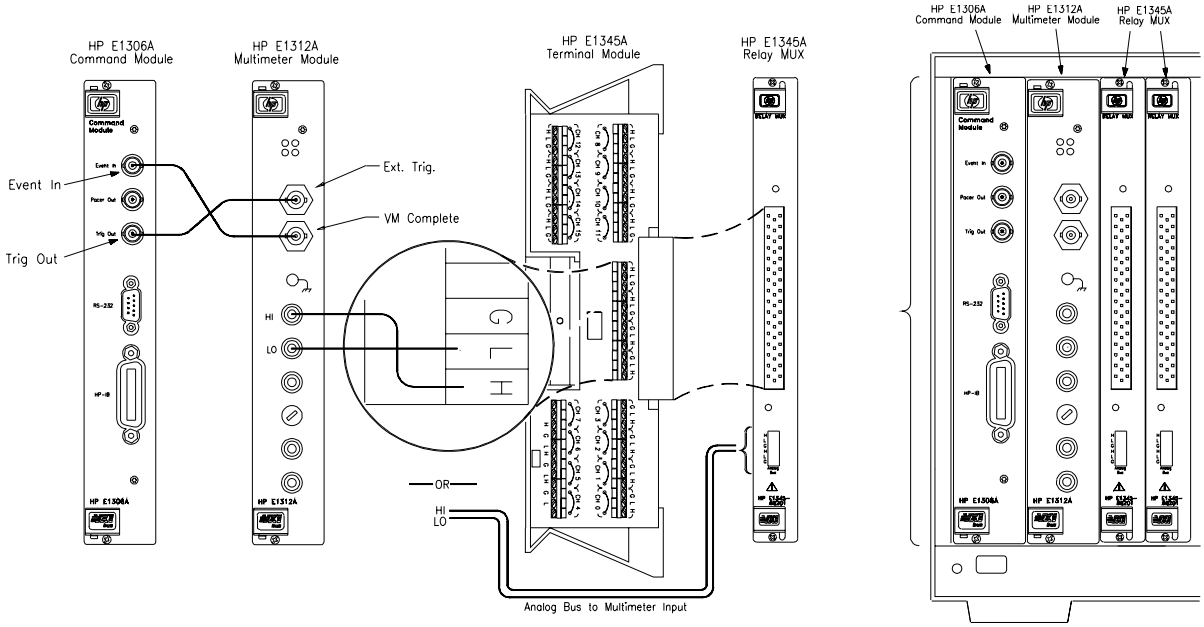


Figure 2-3. HP E1312A Multimeter and Switch Module Synchronization

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This example monitors the switch module's status system. The switch module's status system (HP E1476A) is shown in Figure 2-4. 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 2-5 for the HP E1312A/E1412A Multimeter status system.

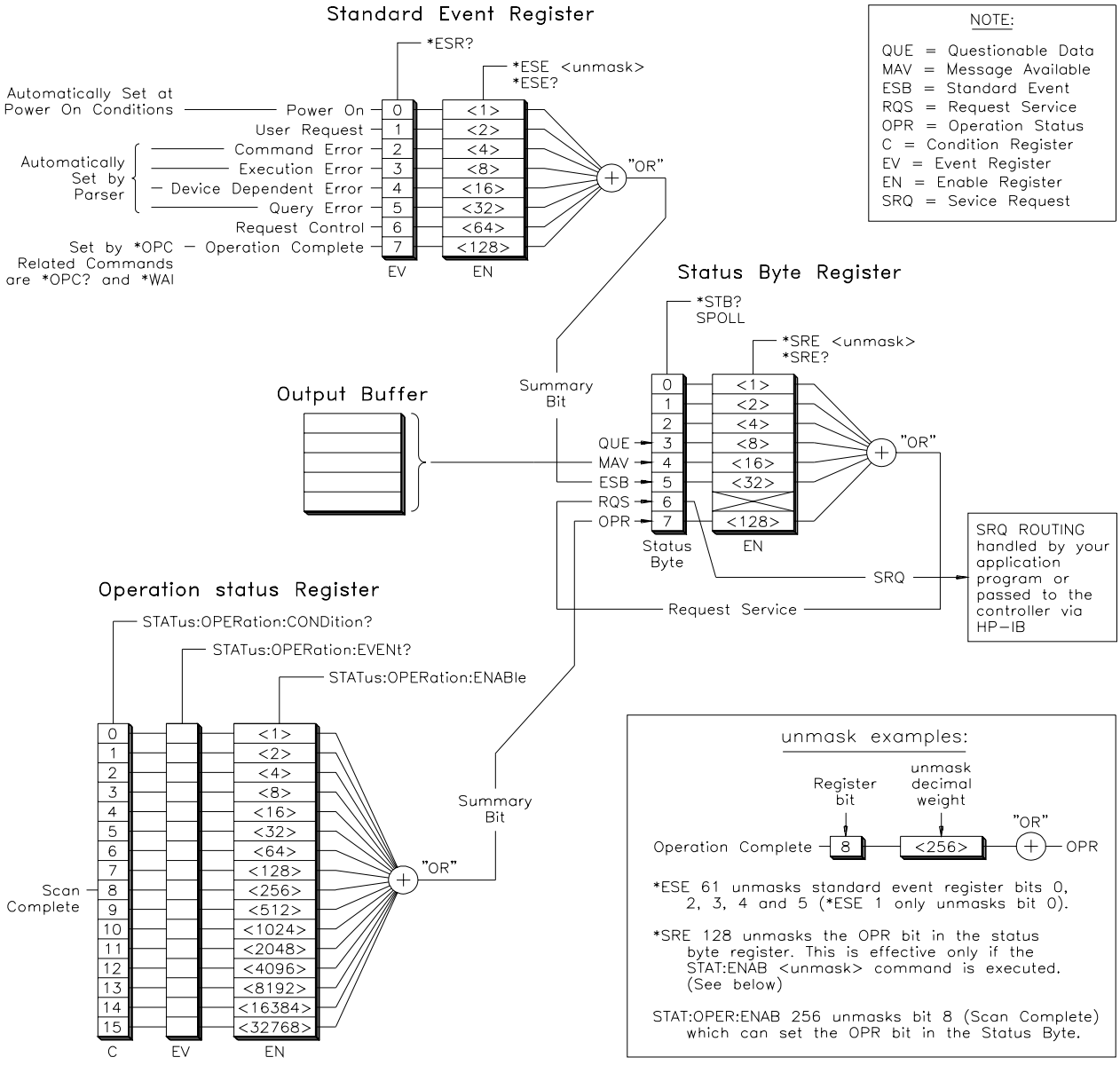


Figure 2-4. HP E1476A Switch Module Status System

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HP E1412A SCAN Source Code File

See SCAN1312 Example Program for HP E1312A Code (The HP 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 memory.*

****

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.*

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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 2-5 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 HP E1412A does not require this unmasking). The example programs illustrate this requirement.

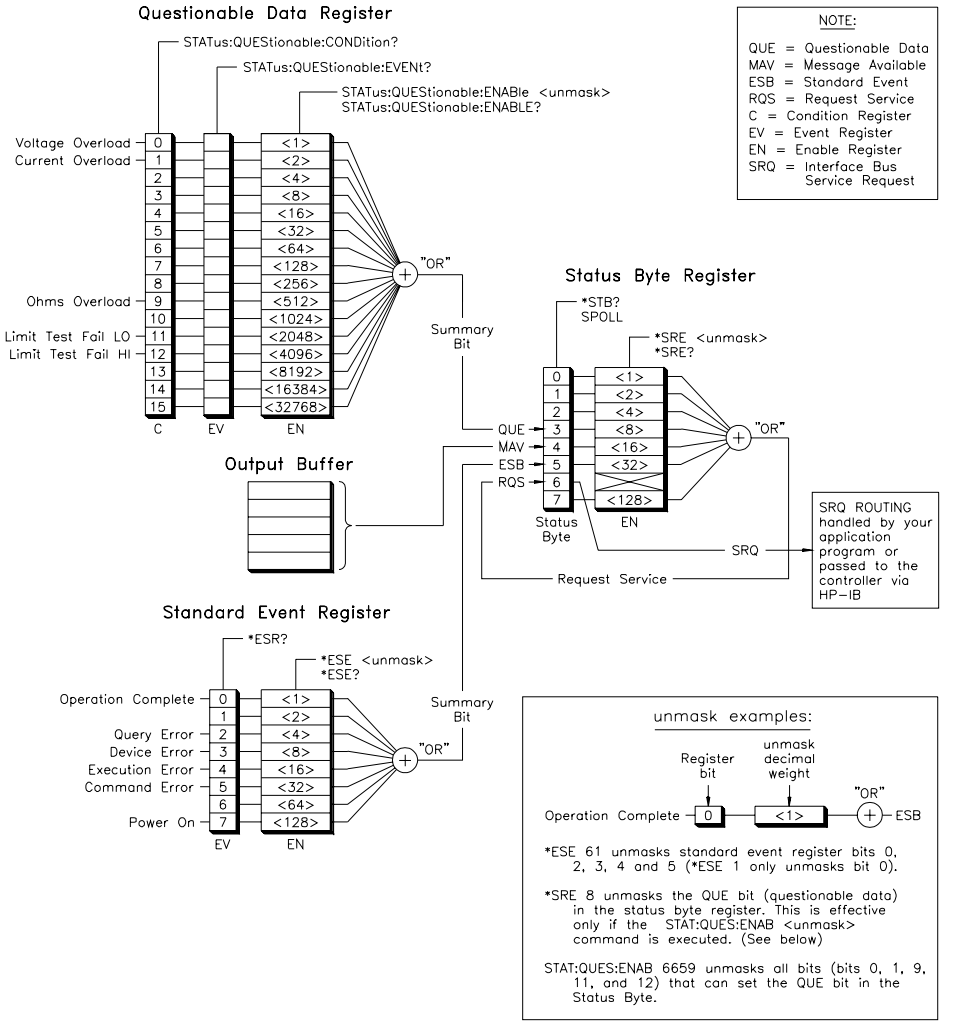


Figure 2-5. HP E1312A/E1412A Multimeter Status System

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SYNCHOPC Source Code File

This program has the multimeter take 10 measurements. The Standard Event bit (ESB) in the status byte (see Figure 2-5 on page 60) 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	*Reset the multimeter.*
*CLS	*Clear the multimeter's status registers.*
*ESE 1	*Enables bit 0 of the multimeter's standard event register.*
CONF:VOLT 15	*Configure for dc volts, expected input of 15V.*
VOLT:DC:NPLC 10	*Set number of power line cycles to 10.*
TRIG:COUN 10	*Multimeter will accept 10 triggers.*
TRIG:DEL .01	*Use a 10ms delay before each measurement.*
CALC:FUNC AVER	*Select the math function AVERage.*
CALC:STAT ON	*Enable math operations.*
*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?	*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.*

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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 2-5 on page 60) 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	*Reset the multimeter.*
*CLS	*Clear the multimeter's status registers.*
CONF:VOLT 15	*Configure for dc volts, expected input of 15V.*
VOLT:DC:NPLC 10	*Set number of power line cycles to 10.*
TRIG:COUN 10	*Multimeter will accept 10 triggers.*
TRIG:DEL .01	*Use a 10ms delay before each measurement.*
CALC:FUNC AVER	*Select a math function.*
CALC:STAT ON	*Enable the math operations.*
*SRE 16	*Required by the E1312A to detect MAV bit in SPOLL.*
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?	*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.*

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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.
```


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HP VEE Programming Example

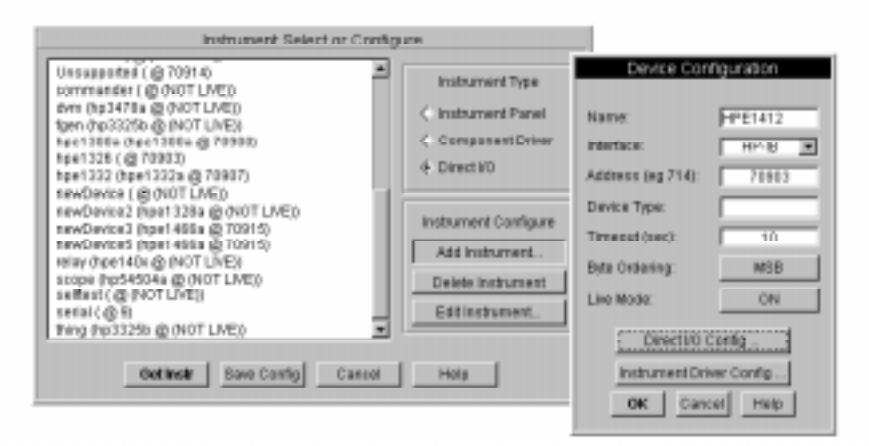
HP VEE is HP's *Visual Engineering Environment*, a graphical programming language for creating test systems and solving engineering problems. This section provides an instrument control example using the "Direct I/O" feature of HP VEE. Direct I/O allows you to directly specify messages to be sent to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



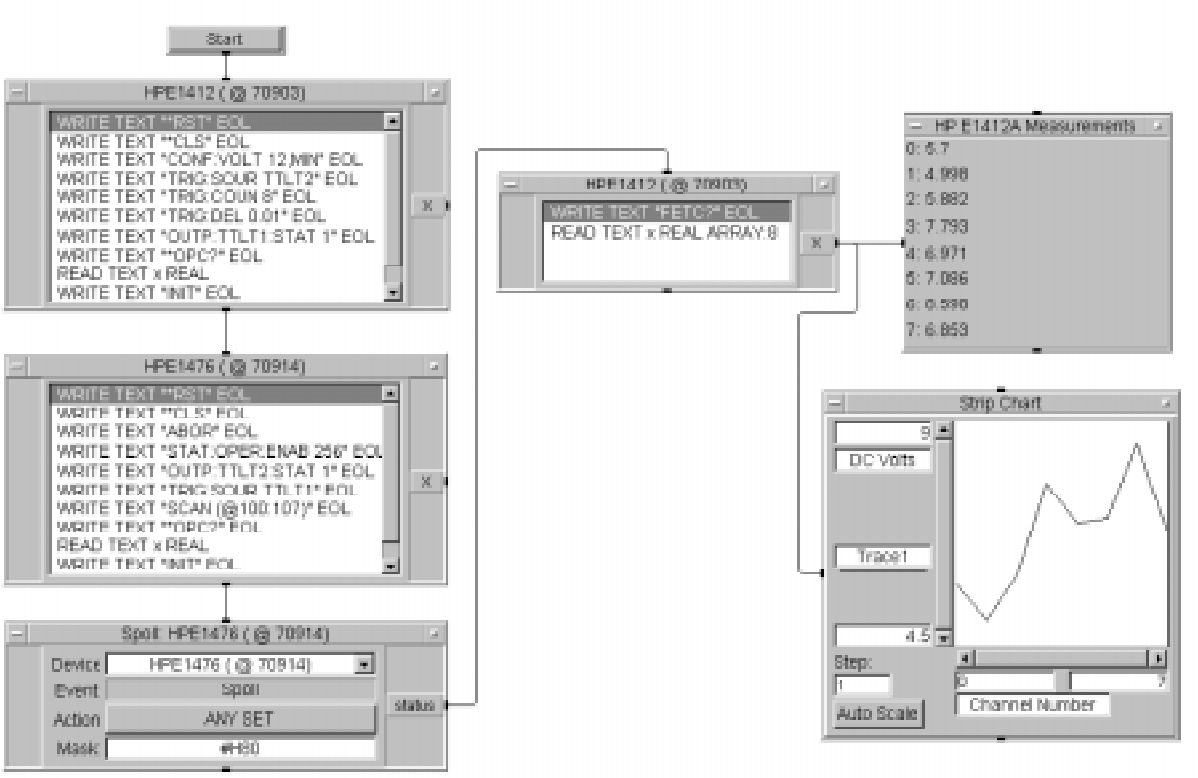
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Program Description

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.



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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*
- *HP VEE The Most Productive Language for Test and Measurement*
- *HP VEE Visual Engineering Environment Technical Data*

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Chapter 3
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.

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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"
```


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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
```


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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 µV	10 µV
1 V	1.2 V	300 nV	1 µV	3 µV	10 µV	100 µV
10 V	12 V	3 µV	10 µV	30 µV	100 µV	1 mV
100 V	120 V	30 µV	100 µV	300 µV	1 mV	10 mV
300 V	300 V	300 µV	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 µA
100 mA	120 mA	30 nA	100 nA	300 nA	1 µA	10 µA
1 A	1.2 A	3 nA	1 µA	3 µA	10 µA	100 µA
3 A	3 A	900 nA	3 µA	9 µA	30 µA	300 µA

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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
100 Ω	120 Ω	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	1 Ω
100 kΩ	120 kΩ	30 mΩ	100 mΩ	300 mΩ	1 Ω	10 Ω
1 MΩ	1.2 MΩ	300 mΩ	1 Ω	3 Ω	10 Ω	100 Ω
10 MΩ	12 MΩ	3 Ω	10 Ω	30 Ω	100 Ω	1 kΩ
100 MΩ	100 MΩ	30 Ω	100 Ω	300 Ω	1 kΩ	10 kΩ

Table 3-4. AC Voltage: Range versus Resolution

Resolution Choices versus Range					
RANGE	100 mV	1 V	10 V	100 V	300 V
MIN	100 nV	1 µV	10 µV	100 µV	1 mV
power-on and *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	1 A	3 A
MIN	1 µA	3 µA
power-on and *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 HP E1412A 6½-Digit Multimeters. Commands are listed alphabetically by subsystem and also within each subsystem.

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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          Function: DC voltage.
TRIG:SOUR BUS         Trigger source is BUS trigger.
INIT                  Place multimeter in wait-for-trigger state.
ABOR                  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.

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There are five math operations available (AVERage, DB, DBM, LIMit, and NULL), 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.*

Valid Math/Measurement Function Combinations

	Measurements								
	DCV	**ACV**	**DCI**	**ACI**	**Ω2W**	**Ω4W**	**Freq**	**Per**	**Ratio**
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
NULL	X	X	X	X	X	X	X	X	

Subsystem Syntax

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


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: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:AVERage:COUNt? reads the number of readings taken since AVERage was enabled (CALC:FUNC AVER and CALC:STAT ON commands). The count value is cleared when AVERage is enabled by the CALC:FUNC AVER and CALC:STAT ON commands, when 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.
```

: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: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.
```


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: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
CALC:DB:REF 60
CALC:FUNC DB
```

Turn on the math operation.
Sets DB reference to 60 dBm.
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.

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:FUNCtion

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

- 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?.
- 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.
- The LIMit parameter enables pass/fail testing on the upper and lower limits you specify using the LIMit:UPPer and LIMit:LOWer commands.
- NULL measurements (also called *relative* measurements) provide a reading which is the difference between a stored null value and the input signal.
- See the section titled “Math Operations” beginning on page 41, 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          Set calculate function to limit.
CALC:LIM:LOWer         Set the lower limit to test against.
CALC:LIM:UPPer         Set the upper limit to test against.
CALC:STATe ON          Enable the limit math operation.
```

:FUNCtion?

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

Example

Query the Calculate Math Function

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


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: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          Turn on the math operation.
CALC:LIM:LOW 1000     Set the lower 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: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 ±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.
```


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: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 ±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" beginning on page 41 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.
```

: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            The selected or default math function is
                        enabled.
```

: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.
```


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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 command).

Subsystem Syntax

```
CALibration
    :COUNt?
    :LFRequency 50|60|400
    :LFRequency? [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

Query the Number of Occurrences of Point Calibrations

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

:LFRequency

CALibration:LFRequency 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

Set the Line Frequency to 50 Hz

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


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:LFRequency?

CALibration:LFRequency? 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 CAL: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).
```


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: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
<*code*>	discrete	up to 12 characters set by CAL: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.

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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 the 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.

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:ZERO:AUTO

CALibrate:ZERO:AUTO ***<mode>*** enables or disables the autozero mode. Autozero 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.

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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.

Example

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.
```


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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) Trigger count (TRIG:COUN) Trigger delay (TRIG:DEL) Trigger source (TRIG:SOUR) VM Complete routing (OUTP:TTLT<*n*>:STAT)	1 sample 1 trigger AUTO (Automatic delay) IMM (trigger signal is always true) 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: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]]
```

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

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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	1µA
CURR:AC	1A	10µA
FREQ	FREQ:RANG = 3Hz VOLT:RANG = 10V	30µHz
FRES	1kΩ	1mΩ
PER	PER:RANG = 0.333sec VOLT:RANG = 10V	3.33µseconds
RES	1kΩ	1mΩ
VOLT[:DC]	10V	10µV
VOLT[:DC]:RAT	10V	10µV
VOLT:AC	10V	100µV

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: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
<*range*>	numeric	1A|3A| MIN|MAX|DEF|AUTO	A
<*resolution*>	numeric	*resolution*| | 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*: 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 3-5 on page 71 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.
```


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: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
<*range*>	numeric	10mA|100mA|1 A|3 A| MIN|MAX|DEF|AUTO	A
<*resolution*>	numeric	*resolution*| 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 3-1 on page 70 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: 0.3mA.*
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.*

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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
<*range*>	numeric	3E+00	Hz
<*resolution*>	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

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: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
<*range*>	numeric	100Ω|1kΩ|10kΩ|100kΩ|1MΩ |10MΩ|100MΩ| MIN|MAX|DEF|AUTO	ohms
<*resolution*>	numeric	*resolution*|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 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: 10kΩ; 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.*

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: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
<*range*>	numeric	3.33E-01	Sec
<*resolution*>	numeric	3.33E-05| 3.33E-06 | 3.33E-07	Sec

Comments

- The period function uses one "range" for all inputs between 0.33 seconds and 3.3µSec. 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

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: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
<*range*>	numeric	100Ω|1kΩ|10kΩ| 100kΩ|1MΩ| 10MΩ|100MΩ| MIN|MAX|DEF|AUTO	ohms
<*resolution*>	numeric	*resolution*|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: 1kΩ;
                        MAX resolution: 0.1Ω.
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.
```


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: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
<*range*>	numeric	0.1V|1V|10V|100V|300V| MIN|MAX|DEF|AUTO	volts
<*resolution*>	numeric	*resolution*|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 3-4 on page 71 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 µA.
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.
```


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[: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
<range>	numeric	100mV|1V|10V|100V|300V| MIN|MAX|DEF|AUTO	volts
<resolution>	numeric	*resolution*|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 = 100 mV; MAX = 300 V.
  For *resolution*: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range. See Table 3-1 on page 70 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.
```


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[: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.

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

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 10 V range only. Maximum voltage you can apply to the "Sense" terminals is 10 V.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*range*> (HI-LO input)	numeric	100mV|1V|10V|100V|300V| MIN|MAX|DEF|AUTO	volts
<*resolution*>	numeric	*resolution*|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 = 100 mV; MAX = 300 V.
  For *resolution*: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.

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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: 1kΩ;
                                MAX resolution: 100mΩ.
CONF?                           Query configuration.
enter statement                 Enter string into computer.
```

String Returned:

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


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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.

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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 do not 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:

  ±1.23456E±12 *LF or*
  ±1.234567E±12 *LF*

- Each measurement is terminated with a Line Feed (*LF*). The HP-IB End-or-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:

  ±1.23456E±12 *LF,*±1.234567E±12 *LF,*±1.23456E±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                 Dimension computer array to store
                                100 readings.
CONF:VOLT:DC                    Function: DC voltage.
SAMP:COUN 100                   100 readings per trigger.
INIT                            Store readings in internal memory; trigger
                                source is IMMediate by default.
FETC?                           Place readings in output buffer.
enter statement                 Enter readings into computer.
```


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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" beginning on page 45 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          Function: DC voltage.
TRIG:SOUR EXT         Trigger source is the external BNC on the
                      multimeter.
INIT                  Place multimeter in wait-for-trigger state;
                      store readings in internal memory when ext
                      trigger is received.
FETC?                 Place readings in output buffer.
INIT                  You must re-initiate the wait-for-trigger state
                      after each trigger cycle.
```


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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 MΩ 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
<*mode*>	boolean	OFF|0|ON|1	None

mode **(Impedance)**	**AUTO OFF (10 MΩ)**	**AUTO ON (>10 GΩ)**
Range for Impedance	all ranges	100 mV, 1 V and 10 V (other ranges are at 10 MΩ)

Example

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

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

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

Query 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.
```


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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) Trigger count (TRIG:COUN) Trigger delay (TRIG:DEL) Trigger source (TRIG:SOUR)	1 sample 1 trigger AUTO (Automatic delay) IMM (trigger signal is always true)
Math function (CALCulate:STATe)	OFF

Subsystem Syntax

```
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]]
```


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: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
<*range*>	numeric	1A|3A| MIN|MAX|DEF|AUTO	A
<*resolution*>	numeric	*resolution*| | 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 Table 3-5 on page 71 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.

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: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
<*range*>	numeric	10mA|100mA|1 A|3 A| MIN|MAX|DEF|AUTO	A
<*resolution*>	numeric	*resolution*| 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 = 3 A
  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-05A.

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: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
<*range*>	numeric	3E+00	Hz
<*resolution*>	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 module reset (*RST)	3E+00	3E+05

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: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
<*range*>	numeric	100Ω|1kΩ|10kΩ|100kΩ|1MΩ |10MΩ|100MΩ| MIN|MAX|DEF|AUTO	ohms
<*resolution*>	numeric	*resolution*|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 =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 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: 10kW; MAX resolution: 1Ω.

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: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
<*range*>	numeric	3.33E-01	Sec
<*resolution*>	numeric	3.33E-05| 3.33E-06 | 3.33E-07	Sec

Comments

- The period function uses one "range" for all inputs between 0.33 seconds and 3.3µSec. 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).

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

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: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
<*range*>	numeric	100Ω|1kΩ|10kΩ| 100kΩ|1MΩ| 10MΩ|100MΩ| MIN|MAX|DEF|AUTO	ohms
<*resolution*>	numeric	*resolution*|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 = 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 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: 10kΩ; MAX resolution: 1.0Ω.

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: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
<*range*>	numeric	0.1V|1V|10V|100V|300V| MIN|MAX|DEF|AUTO	volts
<*resolution*>	numeric	*resolution*|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. See Table 3-4 on page 71 for valid resolution choices for each 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*µV.

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[: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
<*range*>	numeric	100mV|1V|10V|100V|300V| MIN|MAX|DEF|AUTO	volts
<*resolution*>	numeric	*resolution*|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 = 100 mV; MAX = 300 V.
  For *resolution*: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range. See Table 3-1 on page 70 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 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

```
MEAS:VOLT:DC? 0.825,MAX
```

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

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[: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 10 V.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*range*>	numeric	100mV|1V|10V|100V|300V| MIN|MAX|DEF|AUTO	volts
<*resolution*>	numeric	*resolution*|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 = 100 mV; MAX = 300 V.
  For *resolution*: MIN selects the best resolution (the smallest value) for the selected range. MAX selects the worst resolution (the largest value) for the selected range.
- To select 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: 1 V; MAX resolution: 100 µV.

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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
<*n*>	discrete	0|1|2|3|4|5|6|7	none
<*mode*>	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
320ms (50Hz)	350ms	350µs
267ms (60Hz)	370µs	370µs
20ms (50Hz)	20.5ms	370µs
16.7ms (60Hz)	17.2ms	390µs
2.5ms (400Hz)	3.1ms	430µs
100µs	520µs	250µs
10µs		70µs

- 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:TTLT*n* OFF

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Example Route 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 Query 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.
```


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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-or-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

Transfer 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.
```


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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
<*number*>	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:COUN 1

Example

Set the Sample Count

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


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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 Query 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.
```


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The [SENSe:] command subsystem is most commonly used with CONFigure to change specific “low-level” measurement parameters. [SENSe:] enables you to change the following measurement parameters, predefined by the CONFigure command, without completely reconfiguring the multimeter.

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

Subsystem Syntax

```
[SENSe:]
    FUNCtion “CURRent:AC”
    FUNCtion “CURRent[:DC]”
    FUNCtion “FREQuency”
    FUNCtion “FRESistance”
    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]
        :VOLTage:RANGe <range>|MIN|MAX
        :VOLTage:RANGe? [MIN|MAX]
        :VOLTage:RANGe:AUTO OFF|ON
        :VOLTage:RANGe:AUTO?
```


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


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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
<*function*>	discrete	:CURRent:AC| :CURRent[:DC]| :FREQuency| :FRESistance| :PERiod| :RESistance| :VOLTage:AC| :VOLTage[:DC]| :VOLTage[:DC]:RATio	none

Comments

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

Example

Change Measurement Function

```
CONF:VOLT                 Function: DC voltage.
FUNC "FRES"               Set function to 4-wire resistance.
READ?                     Place multimeter in wait-for-trigger state and
                          make measurement; send reading to output
                          buffer.
enter statement           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

Query the Measurement Function

```
FUNC "FRES"               Function: 4-wire ohms.
FUNC?                     Query multimeter to return selected function.
enter statement           Enter quoted string into computer.
```


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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
<*range*>	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

Query the AC Current Measurement Range

```
CURR:AC:RANG 3          Select 3A range.
CURR:AC:RANG?           Query multimeter to return the present range.
enter statement         Enter value into computer.
```


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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
<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 CURRent:AC:RANGe, autoranging is turned OFF.
- **Related Commands:** CONFigure, :DC:RANGe, RESistance:RANGe
- ***RST Condition:** CURR:AC:RANG:AUTO ON

Example

Disable 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

Query 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.
```


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CURRent:AC:RESolution

[SENSe:]CURRent:AC:RESolution <*resolution*> selects the resolution for AC current measurements. See Table 3-5 on page 71.

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: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

Query the AC Current Measurement Range

```
CURR:AC:RES 1E-4          Select 100 µA resolution
CURR:AC:RES?              Query multimeter to return the present
                          resolution.
enter statement           Enter value into computer.
```


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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
<*number*>	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 (60Hz) or 2 seconds (50Hz).
- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7ms (60Hz 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:LFRequency
- ***RST Condition:** CURR:DC:APER 0.166667 seconds (60Hz) or CURR:DC:APER 0.20000 (50Hz)

Example **Set an Aperture Time of 16.7ms**

```
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 @ 60Hz; 2 s @ 50Hz) if MAX is specified.

Example **Query the Aperture Time**

```
CURR:APER 167E-03           Aperture time is 167ms.
CURR:APER?                  Query multimeter to return aperture time.
enter statement             Enter value into computer.
```


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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
<*number*>	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 CURR: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

Set the DC Current Integration Time in PLCs

```
CURR: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

Query the DC Current Integration Time

```
CURR:DC:NPLC 100          Integration time is 100 PLCs.
CURR:DC:NPLC?             Query multimeter to return integration time.
enter statement           Enter value into computer.
```


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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
<*range*>	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.
- MIN selects the minimum range available with the CURRent:DC:RANGe command: 10mA. MAX selects the maximum range available: 3A.
- 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

Set 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 100mA range, 100mA is the range returned.
- The minimum current range available (10mA) if MIN is specified.
- The maximum current range available (3A) if MAX is specified.

Example

Query the DC Current Measurement Range

```
CURR:DC:RANG 3          Select 3A range.
CURR:DC:RANG?           Query multimeter to return the present range.
enter statement         Enter value into computer.
```


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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
<*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 CURRent:DC:RANGe, autoranging is turned OFF.
- **Related Commands:** CONFigure, :AC:RANGe, RESistance:RANGe
- ***RST Condition:** CURR:DC:RANG:AUTO ON

Example

Disable 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

Query 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.
```


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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 10mA resolution, 10mA is the resolution returned.
- The minimum current resolution available (1µA) if MIN is specified.
- The maximum current resolution available (100µA) if MAX is specified.

Example

Query 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.
```


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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 20Hz filter.
-- Specifying a parameter less than 20 but greater than 3 selects the 3Hz filter.
-- Specifying a parameter greater than 200 but not greater than 300E+03 (300kHz) selects the 200Hz filter.
-- Any value greater than 300kHz will cause a "Data out of range" error. The maximum range for all three filters is 300kHz. 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.

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

- The ac filter selection is stored in volatile memory and returns to the 20Hz filter (medium) when power is removed or after a module reset. The upper limit on all three filters is 300kHz.
- The slow filter is 3Hz, the medium filter is 20Hz and the fast filter is 200Hz.
- The CONFigure and MEASure commands select the 20Hz filter.
- ***RST Condition**: DET:BAND 20 (medium filter)

Example

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

```
DET:BAND 200                    Selects the fast filter.
```


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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 Query the Detector Bandwidth

```
DET:BAND 200
DET:BAND?
```

Select 200Hz bandwidth (fast filter).
Query multimeter to return the detector bandwidth setting.

FREQuency:APERture

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

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

Comments

- Specify 0.01 (10ms) for 4½-digits, 0.1 (default, 100ms) for 5½-digits or 1 second for 6½-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**).

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FREQuency:VOLTage:RANGe

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

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*range*>	numeric	100mV|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 :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 100 V

```
FREQ:VOLT:RANG 100          Voltage range for frequency measurements is 100 V.
```

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

Query the Measurement Range

```
FREQ:VOLT:RANG 10           Select 10 V range.
FREQ:VOLT:RANG?             Query the present range.
enter statement             Enter value into computer.
```


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

Example

Disable 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

Query 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.
```


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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
<*number*>	numeric	0.333ms|3.33ms|16.7ms| 167ms|1.67s|MIN|MAX	seconds

Comments

- MIN sets the aperture time to 0.333ms. MAX sets the aperture time to 1.66667 seconds (60Hz) or 2 seconds (50Hz).
- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7ms (60Hz 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:LFRequency
- ***RST Condition:** FRES:APER 0.166667 seconds (60Hz) or FRES:APER 0.20000 (50Hz)

Example **Set an Aperture Time of 16.7ms**

```
FRES:APER 16.7E-03          Aperture time is 16.7ms.
```

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 (.333ms) if MIN is specified.
- The maximum aperture time available (1.67s @ 60Hz; 2s @ 50Hz) if MAX is specified.

Example **Query the Aperture Time**

```
FRES:APER 167E-03           Aperture time is 167ms.
FRES:APER?                  Query multimeter to return aperture time.
enter statement             Enter value into computer.
```


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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
<*number*>	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 Set 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 Query 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.
```


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FRESistance:RANGe

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

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*range*>	numeric	100Ω|1kΩ|10kΩ|100kΩ|1MΩ |10MΩ|100MΩ|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: 100MΩ.
- 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 1kΩ (1E+03)

Example

Set Four-Wire Resistance Range to 10MΩ

```
FRES:RANG 1E+07          4-wire resistance range is 10MΩ.
```

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 (100Ω) if MIN is specified.
- The maximum resistance range available (100MΩ) if MAX is specified.

Example

Query the Measurement Range

```
FRES:RANG 100            Select 100Ω range.
FRES:RANG?               Query multimeter to return the present range.
enter statement          Enter value into computer.
```


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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
<*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 FRESistance:RANGe, autoranging is turned OFF.

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

Query the Autorange Mode

```
FRES:RANG:AUTO OFF         Disable autorange.
FRES:RANG:AUTO?            Query multimeter to return autorange mode.
enter statement            Enter value into computer.
```


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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 1mΩ (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

Query the Resolution

```
FRES:RES 0.3E-03          Set resolution to 0.3mΩ.
FRES:RES?                 Query multimeter to return the present
                          resolution.
enter statement           Enter value into computer.
```


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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
<*time*>	numeric	10ms|100ms|MIN|MAX	seconds

Comments

- MINimum sets the aperture time to 10ms. MAXimum sets the aperture time to 1 second.
- The fastest aperture time available when autoranging is 100ms. In order to specify an aperture time of 10ms, you must select a fixed range.
- Setting the aperture time also sets the resolution. Aperture time of 0.01 sets resolution at 4½-digits, 0.1 sets 5½-digits and 1 sets 6½-digits.
- ***RST Condition:** 0.1 (100ms)

Example

Set 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

Query the Aperture Time

```
PER:APER MIN                  Aperture time is 10ms.
PER:APER?                     Query multimeter to return aperture time.
enter statement               Enter value into computer.
```


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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	100mV|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 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 100 V.
```

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.
```


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

Example **Disable 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 **Query 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.
```


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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
<*number*>	numeric	0.333ms|3.33ms|16.7ms| 167ms|1.67s|MIN|MAX	seconds

Comments

- MIN sets the aperture time to 0.333ms. MAX sets the aperture time to 1.66667 seconds (60Hz) or 2 seconds (50Hz).
- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7ms (60Hz line frequency) sets an integration time of 1 PLC. The corresponding resolution depends on the function and range you select.
- The RES:APER command overrides the results of previously executed RES:NPLC and RESistance:RESolution 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:LFRequency
- ***RST Condition:** RES:APER 0.166667 seconds (60Hz) or RES:APER 0.20000 (50Hz)

Example **Set an Aperture Time of 16.7ms**

```
RES:APER 16.7E-03          Aperture time is 16.7ms.
```

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 (1.67s @ 60Hz; 2s @ 50Hz) if MAX is specified.

Example **Query the Aperture Time**

```
RES:APER 167E-03           Aperture time is 167ms.
RES:APER?                  Query multimeter to return aperture time.
enter statement            Enter value into computer.
```


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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
<*number*>	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 **Set 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 **Query 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.
```


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RESistance:RANGe

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

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*range*>	numeric	100Ω|1kΩ|10kΩ|100kΩ|1MΩ |10MΩ|100MΩ|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 RESistance:RANGe command: 100Ω. MAX selects the maximum range available: 100MΩ.
- You must select a range using RESistance:RANGe before specifying resolution. Also, in order to specify an aperture time of 10ms, 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 1kΩ

Example

Change the Range

```
CONF:RES 1320,MAX      Function: 2-wire ohms;
                       range selected: 10kΩ; MAX resolution: 1Ω.
RES:RANG 220           Range selected: 1kΩ; 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, 1kΩ is the range returned.
- The minimum resistance range available (100Ω) if MIN is specified.
- The maximum resistance range available (100MΩ) if MAX is specified.

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Example Query 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
<*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 RESistance:RANGe, autoranging is turned OFF.
- **Related Commands:** CONFigure, RESistance:RANGe
- ***RST Condition:** RES:RANG:AUTO ON

Example Disable 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 Query the Autorange Mode

```
RES:RANG:AUTO OFF     Disable autorange.
RES:RANG:AUTO?        Query multimeter to return autorange mode.
enter statement       Enter value into computer.
```


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RESistance:RESolution

[SENSe:]RESistance:RESolution <*resolution*> selects the resolution for 2-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 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.
- 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

Change the Resolution

```
CONF:RES 1560,MAX          Function: 2-wire ohms; range selected: 10kΩ;
                           MAX resolution: 1Ω.
RES:RES 10E-03             Set resolution to 10mΩ.
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.

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Example Query the Resolution

```
RES:RES 10E-03          Set resolution to 10 mΩ.
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
<*range*>	numeric	100mV|1V|10V|100V|300V| 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.
- MIN selects the minimum range available with the VOLTage:AC:RANGe command: 100 mV. MAX selects the maximum range available: 300 V.
- 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 Change 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 10 V range, 10 V 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 (300 V) if MAX is specified.

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Example Query the Measurement Range

```
VOLT:AC:RANG 10          Select 10V range.
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 10µs, 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 Disable 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 Query 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.
```


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VOLTage:AC:RESolution

[SENSe:]VOLTage:AC:RESolution <*resolution*> selects the resolution for AC voltage measurements. See Table 3-4 on page 71 to avoid a settings conflict error when specifying resolution.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*resolution*>	numeric	*resolution*|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 Change 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: 100µV.
VOLT:AC:RES 10E-06         Set resolution to 10µV.
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 Query the Resolution

```
VOLT:AC:RANG 100E-03       Set range to 0.1 volts.
VOLT:AC:RES 1.0E-07        Set resolution to 0.1µV.
VOLT:AC:RES?               Query multimeter to return the present
                           resolution.
enter statement            Enter value into computer.
```


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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
<*number*>	numeric	0.333ms|3.33ms|16.7ms| 167ms|1.67s|MIN|MAX	seconds

Comments

- MIN sets the aperture time to 0.333ms. MAX sets the aperture time to 1.66667 seconds (60Hz) or 2 seconds (50Hz).
- Setting the aperture time also sets the integration time in power line cycles (PLCs) and the resolution. For example, an aperture time of 16.7ms (60Hz 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:LFRequency
- ***RST Condition:** VOLT:APER 0.166667 seconds (60Hz) or VOLT:APER 0.20000 (50Hz)

Example **Set an Aperture Time of 16.7ms**

```
VOLT:APER 16.7E-03          Aperture time is 16.7ms.
```

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 (.333ms) if MIN is specified.
- The maximum aperture time available (1.67s @ 60Hz; 2 s @ 50Hz) if MAX is specified.

Example **Query the Aperture Time**

```
VOLT:APER 167E-03           Aperture time is 167ms.
VOLT:APER?                  Query multimeter to return aperture time.
enter statement             Enter value into computer.
```


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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 **Set 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 **Query the Integration Time**

```
VOLT:DC:NPLC 100                Integration time is 100 PLCs.
VOLT:DC:NPLC?                   Query multimeter to return integration time.
enter statement                 Enter value into computer.
```


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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
<*range*>	numeric	100mV|1V|10V|100V|300V| 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.
- MIN selects the minimum range available with the VOLTage:DC:RANGe command: 100mV. 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 Change 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 (100mV) if MIN is specified.
- The maximum voltage range available with the VOLTage:DC:RANGe command (300V) if MAX is specified.

Example Query 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.
```


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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 10µs, 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 **Disable 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 **Query 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.
```


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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
<*resolution*>	numeric	*resolution*|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

Change 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 0.3µV.
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.

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Example Query 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. Autozero 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 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.
- 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?             Queries the autozero mode.
enter statement        Enter response into computer.
```


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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
        :CONDition?
        :ENABle <unmask>
        :ENABle?
        [:EVENt]?
```

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: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.

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: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.

: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.

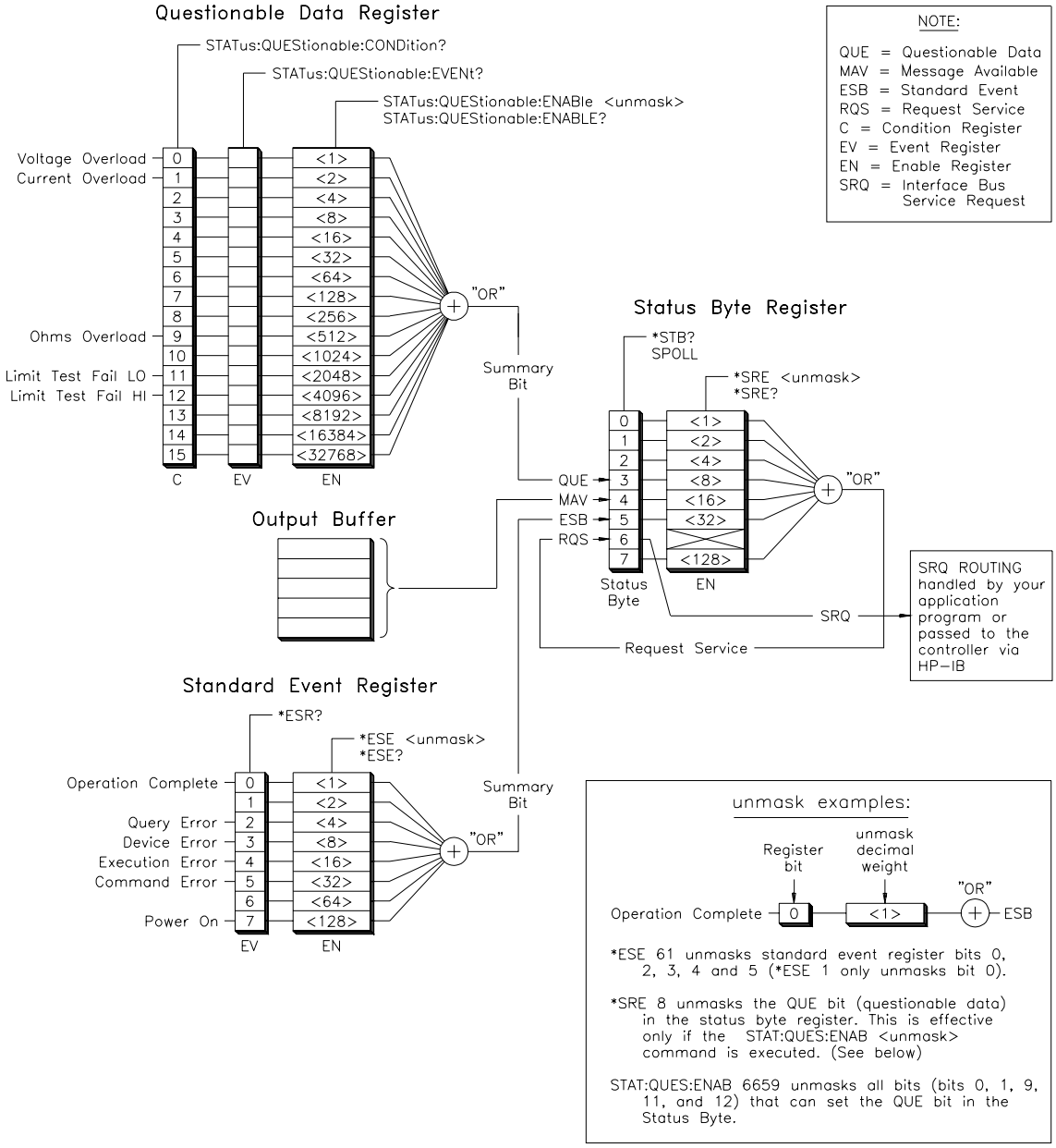


Figure 3-1. HP E1312A/E1412A Status System Register Diagram

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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?                    Query the error queue.
enter statement              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.

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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
<*number*>	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:COUN 1

Example

Set the Trigger Count

```
CONF:VOLT:DC                 Function: DC voltage.
TRIG:SOUR  EXT               Trigger source is "Trig" BNC on multimeter
                             front panel.
TRIG:COUN 10                 Multimeter will accept 10 external triggers
                             (one measurement is taken with each trigger).
READ?                        Place multimeter in wait-for-trigger state;
                             make measurement when external trigger is
                             received; send readings to output buffer.
enter statement              Enter readings into computer.
```


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: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 Query the Trigger Count

```
TRIG:COUN 10          Multimeter will accept 10 triggers.
TRIG:COUN?            Query multimeter to return trigger count.
enter statement       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 page 45 for a triggering process diagram.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*seconds*>	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 TRIGger:DELay:AUTO command on page 158).
- ***RST Condition:** TRIGger:DELay:AUTO ON

Example Set the Trigger Delay

```
TRIG:DEL .002         Wait 2ms between trigger and start of
                      measurement.
```


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: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

Query the Trigger Delay

```
TRIG:DEL  .002          Wait 2ms 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
<*mode*>	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

Disable Automatic Trigger Delay

```
TRIG:DEL:AUTO OFF       Disable automatic trigger delay.
```


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Default Trigger Delays for DC Voltage and DC Current (all ranges):	
Integration Time	**Trigger Delay**
NPLC ≥1	1.5ms
NPLC <1	1.0ms

Default Trigger Delays for 2-Wire and 4-Wire Resistance:		
Range	**Trigger Delay (For NPLC ≥1)**	**Trigger Delay (For NPLC <1)**
100Ω	1.5ms	1.0ms
1kΩ	1.5ms	1.0ms
10kΩ	1.5ms	1.0ms
100kΩ	1.5ms	1.0ms
1MΩ	1.5ms	10ms
10MΩ	100ms	100ms
100MΩ	100ms	100ms

Default Trigger Delays for AC Voltage and AC Current (all ranges):	
AC Filter	**Trigger Delay**
3Hz - 300kHz filter (Slow)	7.0sec
20Hz - 300kHz filter (Medium)	1.0sec
200Hz - 300kHz filter (Fast)	600ms

Default Trigger Delay for Frequency and Period:
1.0s

: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 Query 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.
```


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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 ±5V TTL input signal).
- **IMMediate:** The trigger system is always true.
- **TTLTrg0 - TTLTrg7:** Trigger source is VXIbus trigger line 0 through 7. NOTE: B-size controllers do not support VXIbus TTL triggers (e.g., HP E1306A Command Module, HP E1300/E1301A B-Size Mainframes).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*source*>	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 ±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

Set 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.
```


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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 Query 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.*

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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” beginning on page 189 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 and 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.

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*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 unmasks 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).

***ESE?** returns the current enable unmask value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*unmask*>	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.
```


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*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

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*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 unmasks 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).

***SRE?** returns the current enable unmask value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*unmask*>	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.

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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

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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	:AVERage:AVERage?	Query average value of the average.
	:AVERage:COUNt?	Query average count
	:AVERage:MAXimum?	Query average maximum.
	:AVERage:MINimum?	Query average minimum.
	:DB:REFerence <*value*> |MIN|MAX	Set dB reference value
	:DB:REFerence? [MIN|MAX]	Query dB reference value.
	:DBM:REFerence <*value*> |MIN|MAX	Set dBm reference value.
	:DBM:REFerence? [MIN|MAX]	Query dBm reference value.
	:FUNCtion AVERage|DB|DBM|LIMit|NULL	Set math function to calculate.
	:FUNCtion?	Query math function set.
	:LIMit:LOWer <*value*> |MIN|MAX	Set lower limit value.
	:LIMit:LOWer? [MIN|MAX]	Query lower limit value.
	:LIMit:UPPer <*value*> |MIN|MAX	Set upper limit value.
	:LIMit:UPPer? [MIN|MAX]	Query upper limit value.
	:NULL:OFFSet <*value*> |MIN|MAX	Set null offset value.
	:NULL:OFFSet? [MIN|MAX]	Query null offset value.
	:STATe OFF|ON	Enable/disable math function state.
	:STATe?	Query math function state.
CALibration	:COUNt?	Query number of cal operations.
	:LFRequency 50|60|400	Sets line reference frequency.
	:LFRequency? [MIN|MAX]	Query line reference frequency.
	:SECure:CODE <*new code*>	Enters a new security code.
	:SECure:STATe OFF|ON,<*code*>	Enables/disables the security code.
	:SECure:STATe?	Queries the security state.
	:STRing <*quoted string*>	Lets you store info about your calibration.
	:STRing?	Queries the cal string.
	:VALue <*cal_value*>	Sets the calibration value.
	:VALue?	Queries the calibration value.
	:ZERO:AUTO ON|OFF	Enable/disable autozero mode.
	:ZERO:AUTO?	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.

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Command		Description
CONFigure	:CURRent:AC [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for AC current.
	:CURRent[:DC] [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for DC current.
	:FREQuency [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for frequency.
	:FRESistance [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for 4-wire ohms.
	:PERiod [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for period.
	:RESistance [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for 2-wire ohms.
	:VOLTage:AC [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for AC voltage.
	[:VOLTage[:DC]] [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Configure multimeter for DC voltage.
	[:VOLTage[:DC]]:RATio [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]	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	Enable/disable auto impedance mode.
	:IMPedance:AUTO?	Query impedance mode.
MEASure	:CURRent:AC? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make an AC current measurement.
	:CURRent[:DC]? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make a DC current measurement.
	:FREQuency? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make a frequency measurement.
	:FRESistance? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make a 4-wire ohms measurement.
	:PERiod? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make a period measurement.
	:RESistance? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make a 2-wire ohms measurement.
	:VOLTage:AC? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make an AC voltage measurement.
	[:VOLTage[:DC]]? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make a DC voltage measurement.
	[:VOLTage[:DC]]:RATio? [<*range*>|MIN|MAX|DEF|AUTO [,<*resolution*>|MIN|MAX|DEF]]	Make a DC voltage ratio measurement.
OUTPut	:TTLTrg0|1|2|3|4|5|6|7[:STATe]1|0|ON|OFF	Send voltmeter complete to VXIbus trigger lines.
	:TTLTrg0|1|2|3|4|5|6|7[:STATe]?	Query voltmeter complete destination.
READ?		Place multimeter in wait-for-trigger state; place readings in output buffer.
SAMPle	:COUNt 1-50000|MIN|MAX	Set number of readings per trigger.
	:COUNt? [MIN|MAX]	Query number of readings per trigger.

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Command		Description
[SENSe:]	FUNCtion "*function*"	Select measurement function.
	FUNCtion?	Query measurement function.
	CURRent:AC:RANGe <*range*>|MIN|MAX	Set range.
	CURRent:AC:RANGe? [MIN|MAX]	Query range.
	CURRent:AC:RANGe:AUTO OFF|ON	Enable/disable autoranging.
	CURRent:AC:RANGe:AUTO?	Query autorange mode.
	CURRent:AC:RESolution <*resolution*> |MIN|MAX	Set resolution.
	CURRent:AC:RESolution? [MIN|MAX]	Query resolution.
	CURRent[:DC]:APERture .333ms|3.33ms|16.7ms| 167ms|1.67s|MIN|MAX	Set the integration time in seconds.
	CURRent[:DC]:APERture? [MIN|MAX]	Query integration time (seconds).
	CURRent[:DC]:NPLCycles .02|.2|1|10|100|MIN|MAX	Set integration time in PLCs.
	CURRent[:DC]:NPLCycles? [MIN|MAX]	Query integration time (PLCs).
	CURRent[:DC]:RANGe <*range*>|MIN|MAX	Set range.
	CURRent[:DC]:RANGe? [MIN|MAX]	Query range.
	CURRent[:DC]:RANGe:AUTO OFF|ON	Enable/disable autoranging.
	CURRent[:DC]:RANGe:AUTO?	Query autorange mode.
	CURRent[:DC]:RESolution <*resolution*>|MIN|MAX	Set resolution.
	CURRent[:DC]:RESolution? [MIN|MAX]	Query resolution.
	DETector:BANDwidth 3|20|200|MIN|MAX	Set the AC filter.
	DETector:BANDwidth? [MIN|MAX]	Query AC filter.
	FREQuency:APERture 0.01|0.1|1|MIN|MAX	Set integration time in seconds.
	FREQuency:APERture? [MIN|MAX]	Query aperture (integration) time.
	FREQuency:VOLTage:RANGe <*range*>|MIN|MAX	Select range.
	FREQuency:VOLTage:RANGe? [MIN|MAX]	Query range.
	FREQuency:VOLTage:RANGe:AUTO OFF|ON	Enable/disable autoranging.
	FREQuency:VOLTage:RANGe:AUTO?	Query autorange mode.
	FRESistance:APERture .333ms|3.33ms|16.7ms| 167ms|1.67s|MIN|MAX	Set integration time in seconds.
	FRESistance:APERture? [MIN|MAX]	Query integration time (seconds).
	FRESistance:NPLCycles 0.02|0.2|1|10|100|MIN|MAX	Set integration time in PLCs.
	FRESistance:NPLCycles? [MIN|MAX]	Query integration time (PLCs).
	FRESistance:RANGe <*range*>|MIN|MAX	Select range.
	FRESistance:RANGe? [MIN|MAX]	Query range.
	FRESistance:RANGe:AUTO OFF|ON	Enable/disable autoranging.
	FRESistance:RANGe:AUTO?	Query autorange mode.
	FRESistance:RESolution <*resolution*>|MIN|MAX	Specify resolution.
	FRESistance:RESolution? [MIN|MAX]	Query resolution.
	PERiod:APERture 0.01|0.1|1|MIN|MAX	Set integration time in seconds.
	PERiod:APERture? [MIN|MAX]	Query integration time (seconds).
	PERiod:VOLTage:RANGe <*range*>|MIN|MAX	Select range.
	PERiod:VOLTage:RANGe? [MIN|MAX]	Query range.
	PERiod:VOLTage:RANGe:AUTO OFF|ON	Enable/disable autoranging.
	PERiod:VOLTage:RANGe:AUTO?	Query autorange mode.
	RESistance:APERture .333ms|3.33ms|16.7ms|167ms| 1.67s|MIN|MAX	Set integration time in seconds.
	RESistance:APERture? [MIN|MAX]	Query integration time (seconds).
	RESistance:NPLCycles 0.02|0.2|1|10|100|MIN|MAX	Set integration time in PLCs.
	RESistance:NPLCycles? [MIN|MAX]	Query integration time (PLCs).
	RESistance:RANGe <*range*>|MIN|MAX	Set range.
	RESistance:RANGe? [MIN|MAX]	Query range.
	RESistance:RANGe:AUTO OFF|ON	Set autorange mode.
	RESistance:RANGe:AUTO?	Query autorange mode.
	RESistance:RESolution <*resolution*>|MIN|MAX	Specify resolution.
	RESistance:RESolution? [MIN|MAX]	Query resolution.

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Command		Description
[SENSe:]	VOLTage:AC:RANGe <*range*>|MIN|MAX	Set range.
	VOLTage:AC:RANGe? [MIN|MAX]	Query range.
	VOLTage:AC:RANGe:AUTO OFF|ON	Enable/disable autoranging.
	VOLTage:AC:RANGe:AUTO?	Query autorange mode.
	VOLTage:AC:RESolution <*resolution*>|MIN|MAX	Specify resolution.
	VOLTage:AC:RESolution? [MIN|MAX]	Query resolution.
	VOLTage[:DC]:APERture .333ms|3.33ms|16.7ms|167ms|1.67s|MIN|MAX	Set integration time in seconds.
	VOLTage[:DC]:APERture? [MIN|MAX]	Query integration time (seconds).
	VOLTage[:DC]:NPLCycles 0.02|0.2|1|10|100|MIN|MAX	Set integration time in PLCs.
	VOLTage[:DC]:NPLCycles? [MIN|MAX]	Query integration time (PLCs).
	VOLTage[:DC]:RANGe <*range*>|MIN|MAX	Set range.
	VOLTage[:DC]:RANGe? [MIN|MAX]	Query range.
	VOLTage[:DC]:RANGe:AUTO OFF|ON	Enable/disable autoranging.
	VOLTage[:DC]:RANGe:AUTO?	Query autorange mode.
	VOLTage[:DC]:RESolution <*resolution*>|MIN|MAX	Specify resolution.
	VOLTage[:DC]:RESolution? [MIN|MAX]	Query resolution.
	ZERO:AUTO OFF|ONCE|ON	Enable/disable autozero mode.
	ZERO:AUTO?	Query autozero mode.
STATus	:PRESet	Sets all bits of enable register to “0”.
	:QUEStionable:CONDition?	Query the questionable condition register.
	:QUEStionable:ENABle <*unmask*>	Sets conditions in enable register.
	:QUEStionable:ENABle?	Query the questionable enable register.
	:QUEStionable[:EVENt]?	Query the questionable event register.
SYSTem	:ERRor?	Return error number/message from error queue.
	:VERSion?	Return the multimeter's SCPI version.
TRIGger	:COUNt <*number*>|MIN|MAX|INFinite	Set number of triggers or scans.
	:COUNt? [MIN|MAX]	Query trigger count.
	:DELay <*seconds*>|MIN|MAX	Set delay between trigger and start of measurement.
	:DELay? [MIN|MAX]	Query trigger delay.
	:DELay:AUTO OFF|ON	Enable/disable automatic trigger delay.
	:DELay:AUTO?	Query automatic trigger delay mode.
	:SOURce BUS|IMMediate|EXTernal|TTLTrg0-7	Specify trigger source.
	:SOURce?	Query trigger source.

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Appendix A
HP E1312A and HP E1412A Multimeter Specifications

DC Characteristics

Accuracy Specifications ± (% of reading + % of range) [1]

Function	Range [3]	Test Current or Burden Voltage	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
DC Voltage	100.0000mV		0.0030 + 0.0030	0.0040 + 0.0035	0.0050 + 0.0035	0.0005 + 0.0005
	1.000000V		0.0020 + 0.0006	0.0030 + 0.0007	0.0040 + 0.0007	0.0005 + 0.0001
	10.00000V		0.0015 + 0.0004	0.0020 + 0.0005	0.0035 + 0.0005	0.0005 + 0.0001
	100.0000V		0.0020 + 0.0006	0.0035 + 0.0006	0.0045 + 0.0006	0.0005 + 0.0001
	300.0000V		0.0020 + 0.0018	0.0035 + 0.0030	0.0045 + 0.0030	0.0005 + 0.0003
Resistance [4]	100.0000Ω	1mA	0.0030 + 0.0030	0.0080 + 0.0040	0.0100 + 0.0040	0.0006 + 0.0005
	1.000000kΩ	1mA	0.0020 + 0.0005	0.0080 + 0.0010	0.0100 + 0.0010	0.0006 + 0.0001
	10.00000kΩ	100µA	0.0020 + 0.0005	0.0080 + 0.0010	0.0100 + 0.0010	0.0006 + 0.0001
	100.0000kΩ	10µA	0.0020 + 0.0005	0.0080 + 0.0010	0.0100 + 0.0010	0.0006 + 0.0001
	1.000000MΩ	5µA	0.0020 + 0.0010	0.0080 + 0.0010	0.0100 + 0.0010	0.0010 + 0.0002
	10.00000MΩ	500nA	0.0150 + 0.0010	0.0350 + 0.0010	0.0540 + 0.0010	0.0030 + 0.0004
	100.0000MΩ	500nA || 10MΩ	0.3000 + 0.0100	0.8000 + 0.0100	0.8000 + 0.0100	0.1500 + 0.0002
DC Current	10.00000mA	<0.1V	0.0050 + 0.0100	0.0500 + 0.0200	0.0700 + 0.0200	0.0050 + 0.0020
	100.0000mA	<0.7V	0.0100 + 0.0040	0.0500 + 0.0050	0.0700 + 0.0050	0.0060 + 0.0005
	1.000000A	<1V	0.1000 + 0.0060	0.1300 + 0.0100	0.1500 + 0.0100	0.0060 + 0.0010
	3.000000A	<2V	0.7000 + 0.0200	0.7200 + 0.0200	0.7200 + 0.0200	0.0060 + 0.0020
DC:DC Ratio	100mV 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.			

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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:	0.1 V, 1 V, 10 V ranges	Selectable 10 MΩ or >10 GΩ
	100 V, 300 V ranges	10 MΩ ± 1%
Input Bias Current:	<30 pA at 25 °C	
Input Terminals:	Copper alloy	
Input Protection:	300 V on all ranges	

Resistance

Measurement Method:	Selectable 4-wire or 2-wire ohms. Current source referenced to LO input.
Max. Lead Resistance: (4-wire ohms)	10% of range per lead for 100 Ω and 1 kΩ ranges. 1 kΩ per lead on all other ranges.
Input Protection:	300 V on all ranges

DC Current

Shunt Resistor:	0.1 Ω for 1 A and 3 A. 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 = Ω4W Sense terminals)
Input HI-LO	100 mV to 300 V ranges
Reference HI-LO	100 mV to 10 V ranges (autoranged)
Input to Reference	Reference LO to Input LO voltage <2 V
	Reference HI to Input LO voltage <12 V

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 3 A 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.

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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 ±1°C and <10 minutes:
100 mV - 100 V ranges: add (0.0002% range additional error +5 µV). 300 V 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.

[5] For 1 kΩ unbalance in LO lead.
[6] For power-line frequency ±0.1%.
[7] For power-line frequency ±1%, subtract 20 dB; for ±3%, subtract 30 dB.
[8] Readings speeds for 60 Hz and (50 Hz) operation, Autozero OFF.
[9] For 300 V and 3 A 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 mΩ 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.

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AC Characteristics

Accuracy Specifications ± (% 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)

Frequency	AC Filter 3 Hz	20 Hz	200 Hz
10Hz-20Hz	0	0.74	--
20Hz-40Hz	0	0.22	--
40Hz-100Hz	0	0.06	0.73
100Hz-200Hz	0	0.01	0.22
200Hz-1kHz	0	0	0.18
>1kHz	0	0	0

Additional Crest Factor Errors (non-sinewave) [6]

Crest Factor	Error (% or reading)
1-2	0.05%
2-3	0.15%
3-4	0.30%
4-5	0.40%

NOTE: Crest Factor is not specified for non sinewave inputs <100Hz using the slow (3Hz) AC filter. See note [6].

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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 MΩ ± 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 1 A and 3 A ranges
Burden Voltage:	1 A range: <1 Vrms 3 A 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.

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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 kΩ 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] 100 Vac and 300 Vac 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.

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Frequency and Period Characteristics

Accuracy Specifications ±(% of reading) [1] [4]

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
Frequency, Period	100mV to 300V	3Hz - 5Hz	0.10	0.10	0.10	0.005
		5Hz - 10Hz	0.05	0.05	0.05	0.005
		10Hz - 40Hz	0.03	0.03	0.03	0.001
		40Hz - 300kHz	0.006	0.01	0.01	0.001

Additional Low-Frequency Errors (% of reading) [4]

	Integration Time (number PLCs)		
Frequency	**100 & 10**	**1 & 0.2**	**0.02**
3Hz-5Hz	0	0.12	0.12
5Hz-10Hz	0	0.17	0.17
10Hz-40Hz	0	0.2	0.2
40Hz-100Hz	0	0.06	0.21
100Hz-300Hz	0	0.03	0.21
300Hz-1kHz	0	0.01	0.07
>1kHz	0	0	0.02

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.

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Frequency and Period Characteristics (*continued*)

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.

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General Specifications

Overvoltage Category 1 (1500 V peak max impulse)

HP E1312A and HP E1412A Available Power (Amps):

+5V:	Ipm (maximum peak current):	0.20 A
	Idm (maximum dynamic current):	0.10 A
+12V:	Ipm (maximum peak current):	0.70 A
	Idm (maximum dynamic current):	0.06 A

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 not recommended for use in the HP E1300A or HP E1301A B-size Mainframe.

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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” beginning on page 182 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°C±5°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	Range Error (% of range)	Range Error Voltage
10Vdc	10Vdc	0.0015	≤150µV
10Vdc	1Vdc	0.0015	≤15µV
10Vdc	0.1Vdc	0.0015	≤1.5µV

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
10Vdc	10Vdc	0.0004	≤40µV
10Vdc	1Vdc	0.0004	≤40µV
10Vdc	0.1Vdc	0.0004	≤40µV

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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.

$$\%\ of\ input\ error = \frac{Total\ Measurement\ Error}{Input\ Signal\ Level} \times 100$$

$$ppm\ of\ input\ error = \frac{Total\ Measurement\ Error}{Input\ Signal\ Level} \times 1,000,000$$

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).

Reading error	= 0.0020% x 5 Vdc	= 100 µV
Range error	= 0.0005% x 10 Vdc	= 50 µV
Total error	= 100 µV + 50 µV	= ±150 µV = ±0.0030% of 5 Vdc = ±30 ppm of 5 Vdc

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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 "½" digit.

For example, the HP E1412A can measure 9.99999 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 6½-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 µV. You could use a 6½-digit multimeter if it has a 1 Vdc or smaller range. You could also use a 4½-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 measurable value divided by the minimum measurable value on a selected range. Resolution is often expressed in percent, parts-per-million (ppm), counts, or bits. For example, a 6½-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.

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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 ±2 sigma	4.5%
Mean ±3 sigma	0.3%
Mean ±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 ±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 ±1°C temperature range.

90-Day and 1-Year Accuracy

These long-term accuracy specifications are valid for a 23°C ± 5°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°C ± 5°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°C ± 5°C temperature range.

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Configuring for High 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 GΩ (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).

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Appendix B
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

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-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: TRIGG:COUN 3

-121 Invalid character in number
An invalid character was found in the number specified for a parameter value. Example: STAT:QUES:ENAB #B01010102

-123 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'

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-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.

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-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.

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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 µA source failed

614 DC 300 V zero failed

615 Ohms 10 µA source failed

616 DC current sense failed

617 Ohms 100 µA source failed

618 DC high voltage attenuator failed

619 Ohms 1 mA source failed

620 AC rms zero failed

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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.

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709 **No cal for this function or range**
You cannot perform calibrations for ac current, period, continuity, diode, ratio, or on the 100 MΩ range.

710 **Full scale correction out of range**

720 **Cal DCV offset out of range**

721 **Cal DCI offset out of range**

722 **Cal RES offset out of range**

723 **Cal FRES offset out of range**

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**

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Notes:

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Appendix C
Measurement Speed and Accuracy Trade-offs

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 setup 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.

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.

The table on the following page shows equivalent [SENSe:] commands for the special commands.

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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.

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

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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 Tables 3-1, 3-2, and 3-3 beginning on page 70.

The following table shows range and NPLC settings for power-on and after a module reset. Changing a range within one function does not place other functions at that range setting. Each function operates independently.

Special Function	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	1kΩ (R2), NPLC = 10	1kΩ (R2), NPLC = 10
F4	1kΩ (R2), NPLC = 10	1kΩ (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 10µV resolution (see Table 3-1 on page 70). 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 1mV (see Table 3-1 on page 70).

Use the special function command F3 to change the function to 2-Wire Resistance. The range goes to the resistance power-on state (1kΩ for 2-Wire Resistance, NPLC = 10); it does not change with the previous DCV R5 command. NPLC remains at 10 PLCs providing resolution of 1mΩ.

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.

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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 autozero to ONCE or OFF.
5. Turn autorange 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 HP 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.

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Set Autozero to ONCE or OFF

Autozero causes the A/D to alternately measure its internal zero and the external signal. Autozero improves reading accuracy; however, it reduces reading speed by ½.

```
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 Autozero operation when the
                          command is received and also sets the mode
                          to autozero 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 Autorange OFF

Turning autorange OFF makes the HP E1312A and HP E1412A take all measurements on a fixed range which results in fast and predictable measurement times.

Autorange 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. Autorange 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 autorange 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:]FRESistance: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 millivolts. 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 microvolt range.

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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.

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