3458A Multimeter

This product is a RoHS Compliance

(Applicable to serial number MY59350000/SG59350100 and above)

dataTec

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USER'S GUIDE

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CAUTION

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

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Safety Symbols

The following symbols on the instrument and in the documentation indicate precautions which must be taken to maintain safe operation of the instrument.

	Direct current (DC)		Alternating current (AC)
	WARNING, RISK OF ELECTRIC SHOCK.		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.
	Out position of a bi-stable push control		In position of a bi-stable push control

Regulatory Markings

CE CAN ICES/NMB-001(A) ISM GRP 1-A	The CE mark is a registered trademark of the European Community. This CE mark shows that the product complies with all the relevant European Legal Directives. CAN ICES/NMB-001(A) indicates that this ISM device complies with the Canadian ICES-001. Cet appareil ISM est conforme a la norme NMB-001 du Canada. ISM GRP 1-A indicates that this is an Industrial Scientific and Medical Group 1 Class A product.		This symbol indicates the time period during which no hazardous or toxic substance elements are expected to leak or deteriorate during normal use. Forty years is the expected useful life of the product.
UK CA	The UKCA (UK Conformity Assessed) marking is a UK product marking that is used for goods being placed on the market in Great Britain (England, Wales, and Scotland)		This mark, also called the “cTUVus mark”, is used to demonstrate compliance with Canadian national standards issued by the Standards Council of Canada (SCC) and U.S. national standards.
	This symbol is a South Korean Class A EMC Declaration. This is a Class A instrument suitable for professional use and in electromagnetic environment outside of the home.		This instrument complies with the WEEE Directive (2002/96/EC) marking requirement. This affixed product label indicates that you must not discard this electrical/electronic product in domestic household waste.
	The RCM mark is a registered trademark of the Australian Communications and Media Authority.		

South Korean Class A EMC declaration:

Information to the user:

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

– This EMC statement applies to the equipment only for use in business environment.

사 용 자 안 내 문사 용 자 안 내 문

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

Product Regulatory and Compliance

The 3458A digital multimeter complies with safety and EMC requirements.

Refer to Declaration of Conformity at http://www.keysight.com/go/conformity for the latest revision.

Safety Considerations

Read the information below before using this instrument.

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

WARNING **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 cables.

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

WARNING **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.

WARNING **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.

WARNING **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 Keysight for service and repair to ensure that safety features are maintained.

WARNING **Use the device as specified:** If the device is used in a manner not specified by manufacturer, the device protection may be impaired.

WARNING **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.

WARNING **DO NOT substitute parts or modify equipment**: Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the product. Return the product to Keysight for service and repair to ensure that safety features are maintained.

WARNING **Measuring high voltages is always hazardous**: ALL multimeter input terminals (both front and rear) must be considered hazardous whenever inputs greater than 42 V (dc or peak) are connected to ANY input terminal.

WARNING Permanent wiring of hazardous voltage or sources capable of delivering grater than 150 VA should be labeled, fused, or in some other way protected against accidental bridging or equipment failure.

WARNING **DO NOT** leave measurement terminals energized when not in use.

WARNING **DO NOT** use the front/rear switch to multiplex hazardous signals between the front and rear terminals of the multimeter.

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

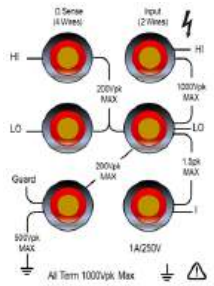
WARNING **Measurement Limits:** To avoid instrument damage and the risk of electric shock, do not exceed any of the Measurement Limits defined in the following section.

CAUTION This is a sensitive measurement product by design. When subjected to continuously present electromagnetic phenomena, some degradation performance may occur.

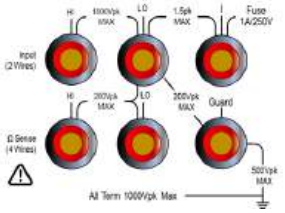
Measurement Limits

This multimeter provides protection circuitry to prevent damage to the instrument and to protect against the danger of electric shock, provided the Measurement Limits are not exceeded. To ensure the safe operation of the instrument, do not exceed the Measurement Limits shown on the front and rear panel, defined as follows:

For Serial Number SG59350366 and MY59357708 and below.



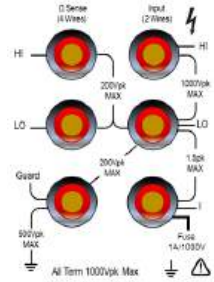
3458A Front Panel Terminal Area



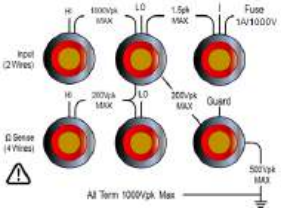
3458A Rear Panel Terminal Area

– To replace the 1 A/250 V fuse, order Keysight part number 2110-0001.

For Serial Number SG59350386 and MY59358376 and above.



3458A Front Panel Terminal Area



3458A Rear Panel Terminal Area

– To replace the 1 A/1000 V fuse, order Keysight part number 2110-1910.

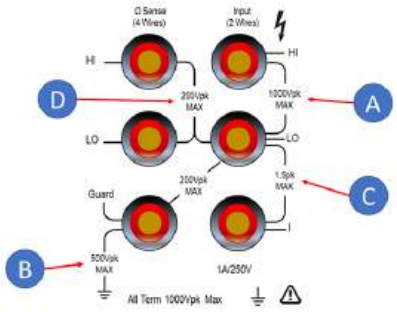
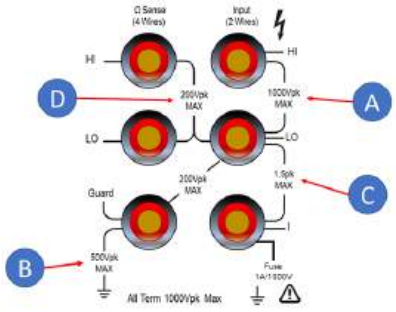
NOTE The Front/Rear switch selects the terminal set to be used. DO NOT operate this switch while signals are present on the front or rear terminals. The user-replaceable 1 A current-protection fuse is on the panels. The current protection fuse is located inside the current input terminal on each front and read side. Contact your Keysight Sales and Service Center or refer to product service documentation for replacement instructions.

Voltage/Current Measurement Safety

Multimeters and other measuring instruments are capable of measuring high voltages and currents are subject to specific safety concerns because of the circuits to which they may be connected. To safely use these instruments, you need to understand the markings on the instrument near the input terminals, which include the Protection Limits and the IEC Measurement Category.

Protection Limits

Keysight multimeters and other voltage measurement instruments provide protection circuitry to prevent damage to the instrument and to protect against the danger of electric shock with provided the protection limits are not exceeded. To ensure the safe operation of the instrument, do not exceed the protection limits as provided on the input terminals. The input terminals and safety markings for 3458A are shown below.

For Serial Number SG59350366 and MY59357708 and below.	For Serial Number SG59350386 and MY59358376 and above.
	

- To replace the 1 A/ 250 V fuse, order Keysight part number 2110-0001.
- To replace the 1 A/1000 V fuse, order Keysight part number 2110-1910.

- **HI and LO Input Terminals**. The HI and LO input terminals are used for voltage and resistance test measurements. Two Protection Limits are defined for these terminals:
- **HI to LO Protection Limit (A)**. The Protection Limit from HI to LO is 1000 VDC or 700 VAC, which is also the maximum voltage measurement. This limit can also be expressed as 1000 Vpk maximum.
- **LO to Ground Protection Limit (B)**. The LO input terminal can safely "float" at a maximum of 500 Vpk relatives to earth ground. As is implied by these limits, the Protection Limit for the HI input terminal is a maximum of 1500 Vpk relative to the ground.
- **Current Input Terminal (C)**. The current input ("I") terminal has a Protection Limit of 1.5Apk for the maximum current to flow to the LO input terminal. Note that the current input terminal will be at approximately the same voltage as the LO terminal.
- **Sense Terminals (D)**. The HI and LO sense terminals are used for four-wire resistance measurements. The Protection Limit is 200 Vpk for each of the following terminal pairings.
  - LO sense to LO input.
  - HI sense to LO input.
  - HI sense to LO sense.

The IEC Measurement Categories

The 3458A multimeter may be connected to line-voltage mains under IEC Measurement Category II conditions, further limited to line voltages up to 300 volts.

If an instrument is marked CAT I (IEC Measurement Category I), or it is not marked with a measurement category, its inputs must not be connected to line-voltage mains. To protect against the danger of electric shock, instruments marked CAT II provide overvoltage protection for line-voltage mains connections under IEC Measurement Category II conditions. Instruments marked CAT III or CAT IV provide protection for IEC Measurement Category III or IV conditions, respectively. These categories are defined below.

- IEC Measurement Category I (CAT I) refers to devices that are isolated from line-voltage mains. Do not connect the inputs of a CAT I instrument to line-voltage mains. Category I instruments often are not marked with the CAT I symbol, as this is not required. Refer to the user's guide or operator's manual for further information.
- IEC Measurement Category II (CAT II) refers to electrical devices (such as small appliances) that are connected to line-voltage mains at an outlet on a branch circuit. The HI and LO inputs of a CAT II instrument may safely be connected to mains in such devices, or to the branch outlet itself. However, a CAT II instrument may not be connected to mains in permanently installed electrical devices such as the service panel, sub-panel disconnect boxes, or permanently wired motors.
- IEC Measurement Category III (CAT III) refers to equipment permanently connected to line-voltage mains and extends from the output side of the circuit breakers in the service panel through all of the building wiring and sub-panels. Category III includes motors and equipment that are permanently wired to the building installation. The HI and LO inputs of a CAT III instrument may safely be connected to line voltage mains for such circuits and equipment, but may not be connected to mains on the input side of the service panel breakers.
- IEC Measurement Category IV (CAT IV) refers to the building entrance, which is generally defined as the circuitry and equipment between the output of the electrical meter and the service panel, inclusive of the input side of the service panel breakers.

Environmental Conditions

The 3458A is designed for indoor use and in an area with low condensation. The table below shows the general environmental requirements for this instrument.

Environmental condition	Requirement
Temperature	Operating condition – 0 °C to 55 °C
Humidity	Operating condition – Up to 95% RH at 40 °C (non-condensing) – Up to 40% RH for 41 °C to 55 °C (non-condensing)
Altitude	Up to 2000 m
Pollution degree	2
Installation category	II
Measurement voltage category	II
Overvoltage protection	II
Power requirements	100/120V, 220/240 V ± 10% 48 - 66 Hz, 360 - 420 Hz automatically sensed < 30 W, < 80 VA (peak) Fused: 1.5 @ 115 V or 0.5 A @ 230 V

WARNING DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE OR WET ENVIRONMENTS
Do not operate the instrument around flammable gases or fumes, vapor, or wet environments.

Waste Electrical and Electronic Equipment (WEEE) Directive

This instrument complies with the WEEE Directive marking requirement. This affixed product label indicates that you must not discard this electrical or electronic product in domestic household waste.

Product category:

With reference to the equipment types in the WEEE directive Annex 1, this instrument is classified as a “Monitoring and Control Instrument” product.

The affixed product label is as shown below.

Do not dispose in domestic household waste.

To return this unwanted instrument, contact your nearest Keysight Service Center, or visit http://about.keysight.com/en/companyinfo/environment/takeback.shtml for more information.

Sales and Technical Support

To contact Keysight for sales and technical support, refer to the support links on the following Keysight websites:

- www.keysight.com/find/3458A
  (product-specific information and support, software and documentation updates)
- www.keysight.com/find/assist
  (worldwide contact information for repair and service)

Preface

This manual contains installation information, operating and programming information, and configuration information for the 3458A multimeter (RoHs Compliance). The manual consists of the following chapters:

Chapter 1 Installation and Maintenance

This chapter contains information on initial inspection, installation, and maintenance. It also contains lists of the multimeter' s available options and accessories.

Chapter 2 Getting Started

This chapter covers the fundamentals of multimeter operation. It shows you how to use the multimeter's front panel, how to send commands to the multimeter from remote, and how to retrieve data from remote.

Chapter 3 Configuring for Measurements

This chapter shows how to configure the multimeter for all types of measurements except digitizing (digitizing is covered in Chapter 5). This chapter also shows you how to use subprogram and state memory, the input buffer, and the status register.

Chapter 4 Making Measurements

This chapter discusses the methods for triggering measurements, discusses the reading formats, shows how to use reading memory, and how to transfer readings across the GPIB bus. This chapter also discusses how to increase the reading rate, how to use the multimeter's EXTOUT signal, and how to use the math operations.

Chapter 5 Digitizing

Digitizing is the process of converting a continuous analog signal into a series of discrete samples (readings). This chapter discusses the various ways to digitize signals, the importance of the sampling rate, and how to use level triggering.

Chapter 6 Command Reference

This chapter discusses the multimeter's language (HPML) and contains detailed descriptions of each command in the language. Commands are listed in alphabetical order.

Chapter 7 BASIC Programming Language

This chapter describes the BASIC commands supported by the 3458A's internal BASIC language operating system. With this feature, many of your special requirements can be easily satisfied by writing and downloading a simple BASIC subprogram to customize the multimeter's behavior.

Appendices

The appendices contain the multimeter's specifications, information on the GPIB commands recognized by the multimeter, information on locking-out the front/rear terminals switch, and contains product notes concerning digitizing and maximizing the multimeter's reading rate and throughput.

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1 Installation and Maintenance

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Introduction

This chapter contains information on initial inspection, installation, and maintenance. It also contains lists of the multimeter's available options and accessories. It's a good idea to read this chapter before making any electrical connections to the multimeter.

Initial Inspection

WARNING If any of the following symptoms exist, or are expected, remove the multimeter from service:

- Visible damage.
- Severe transport stress.
- Prolonged storage under adverse conditions.
- Failure to perform intended measurements or functions.

Do not use multimeter until safe operation can be verified by service trained personnel.

The multimeter was carefully inspected before it left the factory. It should be undamaged and in proper working order upon receipt. If the shipping container or cushioning material is damaged, keep it, until the contents of the shipment have been checked and the multimeter has been inspected. When you unpack the multimeter, verify that the following items are included:

- Line Power Cord (Qty. 1)
- Replacement line power fuses: 500 mA T (Qty 1 for 220/240 operation), 1.5 A NTD (Qty 1 for 100/120 operation)
- Keyboard Overlay (Qty. 5)
- Switch Lockout Caps (Qty. 2)
- Test Lead Kit (Qty. 1)

If the multimeter is damaged or the contents are incomplete, promptly notify the nearest Keysight Technologies office.

Options and Accessories

Table 1-1 lists the available options, and Table 1-2 lists the available accessories for the multimeter.

Table 1-1 Available options

Description	Option number	Part number for field retrofit
High Stability Reference (4 ppm/year)	002	03458-80009
Front Handle Kit	907	1CN106A
Rack Flange Kit	908	1CM110A / 1CM107A
Rack Flange Kit (with handles)	909	1CM111A
2 Additional Years of Return to Keysight Hardware Support	W30	

Table 1-2 Available accessories

Description	Model or part number
Extra User's Guide, Quick Reference Guide, Calibration Manual, Assembly-Level Repair Manual, and Front Panel User's Guide	03458-90101
Extra User's Guide to Keysight 3458A Front Panel Operation (RoHS Compliance)	03458-90007
Extra Quick Reference Guide	03458-90008
Extra Assembly-Level Repair Manual (RoHS Compliance)	03458-90018
Extra Calibration Manual	03458-90017
User-Defined Key Overlay	03458-84323
Switch Lockout Cap (Qty 1)	03458-44123
1 Meter GPIB Cable	10833A
2 Meter GPIB Cable	10833B
4 Meter GPIB Cable	10833C

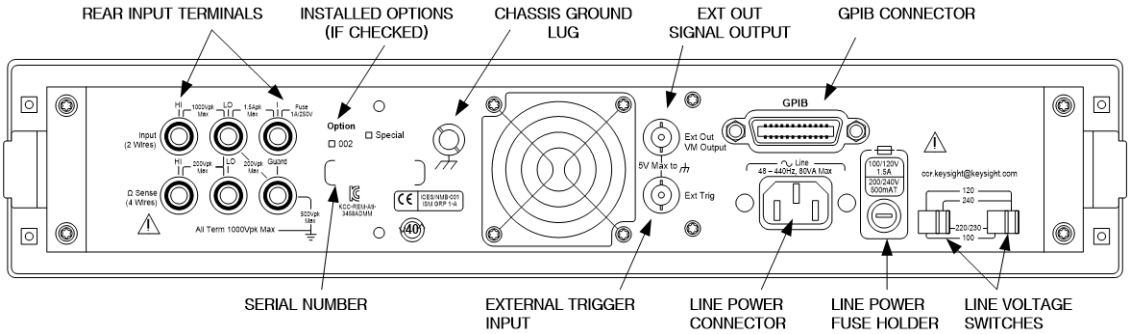
Table 1-2 Available accessories (continued)

Description	Model or part number
0.5 Meter GPIB Cable	10833D
Test Lead Set	34137A
30 Amp Current Shunt	34330A
Kelvin Probe Set (4-wires plus ground, 1m each)	11059A
Kelvin Clip Set (2 each)	11062A
Thermistor Temperature Probe 5 kΩ	E2308A
10 kΩ Thermistor	34308A

Installing the Multimeter

This section discusses the multimeter's grounding and power requirements and contains instructions for installing the multimeter. (Refer to Appendix C for instructions on how to install the switch lockout caps.) Figure 1-1 shows the multimeter's rear panel. Many of the rear panel connectors and switches are referenced in this section.

For Serial Number SG59350366 and MY59357708 and below.



For Serial Number SG59350386 and MY59358376 and above.

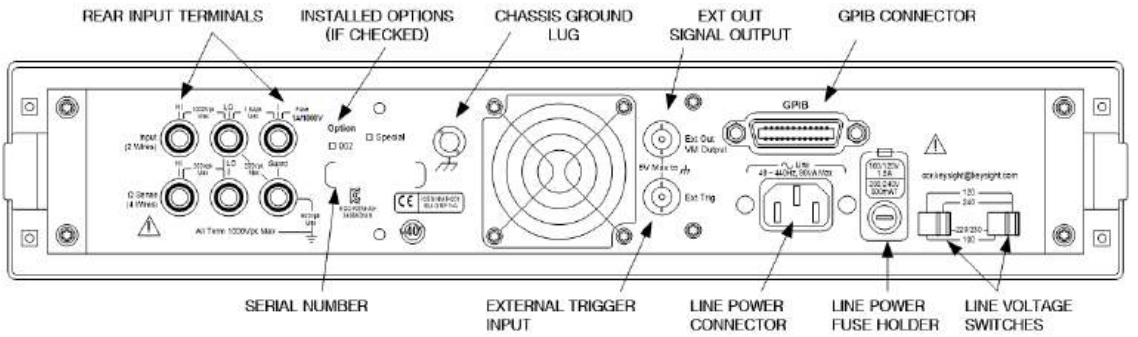


Figure 1-1 Rear panel

Grounding requirements

The multimeter comes with a three-conductor AC power cable (see Figure 1-3). The power cable must be connected to an approved three-contact electrical outlet that has its ground conductor connected to an electrical ground (safety ground). The multimeter's power jack and the supplied power cable meet International Electrotechnical Commission (IEC) safety standards.

NOTE **For protection from electrical shock, the power cord ground must not be defeated.**

Line power requirements

You can operate the multimeter from a single phase power source delivering 100 VAC, 120 VAC, 220 VAC, or 240 VAC (all values RMS), at 48 to 440 Hz. The power line voltage can vary by +/- 10% but cannot exceed 250 VAC RMS. Maximum power consumption is 80 VA (Volt-Amps). The nominal line voltage values and their corresponding limits are shown in Table 1-3.

CAUTION **Possible multimeter damage. Before connecting the multimeter to an AC power source, verify that the multimeter's line voltage selection switches are set to match the AC line voltage and that the proper line fuse is installed. These topics are discussed in the following sections.**

Table 1-3 Line voltage limits

Nominal value (RMS)	Allowable limits (RMS)
100 VAC	90 VAC to 110 VAC
120 VAC	108 VAC to 132 VAC
220 VAC	198 VAC to 242 VAC
240 VAC	216 VAC to 250 VAC

Setting the line voltage switches

The line voltage selection is pre-configured according to the country to which it is shipped. Use the following procedure if you need to change this setting:

1. Remove the multimeter's line power cord before changing the positions of the AC line voltage selection switches
2. With a small flat blade screwdriver, move the switches to the appropriate positions as shown in Figure 1-2
3. Install the correct line power fuse as described in the next section.

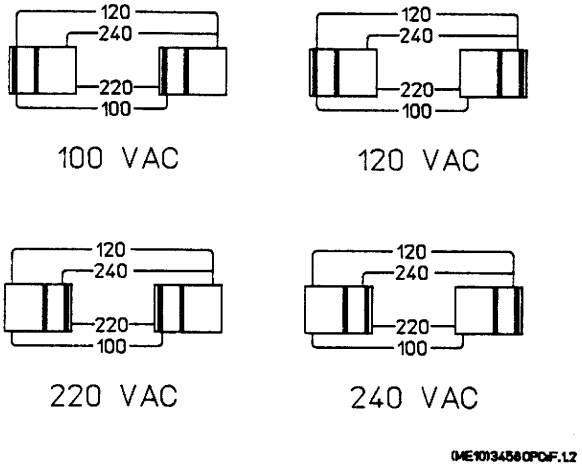


Figure 1-2 AC line voltage switch positions

Installing the line power fuse

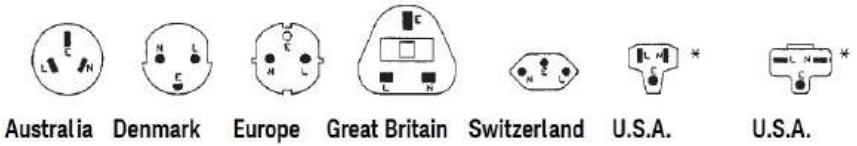
The line power fuse must match the line voltage selection. For 100 VAC or 120 VAC operation install a 1.5 A fuse. For 220 VAC or 240 VAC operation install a 500 mA fuse.

The line power fuse holder is located on the right side of the multimeter's rear panel (see Figure 1-1). To install a fuse, make sure the multimeter's power cord is removed. Insert one end of the fuse into the fuse cap. Insert the fuse/cap assembly into the fuse holder. With a small flatblade screwdriver, push in on the fuse cap and rotate it clockwise.

Power cords

Figure 1-3 shows the various multimeter power cords and their Keysight part numbers. If you received the wrong power cord, notify your Keysight sales office for replacement.

Power cords



Country	Part Number	Option	Voltage
Australia	8120-1369	901	250 V 6 A
Denmark	8120-2956	912	259 V 6 A
Europe	8121-1226	902	250 V 6 A
Great Britain	8120-1351	900	250 V 6 A
Switzerland	8120-2104	906	250 V 6 A
United States	8120-1378	903	120 V 10 A
United States	8120-0698	904	240 V 10 A

Power cords supplied by Keysight have polarities matched to the power input socket on the instrument.

NOTE: Plugs are viewed from connector and shape of molded plug may vary within country.

*CSA certification includes only these power cords.

Figure 1-3 Power cords

Connecting the GPIB cable

Attach the GPIB[1] cable to the 24-pin GPIB connector on the rear panel of the multimeter. Finger tighten the two screws on the cable connector. Figure 1-4 shows a typical GPIB connection between the multimeter and a controller.

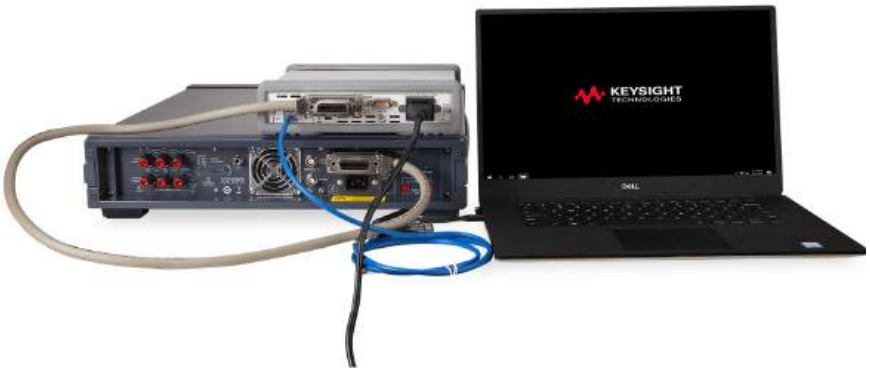


Figure 1-4 Typical GPIB connections

A total of 15 devices can be connected together on the same GPIB bus. The cables have single male/female connectors on each end so that several cables can be stacked. The length of the GPIB cables *must not* exceed 20 meters (65 feet) total, or 2 meters (6.5 feet) per device, whichever is less.

The GPIB address

You can change the multimeter's GPIB address using the ADDRESS command. Refer to Changing the GPIB address, in Chapter 2, for a procedure on how to change the GPIB address. The multimeter leaves the factory with the address set to decimal 22. The corresponding ASCII code is a listen address of 6 and a talk address of V.

[1] GPIB (General Purpose Interface Bus) is an implementation of IEEE Standard 488-1978 and ANSI MC 1.1.

NOTE The examples in this manual are intended for Hewlett-Packard Series 200\300 computers using the BASIC language. They assume a GPIB interface select code of 7 and a device address of 22 resulting in a combined GPIB address of 722.

Mounting the multimeter

The multimeter comes equipped with four feet, which allow it to be used as a bench instrument. It also has two tilt stands that allow you to elevate the front of the multimeter. The multimeter can be mounted in a standard 19-inch rack using the optional rack mount kits listed in Table 1-1.

Installation verification

The following program verifies that the multimeter is operating and can communicate with the controller over the GPIB bus.

```
10 PRINTER IS 1
20 OUTPUT 722;"ID?"
30 ENTER 722; IDENT$
40 PRINT IDENT$
50 END
```

If the multimeter has been correctly installed, the message `Keysight 3458A` will be printed on the designated system printer. If no message is printed, make sure power is applied to the multimeter. Also check the GPIB connections, the interface address setting, and the multimeter's address.

Maintenance

This section describes how to replace the multimeter's fuses and how to obtain repair service.

Replacing the line power fuse

The line power fuse holder is located on the right side of the multimeter's rear panel. Before replacing the fuse, disconnect the multimeter's line power. To replace the fuse, use a small flatblade screwdriver to push in on the fuse cap and rotate it counterclockwise. Remove the fuse cap and replace the fuse with the appropriate type (see Table 1-4). (The Keysight part number for the gray line power fuse cap is 2110-1710.) Re-install the fuse cap and apply power.

Table 1-4 Replacement power line fuses and caps

Line voltage	Power line fuse
100 or 120 VAC (Nominal)	1.5 A NTD, Keysight Part Number 2110-0043
220 or 240 VAC (Nominal)	500 mA SB, Keysight Part Number 2110-0202

Replacing a current fuse

Each of the front and rear current terminals (labeled I) contains a current fuse. To access the fuse, unscrew (rotate counterclockwise) the current terminal binding post knob until it stops. Push in on the terminal and rotate it clockwise. The entire terminal/fuse assembly can now be removed as shown in Figure 1-5. If necessary, replace the fuse for Serial Number SG59350366 and MY59357708 and below with a 1 A 250 V NTD fuse (Keysight part number 2110-0001) or for Serial Number SG59350386 and MY59358376 and above with a 1 A 1000 V NTD fuse (Keysight part number 2110-1910). (CAUTION: never use a slow-blow fuse as a current fuse; multimeter damage will result.) Replace the terminal/fuse assembly by pushing it in and turning counterclockwise until the assembly locks in place.

Figure 1-5 Current terminal/fuse assembly

Repair service

You may have the multimeter repaired at an Keysight Technologies service center whether it is under warranty or not. Contact the nearest Keysight Sales Office for shipping instructions prior to returning the instrument.

Serial number

Keysight instruments are identified by a two part, ten-character serial number of the form 0000A00000. The first four digits are the same for all identical products. They change only when a change is made to the product. The letter indicates the country of origin. An A indicates the product was made in the United States of America. The last five digits are unique to each instrument. The multimeter's serial number is located to the right of the multimeter's rear terminals.

Shipping instructions

If you need to ship the multimeter, be certain that the multimeter is in a protective package (use the original shipping containers and cushioning materials) to prevent transit damage. Such damage is not covered by warranty. Attach a tag to the shipment identifying the owner and indicating the service or repair needed. Include the model number and serial number of the multimeter. We suggest that you insure the shipment.

2 Getting Started

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Introduction

This chapter is intended for the novice multimeter user. It shows you how to use the multimeter's front panel, how to send commands to the multimeter from remote, and how to retrieve data from remote. Since front panel operation is discussed first, it covers important topics such as the power-on state, display annunciators, the various ways to select or enter parameters, and how to make a simple DC voltage measurement. For this reason, you should read the entire chapter even if you intend to use the multimeter primarily from remote.

Before Applying Power

- Make sure the line voltage selection switches on the multimeter's rear panel are set to match the local line voltage.
- Make sure the proper line fuse is installed.

If you have any questions concerning installation or power requirements, refer to Chapter 1.

Applying Power

To turn on the multimeter, depress the front panel Power switch. If the multimeter does not appear to turn on, verify that the multimeter is connected to line power. If line power is not the problem, remove the power cord and check the line power fuse and the line voltage selection switch settings.

Power-on self-test

When power is applied, the multimeter performs a limited power-on self-test. This test verifies that the multimeter is operating but does not necessarily verify that measurements will be accurate.

Power-on state

When the power-on self-test is finished, the multimeter beeps once, automatically triggers, automatically selects the range, and performs DC voltage measurements. Also, the multimeter has set many of its commands to predefined power-on values as shown in Table 2-1, This is called the power-on state.

Table 2-1 Power-on state

Command	Description
ACBAND 20, 2E6	AC bandwidth 20 Hz - 2 MHz
AZERO ON	Autozero enabled
DCV AUTO	DC voltage, autorange
DEFEAT OFF	Defeat disabled
DELAY -1	Default delay
DISP ON	Display Enabled
EMASK 32767	Enable all error conditions
END OFF	Disable GPIB EOI function
EXTOUT ICOMP, NEG	Input complete EXTOUT signal, negative pulse
FIXEDZ OFF	Disable fixed input resistance
FSOURCE ACV	Frequency and period source is AC voltage

Table 2-1 Power-on state (continued)

Command	Description
INBUF OFF	Disable input buffer
LEVEL 0, AC	Level trigger at 0%, AC-coupled
LFILTER OFF	Level filter disabled
LFREQ 50 or 60	Measured line frequency rounded to 50 or 60 Hz
LOCK OFF	Keyboard enabled
MATH OFF	Disable real-time math
MEM OFF	Disable reading memory (last memory operation = FIFO)
MFORMAT SREAL	Single real reading memory format
MMATH OFF	Disable post-process math
NDIG 7	Display 7.5 digits
NPLC 10	10 power line cycles of integration time
NRDGS 1, AUTO	1 reading per trigger, auto sample event
OCOMP OFF	Disable offset compensated resistance
OFORMAT ASCII	ASCII output format
QFORMAT NORM	Normal query format
RATIO OFF	Disable ratio measurements
RQS 0 (or 8)	0 disables status register conditions (if power-on SRQ was on when power was removed, value = 8).
SETACV ANA	Analog AC voltage mode
SLOPE POS	Positive slope for level triggering
SSRC LEVEL, AUTO	Level sync source event, auto synchronous AC voltage
SWEEP lOOE-9,1024	Sample interval 100 nanoseconds, 1024 samples
TARM AUTO	Auto trigger arm event
TBUFF OFF	Disable external trigger buffering
TIMER 1	1 second timer interval

Table 2-1 Power-on state (continued)

Command	Description
TRIG AUTO	Auto trigger event
DEGREE = 20 REF = 1 SCALE = 1 RES = 50 PERC = 1	

The display

In the power-on state, the display is continuously updated with each new DC voltage reading. Along the bottom of the display are a series of annunciators. These annunciators alert you to a variety of conditions. For example, the **SMPL** annunciator flashes whenever the multimeter has completed a reading. Table 2-2 describes the meaning of each display annunciator.

Table 2-2 Display annunciators

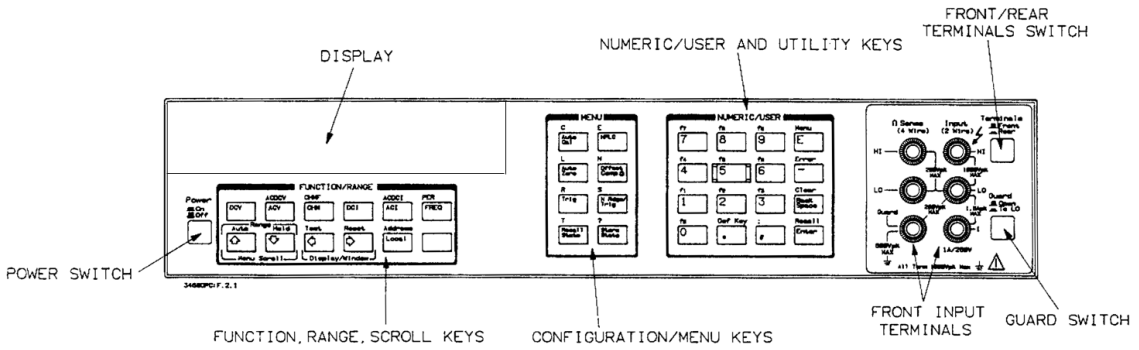
Display annunciator	Description
SMPL	Flashes whenever a reading is completed
REM	The multimeter is in the GPIB remote mode
SRQ	The multimeter has generated a GPIB service request
TALK	The multimeter is addressed to talk on GPIB
LSTN	The multimeter is addressed to listen on GPIB
AZERO OFF	Autozero is disabled
MRNG	Autorange is disabled (the multimeter is using a fixed range)
MATH	One or two real-time or post-process math operations enabled
ERR	An error has been detected
SHIFT	The shift key has been pressed
MORE INFO	More information concerning the present configuration is available (use the right arrow key to view the information)

NOTE If the **ERR** annunciator is illuminated at this point, an error was detected during or after the power-on self-test. You will learn how to determine the error later in this chapter in Reading the error register.

Operating from the front panel

This section shows you how to make a simple DC voltage measurement, how to use the various front panel keys, and describes the multimeter functions important to front panel operation. Figure 2-1 shows the multimeter's front panel features.

For Serial Number SG59350366 and MY59357708 and below.



For Serial Number SG59350386 and MY59358376 and above.

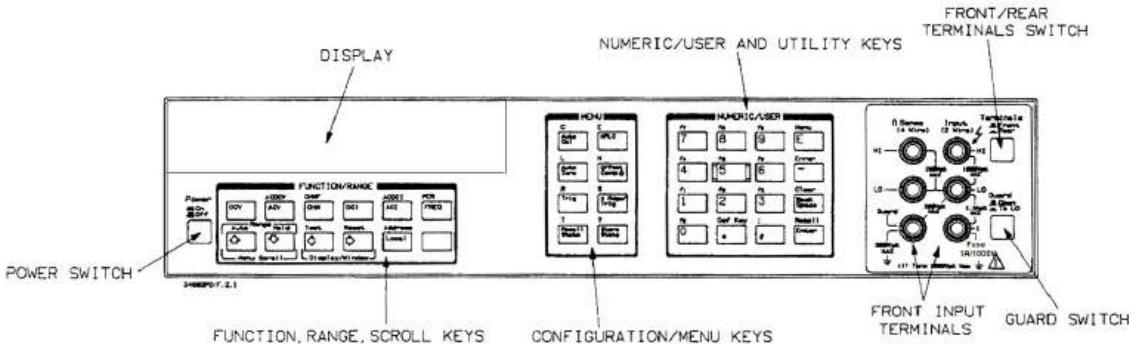


Figure 2-1 Front panel

Making a measurement

In the power-on state, DC voltage measurements are selected and the multimeter automatically triggers and selects the range. In the power-on state, you can make DC voltage measurements simply by connecting a DC voltage to the input terminals as shown in Figure 2-2. The connections shown in Figure 2-2 also apply for AC voltage, 2-wire resistance, AC+DC voltage, digitizing, and frequency or period measurements from a voltage input source. Refer to Chapter 3 for a CAUTION concerning the multimeter's maximum input voltage and current.

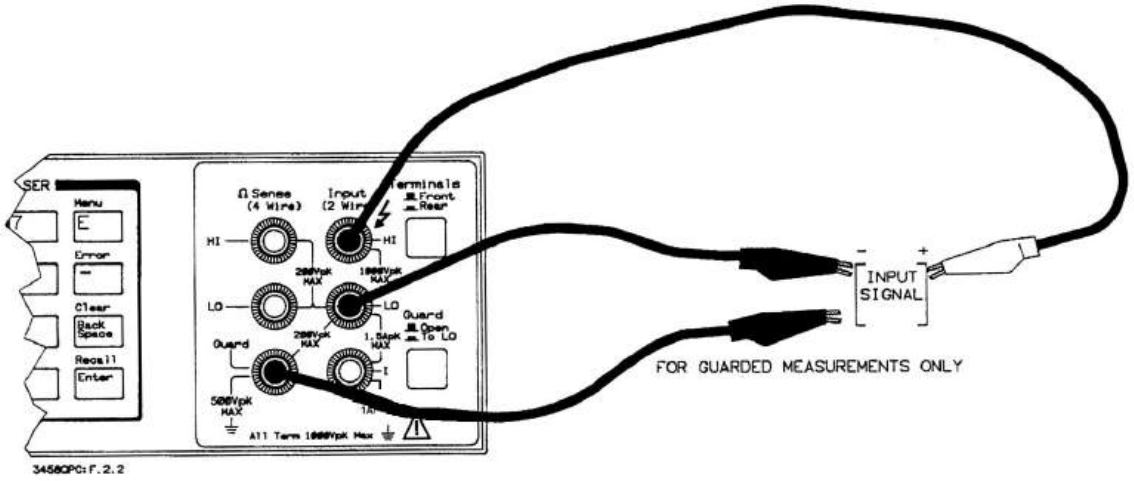


Figure 2-2 Standard 2-wire (plus guard) measurements

Changing the measurement function

The row of keys located directly under the display (**FUNCTION** keys) select the multimeter's standard measurement functions. Figure 2-3 shows the **FUNCTION** keys and the measurement function selected by each.

Key	Description
DCV	DC voltage measurements
ACV	AC voltage measurements
OHM	2-wire resistance measurements
DCI	DC current measurements
ACI	AC current measurements
FREQ	Frequency measurements
ACDCV + ACV	AC+DC voltage measurements
OHMF + OHM	4-wire resistance measurements
ACDCI + ACI	AC+DC current measurements
PER + FREQ	Period measurements

Figure 2-3 Function keys

In addition to the functions selected by the **FUNCTION** keys, the multimeter can perform direct-sampled or sub-sampled digitizing, ratio measurements, and AC or AC+DC voltage measurements using the synchronous or random measurement methods. These functions can be selected from the front panel by accessing the appropriate command(s) using the alphabetic menu keys (these keys are

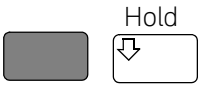
discussed later in this section under Using the MENU keys). For more information on any measurement function or method, refer to Chapter 1.

Autorange and manual ranging

In the power-on state, the multimeter automatically selects the appropriate measurement range. This is called autorange. In many cases, you will probably want to continue using autorange. However, you have two other ranging choices: hold and manual ranging.

Hold

This choice allows you to shut off autoranging. To do this, let autorange choose a range and then press:



NOTE **When you press the blue shift key, the display's SHIFT annunciator illuminates. The shifted keyboard functions are printed in blue above the keys.**

Notice the display's **MRNG** (manual range) annunciator is on. This annunciator is on whenever you are not using autorange.

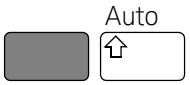
Manual ranging

The second choice lets you manually select the range. When the multimeter is in the measurement mode (that is, the multimeter is making and displaying measurements or the display is showing OVLD) you can change the range by pressing the up or down arrow keys. To go to a higher range, press:

By repeatedly pressing the up arrow key, you can increment up to the highest range. When you reach the highest range, pressing the up arrow key no longer

changes the range. To go to a lower range, press:

By repeatedly pressing the down arrow key, you can decrement down to the lowest range. When you reach the lowest range, pressing the down arrow key no longer changes the range. To return to autoranging, press:

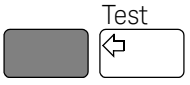


Self-test

When you applied power to the multimeter, it automatically performed a limited power-on self-test. Before you start making measurements, however, you may want to have more confidence that the multimeter is fully operational. This is the job of the self-test. The self-test performs a series of tests that check the multimeter's operability and accuracy.

NOTE **Always disconnect any input signals before you run self-test. If you leave an input signal connected to the multimeter, it cause a self-test failure.**

The self-test takes over 50 seconds. To run self-test press:



If the self-test passed, the display shows:

```
SELFTEST PASSED
```

When self-test passes, you have a high confidence that the multimeter is operational and, assuming proper calibration and autocalibration, that measurements will be accurate.

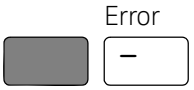
If any of the tests failed, the **ERR** annunciator illuminates and the display shows:

```
SELFTEST FAILED
```

If the self-test failed, one or more error conditions have been detected. Refer to the next section Reading the error register.

Reading the error register

Whenever the display's **ERR** annunciator is illuminated, one or more errors have been detected. A record of hardware errors is stored in the auxiliary error register. A record of programming and syntax errors is stored in the error register. To read the error record(s), press:



The lowest numbered error and a description of the error is displayed. For example, a possible error message is:

```
209,"HARDWARE FAILURE-
INTERNAL OVERLOAD:101"
```

Use the right arrow key to view the entire message. When the error message has a 100-series numeric prefix (e.g., 105), it indicates a programming or syntax error. A 200-series prefix (e.g., 209) indicates a hardware error.

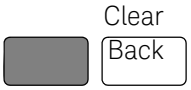
NOTE **When you get a hardware error (200-series prefix), run the self-test again. If you repeatedly get the error, the multimeter may need repair.**

If the **ERR** annunciator is still illuminated, more errors have been recorded. Repeat the above key sequence until all errors have been read and the **ERR** annunciator is no longer illuminated. When you have read all the errors, the error annunciator goes off. If you try to read another error, the display shows:

```
0,NO "ERROR"
```

You do not have to run self-test to get an error. The multimeter detects errors that occur while entering data, when changing functions or ranges, and so on. The multimeter beeps whenever it detects an error.

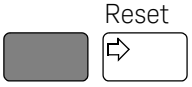
Whenever you want to clear information (such as an error description) from the display and return it to displaying measurements, press:



NOTE **You can also clear the display by repeatedly pressing the Back Space key (unshifted).**

Resetting the multimeter

Many times during operation, you may wish to return to the power-on state. The front panel **Reset** key returns you to the power-on state without having to cycle the multimeter's power. To reset the multimeter, press:



The multimeter begins the reset process with a display test which illuminates all display elements including the annunciators as shown in Figure 2-4. (By holding down the **Reset** key, the multimeter continuously performs its display test).

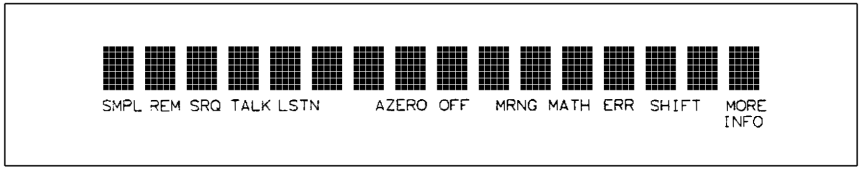


Figure 2-4 Display test

CAUTION

Pressing the shifted front panel **Reset** key performs the power-on sequence which has the same effect as cycling the multimeter's power. This destroys any stored reading and compressed subprograms, sets the power-on SRQ bit in the status register (these functions are discussed later in this manual), resets the A/D converter reference frequency and performs the power-on self test. Executing the RESET command from the alphabetic command menu (**MENU** keys) returns the multimeter to the power-on state but does not perform the power-on sequence. The **MENU** keys are discussed later in this chapter.

Using the configuration keys

The configuration keys (unshifted **MENU** keys) let you rapidly access the most frequently used multimeter features. Figure 2-5 shows each key, the corresponding multimeter command, and the function of each. (These functions are discussed in detail in Chapter 3 and Chapter 4.)

Key	Command	Description
Auto Cal	ACAL	Performs one or all autocal routines (It takes over 11 minutes to run all of the autocal routines. Never reset the multimeter to abort an autocal. Once you start an autocal you must complete it).
NPLC	NPLC	Sets integration time in terms of power line cycles
Auto Zero	AZERO	Enables or disables the autozero function
Offset Comp Ω	OCOMP	Enables or disables offset compensation for 2- or 4-wire resistance measurements
Trig	TRIG	Specifies the trigger event
N Rdgs/ Trig	NRDGS	Selects the number of readings per trigger event and the sample event
Recall State	RSTATE	Recalls a previously stored state from memory
Store State	SSTATE	Stores the multimeter's present state in memory

Figure 2-5 Configuration key functions

We will use the **Trig** key to demonstrate how to use the configuration keys. Press:

The display shows:

TRIG

This is the command header for the trigger command. Notice the multimeter automatically placed a space after the command header.

Selecting a parameter

For parameters that have a list of choices (non-numeric parameters), you can use the up and down arrow keys to review the choices. Press:

The display shows:

TRIG LEVEL

Press:

The display shows:

TRIG AUTO

When using the up or down arrow keys, if you step past the last parameter choice, a wraparound occurs to the other end of the menu. Suppose you want to suspend triggering. Press the up or down arrow key until the display shows:

TRIG HOLD

Press:

You have now changed the trigger event from auto (power-on state) to HOLD which causes the multimeter to stop taking readings. (Triggering is discussed in detail in Chapter 4.)

Default values

Most parameters have a default value. A default value is the value selected when you execute a command but do not specify a value. For example, the default value for the trigger parameter is SGL. Press:

Trig

Press:

Enter

Notice that the multimeter takes one reading and then stops (after the single trigger, the trigger event becomes HOLD regardless of the previously specified trigger event). You can also enter-1 to select the default value. Press:

Enter — 1 Enter

The multimeter again takes a single reading and then stops.

Numeric parameters

Some commands use numeric parameters, A numeric parameter is the actual value used by the multimeter. We will use the NPLC configuration key to demonstrate numeric parameters. Press:

NPLC

This display shows:

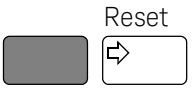
Notice that if you press the up or down arrow key, no parameter choice is displayed. This means there is no menu and you must enter a number. For example, press:

You have now selected 1 power line cycle of integration time for the A/D converter. Integration time is the actual time that the A/D converter measures the input signal. (Integration time is discussed in detail in Chapter 3.)

Exponential parameters

You can also enter numeric parameters using exponential notation. For example, press:

You have now selected 0.1 power line cycles of integration time. At this point, you should reset the multimeter to return the number of power line cycles to 10 by pressing:



Multiple parameters

Many commands have more than one parameter. (Multiple parameters are separated by commas.) We will use the NRDGS command, which has two parameters, as an example of a command with multiple parameters. Press:

The display shows:

The first parameter in the NRDGS command is a numeric parameter that specifies the number of readings made per trigger event. For example, to specify 5 readings

per trigger event, press:

The display shows:

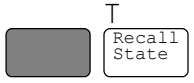
The second parameter of the NRDGS command specifies the event that initiates each reading. Since this is not a numeric parameter, a menu is available for this parameter. Use the up or down arrow keys to cycle through the list of choices. When the display shows:

Execute the command by pressing:

You have now selected five readings per trigger event. If you execute the TRIG SGL command, for example, the multimeter will take five readings and then stop. (The NRDGS command is discussed in detail in Chapter 4.)

Using the MENU keys

In addition to the configuration keys, the multimeter has an alphabetic command menu that can be accessed using the shifted **MENU** keys labeled C, E, L, N, R, S, and T. Each of these letters corresponds to the area you will enter into the command menu. For example, to enter the menu with commands starting with T, press:



The display shows:

You can now use the **Menu Scroll** keys (up or down arrow keys} to step through the menu in alphabetical order (down arrow key) or in reverse alphabetical order (up arrow key). For example, starting with the TARM display shown above, by pressing the down arrow key once, the display shows the next command in alphabetical order (TBUFF). (You can also press and hold the up or down arrow key to rapidly step through the menu.) Once you have found the desired command, you can press the **Enter** key to execute it immediately (using default parameter values if applicable). If you need to specify command parameter(s), with the command displayed, press the right arrow key or the comma key (or, if the first parameter is numeric, a numeric key). This selects the command and allows you to specify or select parameter(s) using the procedures described earlier in this section.

There are two alphabetic menus available: FULL and SHORT. You can select between these menus using the shifted **Menu** key. The specified menu choice is stored in continuous memory (not lost when power is removed). The FULL menu contains all commands except query commands that can be constructed by appending a question mark to a command (e.g., BEEP, BEEP?). (Query commands are discussed next.) The SHORT menu eliminates the GPIB bus-related commands, commands that are seldom used from the front panel, and any commands that have dedicated front panel keys (e.g., the **NPLC** key or the **Trig** key).

Query commands

There are a number of commands in the alphabetic command directory that end with a question mark. These commands are called query commands since each returns a response to a particular question. For example, access the LINE? query command from the command menu and press the **Enter** key. The multimeter responds to this query command by measuring and displaying the power line frequency. (Use the right arrow key to view the entire response.) As another example, access the TEMP? command from the command menu and press Enter. This command returns the multimeter's internal temperature in degrees Centigrade.

Standard queries

The FULL command menu contains the following standard query commands:

```
AUXERR?MCOUNT?

CAL?MSIZE?
```

```
CALNUM?OPT?
ERR?REV?
ERRSTR?SSPARM?
ID?STB?
ISCALE?TEMP?
LINE?
```

Additional queries

In addition to the queries listed above, you can create others by appending a question mark to any command that can be used to program the multimeter. For example, the AZERO command (**Auto Zero** configuration key) enables or disables the autozero function. You can determine the present autozero mode by appending a question mark to the AZERO command. To do this, press:

The multimeter responds by displaying the present autozero mode (power-on mode = ON). (Notice that this command is immediately executed; you do not have to press the **Enter** key.)

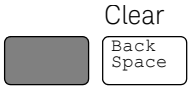
NOTE The QFORMAT command can be used to specify whether query responses will be numeric, alpha, or a combination of alpha and numeric. Refer to the QFORMAT command, in Chapter 6, for more information.

Display control

The shifted **Clear** key, the **Back Space** key, and the **Display/Window** keys (left and right arrow keys) allow you to control the display.

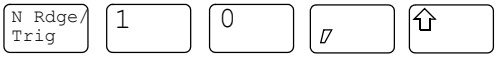
Clearing the display

Whenever you want to clear information (such as a query response) from the display, press:



Display editing

The **Back Space** key allows you to edit parts of a command string while entering the string or when the string is recalled (discussed later), For alpha parameters or command headers, pressing the **Back Space** key once erases the entire parameter or header. For commas, spaces, and numeric parameters, only one character is erased each time you press Back Space. For example, press:



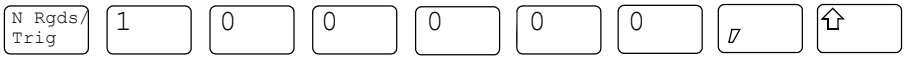
The display shows:

By pressing the **Back Space** key once, the entire second parameter (LINE) is erased. The display shows:

Now by pressing Back Space once, the comma is erased. Pressing Back Space two more times erases both numeric characters (10). At this point, you can reenter the first parameter using the numeric keypad and the second parameter using the **Menu Scroll** keys. Press the **Enter** key to execute the edited command.

Viewing long displays

When entering commands containing more than 16 characters, the previously entered characters are scrolled off the left side of the display to make room for those being entered. The **Display/Window** keys (left and right arrow keys) allow you to view the entire line by scrolling it left or right. The **Display/Window** keys can also be used to view long strings such as error messages, the calibration string (CALSTR? command), and user-defined key definitions (discussed later). For example, press:



The display shows:

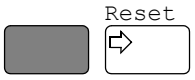
By pressing the left arrow key, you can view the first part of the command while scrolling the last part off the right side of the display. Now, by pressing the right arrow key, you can view the last part of the command and scroll the first part off the left side of the display.

NOTE Think of the display as a window you can move to the left or right using the arrow keys.

MORE INFO display

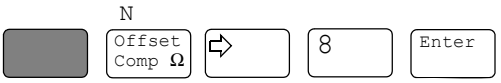
In addition to scrolling the display left and right, the **Display/Window** keys allow you to view additional display information when the display's **MORE INFO** annunciator is illuminated. For example, access and execute the SETACV RNDM command from the alphabetic command menu. Now press the front panel **ACV** key. Notice that the multimeter's **MORE INFO** annunciator is illuminated. This means there is more information available than is being displayed. Press:

The present AC voltage measurement method (SETACV RNDM) is displayed. At this point, reset the multimeter to return it to the power-on state by pressing:



Digits displayed

When the multimeter is displaying readings, you can vary the number of digits it displays. In the power-on state, the display is showing 7.5 digits although the multimeter is resolving 8.5 digits. To display all 8.5 digits, press:



NOTE **The display's leftmost digit (referred to as a 1/2 digit) is implied when you are specifying display digits.**

The NDIG command only masks digits from the display. It does not affect readings sent to reading memory or transferred over the GPIB bus. Also, you cannot view more digits than are being resolved by the multimeter.

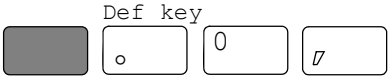
Recall

You can easily recall the last executed command without repeating the command entry process. Press:

The display will show the last command executed. (You cannot recall commands that are executed immediately such as Reset or DCV, or any command that contained the calibration security code.) By repeating the above keystrokes, you can recall previously executed commands. After recalling the desired command, you can modify it (see Display editing earlier in this section) and execute it by pressing Enter.

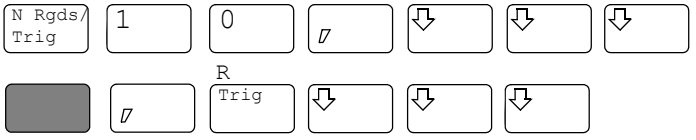
User-defined keys

You can assign a string of one or more commands to each of the **USER** keys labeled **f0** - **f9**. After assigning a string to one of these keys (maximum string length is 40 characters), pressing that key displays the string on the display. You can then execute the string by pressing the **Enter** key. The **Def** key allows you to assign a command string to any of the user-defined keys. For example, to assign the commands NRDGS 10,AUTO; TRIG SGL (the semicolon links multiple commands) to the user-defined key f0, press:



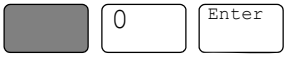
The display shows:

You can now enter the command string by pressing:



To store the string (this does not execute the string, it merely assigns it to the user-defined key), press:

To access and execute the string assigned to key **f0**, press:



The multimeter will take 10 readings and then stop.

As a special keyboard feature, you can access the string assigned to a key without pressing the shift key (except when you are in the process of entering a

command). For example, you can access and execute the string assigned to key **f0** by pressing:

You can also assign commands from the command menu to user-defined keys. You cannot assign a command using an immediate execute key (DCV, ACV, etc.) Instead, you must access that command from the menu. Key definitions stored from the front panel can be edited from the front panel. (You cannot edit a key definition that was downloaded from the controller.) Editing is done by pressing the user-defined key and, while the string is displayed, editing the string as described under Display editing earlier in this section. After editing the string, press the **Enter** key to execute the string. (The previous string is still assigned to the user-defined key.) An edited string cannot be re-assigned to a user-defined key. If you want to change a key definition, you must repeat the above steps.

Installing the keyboard overlay

Figure 2-6 shows the keyboard over-lay that fits over the **USER** keys. You can write on this overlay with a pencil to identify the command(s) assigned to each user-defined key.

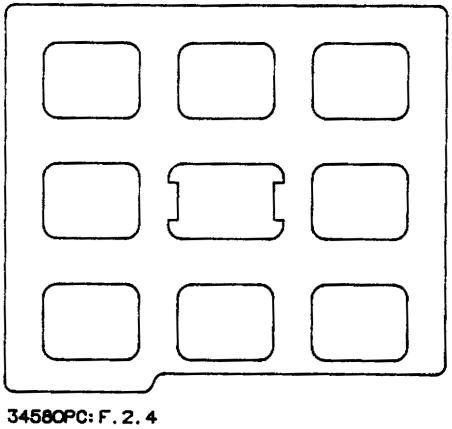


Figure 2-6 Keyboard overlay (Keysight part number 03458-84323)

The overlay is held in place by two tabs that secure it to the collar around numeric key **5**. To install the overlay, insert the overlay's left tab into the left side of the collar. Bend the overlay as shown in Figure 2-7 and press the right tab into the collar.

Figure 2-7 Installing the keyboard overlay

Operating from Remote

This section shows you the fundamentals of operating the multimeter from remote. This includes reading and changing the GPIB address, sending a command to the multimeter, and retrieving data from the multimeter.

Input/Output statements

The statements used to operate the multimeter from remote depend on the computer and its language. In particular, you need to know the statements the computer uses to input and output information. For example, the input statements for the Hewlett-Packard Series 200/300 BASIC language are:

```
ENTER or TRANSFER
```

The output statement is:

```
OUTPUT
```

Read your computer manuals to find out which statements you need to use. The examples in this manual use Hewlett-Packard Series 200/300 BASIC language.

Reading the GPIB address

Before you can operate the multimeter from remote, you need to know its GPIB address (factory setting = 22). To check the address, press:

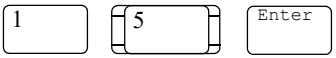
A typical display is:

The displayed response is the device address. When sending a remote command, you append this address to the GPIB interface's select code (normally 7). For example, if the select code is 7 and the device address is 22, the combination is 722.

Changing the GPIB address

Every device on the GPIB bus must have a unique address. If you need to change the multimeter's address, access the ADDRESS command from the command menu (**MENU** keys), with the display showing:

You can enter the new address. For example, press:



You have now changed the address to 15. If you want to change the address back to 22, repeat the above procedure (or use the **Recall** key) and specify 22 instead of 15.

Sending a remote command

To send the multimeter a remote command, combine the computer's output statement with the GPIB select code, the device address, and finally, the multimeter command. For example, to make the multimeter beep, send:

```
OUTPUT 722; "BEEP"
```

Notice the display's REM and LSTN annunciators are illuminated. This means the multimeter is in the remote mode and has been addressed to listen (receive a command).

Getting data from the multimeter

The multimeter is capable of outputting readings and responses to query commands. As an example, have the multimeter generate a response to a query command by sending:

```
OUTPUT 722;"ID?"
```

When you send a query from remote, the multimeter does not display the response as it did when you executed the command from its front panel. Instead, the multimeter sends the response to its output buffer. The output buffer is a register that holds a query response or a single reading until it is read by the

computer or replaced by new information. Use the computer's input statement to get the response from the output buffer. For example, the following program reads the response (Keysight 3458A) and prints it.

```
10 ENTER 722;A$
20 PRINT A$
30 END
```

The same technique allows you to get readings from the multimeter. Whenever the multimeter is making measurements and you have not enabled reading memory (reading memory is discussed in Chapter 4), you can get a reading by running the following program.

```
10 ENTER 722;A
20 PRINT A
30 END
```

The Local key

When you press a key on the multimeter's keyboard while operating from remote, the multimeter does not respond. This is because the multimeter is in the remote mode (as indicated by the display's **REM** annunciator) and is ignoring all but the **Local** key. To return the multimeter to local mode, press:

3 Configuring for Measurements

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Introduction

This chapter shows how to configure the multimeter for all types of measurements except digitizing.[1] This chapter also shows you how to use subprogram and state memory, the input buffer, and the status register. After using this chapter to configure the multimeter for your application, you can then use Chapter 4 to learn how to trigger readings and transfer them to reading memory or the GPIB output buffer. The major sections in this chapter are:

- General Configuration
- Configuring for DC or Resistance Measurements
- Configuring for AC Measurements
- Configuring for Ratio Measurements
- Using Subprogram Memory
- Using State Memory
- Using the Input Buffer
- Using the Status Register

[1] This chapter doesn't address digitizing specifically although most of the information under General Configuration does apply to digitizing. Refer to Chapter 5 for specific information on digitizing.

General Configuration

This section discusses the multimeter's self-test, calibration requirements, and general configuration topics that apply to many or all measurement functions.

Self-test

Prior to configuring for measurements, you should run the self-test to ensure the multimeter is operational. The self-test takes approximately 50 seconds to complete. To run self-test, send:

```
OUTPUT 722;"TEST"
```

If self-test passes, you have a high confidence level that the multimeter is operational and, assuming proper calibration, that measurements will be accurate. If one or more tests fail, the multimeter sets bit(s) in the auxiliary error register, which also sets bit 0 in the error register, and the display's **ERR** annunciator illuminates.

Reading the error registers

When a hardware error is detected, the multimeter sets a bit in the auxiliary, error register and also sets bit 0 in the error register.When a programming error is detected, the multimeter sets a bit in the error register only.

The ERRSTR? command reads each error (one error at a time) and then clears the corresponding bit. If one or more bits are set in the auxiliary error register, the ERRSTR? command reads that register first before proceeding to the error register. The ERRSTR? command returns two responses. The first response is the decimal: value of the least significant (lowest numbered) set bit. The second response is a message (string) explaining the error (the maximum string length returned is 200 characters). After reading a bit, the ERRSTR? command clears that bit.

The following program uses the ERRSTR? command to read all errors, one error at a time. After all set bits have been read and cleared, or if there were no set bits in either register, the ERRSTR? command returns *0, "NO ERROR"*.

```
10 OPTION BASE 1
!COMPUTER ARRAY NUMBERING STARTS WITH 1
20 DIM A$[200]
```

```
!DIMENSION STRING VARIABLE
30 OUTPUT 722; "ERRSTR?"
!READS ERROR MESSAGE
40 ENTER 722; A,A$
!ENTERS NUMERIC INTO A, STRING INTO A$
50 PRINT A,A$
!PRINTS RESPONSES
60 IF A>0 THEN GOTO 30
!LOOP TO READ EACH ERROR
70 END
```

The ERR? and AUXERR? commands return the decimal sum of all set bits in the error register and the auxiliary error register, respectively. Refer to these commands in Chapter 6 for example programs and listings of the possible errors.

Calibration

The multimeter has two forms of calibration: external calibration and autocalibration. The external calibration involves a procedure using external reference sources. Refer to the *3458A Calibration Manual* for more information on the external calibration.

The CALNUM? query command returns a number indicating the number of times the multimeter has been externally calibrated. By routinely checking this number, you can monitor the calibrations performed on the multimeter. The following program reads and returns the present calibration number.

```
10 OUTPUT 722;"CALNUM?"
20 ENTER 722;A
30 PRINT A
40 END
```

Autocalibration

The multimeter has four autocalibration (autocal) routines: DCV, AC, OHMS, and ALL. These routines improve short-term accuracy for many or all measurement functions, but are not substitutes for periodic external calibration of the multimeter. The measurement functions affected by each routine are:

- The DCV routine enhances all measurement functions. This routine takes about 2 minutes and 45 seconds to perform.
- The AC routine performs specific enhancements for AC or AC+DC voltage (all measurement methods), AC or AC+DC current, direct- or sub-sampled digitizing (AC- or DC-coupled), frequency, and period measurements. The AC routine takes about 2 minutes and 45 seconds to perform.
- The OHMS routine performs specific enhancements for 2 or 4-wire ohms. DC current, and AC current measurements. The OHMS routine takes about 11 minutes to perform.
- The ALL routine enhances all measurement functions by performing all of the above routines. The ALL routine takes about 16 minutes to perform.

After performing autocal, let the instrument sit for the recommended time shown below before taking a reading, to allow the relays to thermally stabilize:

Types of ACAL	Settling time
ACAL ALL	30 minutes
ACAL DCV	15 minutes
ACAL OHM	30 minutes
ACAL ACV	15 minutes

NOTE You should not cycle power or reset the multimeter while an autocal routine is being performed. If you do, the multimeter generates the ACAL REQUIRED error (since many or all of its autocal constants have been erased). You must then perform the ALL routine to eliminate the error.

Since the DCV routine applies to all measurement functions, you should perform the DCV autocal before performing the AC or OHMS autocal, or perform ALL of the routines (see second example below).

Running autocal

Suppose you intend to make 4-wire ohms measurements. The DCV autocal routine increases the short term accuracy for all measurements and the OHMS autocal enhances resistance measurements (and current measurements). The following program performs the DCV autocal followed by the OHMS autocal.

```
10 OUTPUT 722; "ACAL DCV"
20 OUTPUT 722; "ACAL OHMS"
30 END
```

If autocal is secured (it is not secured when shipped from the factory), you must enter the security code to perform autocal; refer to the ACAL command in Chapter 6 for more information. You can perform all of the autocal routines (DCV first, followed by OHMS and AC) by sending:

```
OUTPUT 722; "ACAL ALL"
```

Always disconnect any input signals before performing autocal. If you leave an input signal connected to the multimeter, it may adversely affect the autocal and subsequent measurements.

When to use autocal

For maximum accuracy, we recommend performing ACAL ALL once every 24 hours or when the multimeter's temperature changes by ± 1 °C from when it was last externally calibrated or from the last autocal. (We recommend that the calibrator store the multimeter's internal calibration temperature using the CALSTR command; this can be read later using the CALSTR? command.) The following example shows how to use the TEMP? command to monitor the multimeter's internal temperature (in degrees Celsius).

```
10 OUTPUT 722;"TEMP?"
20 ENTER 722;A
30 PRINT A
40 END
```

The autocal constants are stored in continuous memory (they remain intact when power is removed). Therefore, it is not necessary to perform autocal simply because power has been cycled.

Selecting the input terminals

The multimeter has both front and rear terminals for measurement connections. The front panel Terminals switch allows you to select between the two (depressed = Rear, out = Front). You cannot select the input terminals from remote. The measurement connection illustrations in this chapter show the front terminal connections only. For rear terminal connections, connect each wire to the similarly labeled rear terminal. We recommend high impedance, low dielectric absorption cables for all measurement connections.

WARNING

- Only qualified, service trained personnel who are aware of the hazards involved should remove or install the multimeter or connect wiring to the multimeter. Disconnect the multimeter's power cord before removing any covers, changing the line voltage selector switches, or installing or changing the line power fuse.
- Measuring high voltage is always hazardous. All multimeter input terminals (both front and rear) must be considered as hazardous whenever inputs in excess of 42 V are connected to any terminal. Regard all terminals as being at the same potential as the highest voltage applied to any terminal.
- Keysight recommends that the wiring installer attach a label to any wiring having hazardous voltages. This label should be as close to the input terminals as possible and should be an eye catching color, such as red or yellow. Clearly indicate on the label that high voltages may be present.

CAUTION The current input terminals (I) are rated at ±1.5 A peak with a maximum non-destructive input of <1.25 A RMS. Current inputs are fuse protected. The multimeter's input voltage ratings are:

Table 3-1 Input ratings

	Rated input	Maximum non-destructive input
HI to LO Input:	± 1000 V peak	±1200 V peak
HI/LO Ω Sense to LO Input:	± 200 V peak	± 350 V peak
HI to LO Ω Sense Input:	± 200 V peak	± 350 V peak
LO Input to Guard:	± 200 V peak	± 350 V peak
Guard to Earth Ground:	± 500 V peak	± 1000 V peak
HI/LO Input, HI/LO Ω Sense, or I terminal to earth ground:	± 1000 V peak	± 1500 V peak
Front terminals to rear terminals:	± 1000 V peak	± 1500 V peak

The multimeter will be damaged if any of the above maximum non-destructive inputs are exceeded.

Guarding

The measurement connection illustrations in this chapter show the multimeter's Guard terminal connected to the low side of the measurement source (guarded measurements). This configuration provides maximum *effective common mode rejection* (ECMR) on the input terminals selected by the Terminals switch, assuming the Guard switch is in the Open (out) position. For non-guarded measurements, depress the Guard switch (TO LO position) and do not connect the Guard terminal to the measurement source. In the TO LO position, the Guard switch internally connects the Guard terminal to the LO Input terminal on the terminals selected by the Terminals switch. This configuration provides reduced ECMR.The specifications in Appendix A shows the ECMR for guarded measurements. We recommend high impedance, low dielectric absorption cables for all measurement connections.

Suspending readings

In the multimeter's power-on state, the trigger arm, trigger, and sample events are set to AUTO (these events are discussed in detail in Chapter 4). This causes the multimeter to continuously take readings. Prior to configuring the multimeter for measurements, you should suspend readings. Suspending readings decreases the amount of time required for configuration and prevents the possibility of undesired readings being placed in reading memory or the GPIB output buffer. You can suspend readings by presetting the multimeter (discussed next) or by setting the trigger arm or trigger event to HOLD as follows:

```
OUTPUT 722; "TARM HOLD"
```

or

```
OUTPUT 722; "TRIG HOLD"
```

After configuring the multimeter, you can enable measurements by changing the trigger arm or trigger event from HOLD to some other event. (Refer to Chapter 2 for more information on triggering measurements).

Presetting the multimeter

The PRESET NORM command is similar to the RESET command but configures the multimeter to a good starting point for remote operation. (RESET is primarily for front panel use.) It's a good idea to execute PRESET NORM as the first step when configuring the multimeter since it sets the multimeter to a known configuration and suspends readings by setting the trigger event to synchronous (TRIG SYN) command. Table 3-2 shows the commands executed by the PRESET NORM command.

Table 3-2 PRESET NORM state

Command	Description
ACBAND 20,2E+6	AC bandwidth 20 Hz - 2 MHz
AZERO ON	Autozero enabled
BEEP ON	Beeper enabled
DCV AUTO	DC voltage measurements, autorange
DELAY –1	Default delay

Table 3-2 PRESET NORM state (continued)

Command	Description
DISP ON	Display enabled
FIXEDZ OFF	Disable fixed input resistance
FSOURCE ACV	Frequency and period source is AC voltage
INBUF OFF	Disable input buffer
LOCK OFF	Keyboard enabled
MATH OFF	Disable real-time math
MEM OFF	Disable reading memory
MFORMAT SREAL	Single real reading memory format
MMATH OFF	Disable post-process math
NDIG 6	Display 6.5 digits
NPLC 1	1 power line cycle of integration time
NRDGS 1,AUTO	1 reading per trigger, auto sample event
OCOMP OFF	Disable offset compensated ohms
OFORMAT ASCII	ASCII output format
TARM AUTO	Auto trigger arm event
TIMER 1	1 second timer interval
TRIG SYN	Synchronous trigger event
All math registers set to 0 except:	
DEGREE = 20	
PERC = 1	
REF = 1	
RES = 50	
SCALE = 1	

When attempting to preset from remote, it is possible that the multimeter is busy or the GPIB interface is being held. In either case, the multimeter will not respond to a remote command. It's good practice to send the GPIB Device Clear command prior to presetting the multimeter. The multimeter responds immediately to the Device Clear command. The following program sends the Device Clear command followed by the PRESET NORM command:

```
10 CLEAR 722
20 OUTPUT 722;"PRESET NORM"
30 END
```

In addition to the PRESET NORM command, the multimeter has a PRESET FAST command (configures for fast readings and transfers), which is discussed in Chapter 4, and a PRESET DIG command (configures for DCV digitizing) which is discussed in Chapter 5.

Specifying a measurement function

The first parameter of the FUNC command selects the measurement function. For example, to specify DC voltage measurements, send:

```
OUTPUT 722;"FUNC DCV"
```

The FUNC command header is optional and can be omitted. For example, you can specify DC voltage measurements simply by sending:

```
OUTPUT 722;"DCV"
```

The remaining examples in this chapter use the shortened (no FUNC header) version. Table 3-3 shows the various measurement function parameters and the function selected by each.

Table 3-3 Measurement function parameters

Function parameter	Description
ACDCI	Selects AC current measurements, DC coupled
ACDCV	Selects AC voltage measurements, DC coupled
ACI	Selects AC current measurements, AC coupled
ACV	Selects AC voltage measurements, AC coupled
DCI	Selects DC current measurements

Table 3-3 Measurement function parameters (continued)

Function parameter	Description
DCV	Selects DC voltage measurements
DSAC[a]	Direct sampling, AC coupled
DSDC[a]	Direct sampling, DC coupled
FREQ	Selects frequency measurements
OHM	Selects 2-wire ohms measurements
OHMF	Selects 4-wire ohms measurements
PER	Selects period measurements
SSAC[a]	Sub-sampling, AC coupled
SSDC[a]	Sub-sampling, DC coupled

[a] Refer to Chapter 5, "Digitizing" for more information on these functions.

Autorange

When the autorange function is enabled, the multimeter samples the input prior to each reading (when readings are being triggered) and automatically selects the correct range. Since autorange requires sampling the input, measurements made with autorange enabled take longer than measurements made on a fixed range. In the power-on/PRESET NORM state, autorange is enabled. If you intend to measure a fairly stable input signal, you can use the ARANGE ONCE command to allow autorange to select the correct range (when readings are triggered) and then disable autorange for subsequent readings. This allows you to get the automatic range selection advantage of autorange and also the speed advantage of readings made with autorange disabled. To do this, send:

```
OUTPUT 722;"ARANGE ONCE"
```

Now when triggering begins, the multimeter will select the correct range and then disable autorange. Later, if you need to enable autorange, send:

```
OUTPUT 722; "ARANGE ON"
```

Specifying the range

You specify a fixed range using the first parameter of one of the function commands (ACV, DCV, OHM. etc.) or the RANGE command. This parameter is called *max._input*since you specify it as the input signal's maximum expected amplitude (or the maximum resistance for resistance measurements). The multimeter then chooses the correct range. When specifying *max._input*, use the absolute value of the input signal—no negative numbers. For example, to specify DC voltage with a maximum input of -2.5 volts, send:

```
OUTPUT 722; "DCV 2.5"
```

In this case, the multimeter selects the 10 VDC range. To specify a different *max_input* (e.g. 15 V) without changing the measurement function, send:

```
OUTPUT 722; "RANGE 15"
```

In this case, the multimeter selects the 100 V range.

NOTE **For frequency and period measurements, the *max._input* parameter specifies the maximum amplitude of the input signal. It does not specify the frequency range (Hz) or the period range (seconds).**

You select the autorange mode by defaulting the *max._input* parameter or by specifying AUTO. For example, to select, autorange using the DCV command, send:

```
OUTPUT 722; "DCV"
```

Refer to the FUNC or RANGE command in Chapter 6 for tables showing the ranges for each measurement function.

Configuring for DC or Resistance Measurements

This section describes how to configure the multimeter for making DC voltage, DC current, and 2-wire or 4-wire resistance (ohms) measurements.

DC voltage

The multimeter measures DC voltage on any of five ranges. Table 3-4 shows each DC voltage range and its full scale reading (which also shows the maximum number of digits for the range). Table 3-4 also shows the maximum resolution and the input resistance for each range. (Resolution is a function of the specified integration time: refer to Setting the integration time later in this section for more information.) Figure 3-1 shows the front terminal connections for all types of voltage measurements. In the power-on/PRESET NORM states. DC voltage measurements are selected. You can also specify DC voltage measurements using the DCV command. For example, to specify DC voltage measurements on the 1 V range, send:

```
OUTPUT 722;"DCV 1"
```

Table 3-4 DC voltage ranges

DCV range	Full scale reading	Maximum resolution	Input resistance
100 mV	120.00000 mV	10 nV	>10 GΩ[a]
1 V	1.20000000 V	10 nV	>10 GΩ[a]
10 V	12.0000000 V	100 nV	>10 GΩ[a]
100 V	120.000000 V	1 µV	10 MΩ
1000 V	1050.00000 V	10 µV	10 MΩ

[a] With FIXEDZ OFF. With FIXEDZ ON the input resistance is fixed at 10 MΩ. Refer to Fixed input resistance later in this chapter for more information.

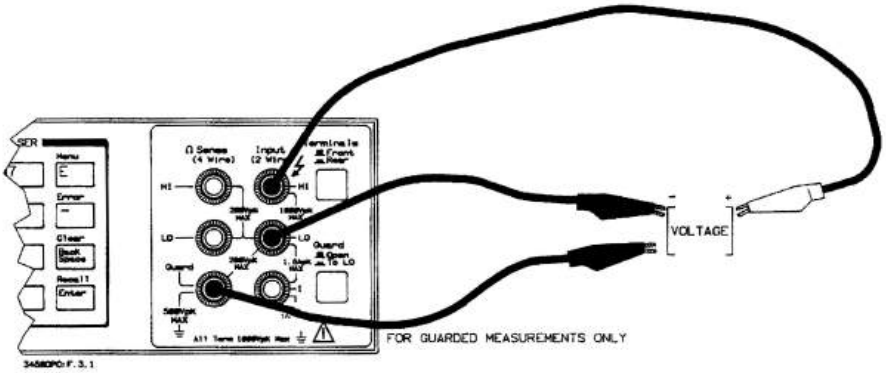

Figure 3-1 Voltage measurement connections

DC current

The multimeter measures current by placing an internal shunt resistor across the input terminals, measuring the voltage across the resistor, and calculating the current (current = voltage/resistance). The multimeter's front and rear current inputs are protected. For Serial Number SG59350366 and MY59357708 and below by 1 A, 250 V fuse. For Serial Number SG59350386 and MY59358376 and above by 1 A, 1000 V fuse. Figure 3-2 shows the front terminal connections for all types of current measurements.

The multimeter measures DC current on any of eight ranges. Table 3-5 shows each DC current range and its full-scale reading (the full scale reading also shows the maximum number of digits for each range). Table 3-5 also shows the maximum resolution and the shunt resistor used for each range. (Resolution is a function of the specified integration time: refer to Setting the integration time later in the section for more information.) You specify DC current measurements using the DCI command. For example, to specify DC current measurements on the 10 µA range, send:

```
OUTPUT 722;"DCI 10E-6"
```

Table 3-5 DC current ranges

DCI range	Full scale reading	Maximum resolution	Shunt resistor
lOO nA	120.000 nA	1 pA	545.2 kΩ
1 µA	1.200000 µA	1 pA	45.2 kΩ
10 µA	12.000000 µA	1 pA	5.2 kΩ
100 µA	120.00000 µA	10 pA	730 Ω
1 mA	1.2000000 mA	lOO pA	100 Ω
10 mA	12.000000 mA	1 nA	10 Ω
100 mA	120.00000 mA	10 nA	1 Ω
1 A	1.0500000 A	100 nA	0.1 Ω

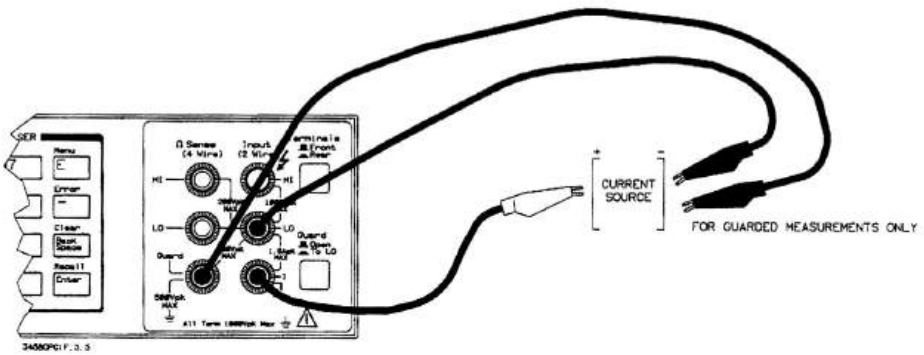

Figure 3-2 Current measurement connections

Resistance

The multimeter measures resistance by supplying a known current through the unknown resistance being measured. The current passing through the resistance generates a voltage across it. The multimeter measures this voltage and calculates the unknown resistance (resistance = voltage/current). Table 3-6 shows each 2-and 4-wire ohms range and its full-scale reading (the full scale reading also shows the maximum number of digits for each range). Table 3-6 also shows the maximum resolution and current sourced for each range. (Resolution is a function of the specified integration time: refer to Setting the integration time later in this section for more information.)

Table 3-6 Resistance ranges

OHM(F) range	Full scale reading	Maximum resolution	Current sourced
10 Ω	12.00000 Ω	10 µΩ	10 mA
100 Ω	120.00000 Ω	10 µΩ	1 mA
1 kΩ	1.2000000 kΩ	100 µΩ	1 mA
10 kΩ	12.000000 kΩ	1 mΩ	100 µA
100 kΩ	120.00000 kΩ	10 mΩ	50 µA
1 MΩ	1.2000000 MΩ	100 mΩ	5 µA
10 MΩ	12.000000 MΩ	1 Ω	500 nA
100 MΩ	120.00000 MΩ	10 Ω	500 nA
1 GΩ	1.2000000 GΩ	100 Ω	500 nA

2-wire ohms

Two-wire ohms is most commonly used when the resistance of the test leads is much less than the value being measured. If the lead resistance is large compared to the resistance to be measured, readings will be inaccurate. For example, suppose you are measuring a 1 Ω resistor located 10 feet away. If you use 24-gauge copper wire to make the connections, the 20 feet of leads contribute about 0.5 ohms to the measurement. This makes the total measurement 1.5 ohms--an error of 50%. Some other factors that may cause high lead resistance are loose or dirty connections, kinked or damaged wires, or a very hot

environment. You can enhance the accuracy of 2-wire ohms measurements with the NULL math operation (refer to NULL in Chapter 4 for more information). Figure 3-3 shows the front connections for 2-wire ohms measurements. You specify 2-wire ohms measurements using the OHM command. For example, to specify 2-wire ohms measurements on the 1 kΩ range, send:

```
OUTPUT 722;"OHM 1E3"
```

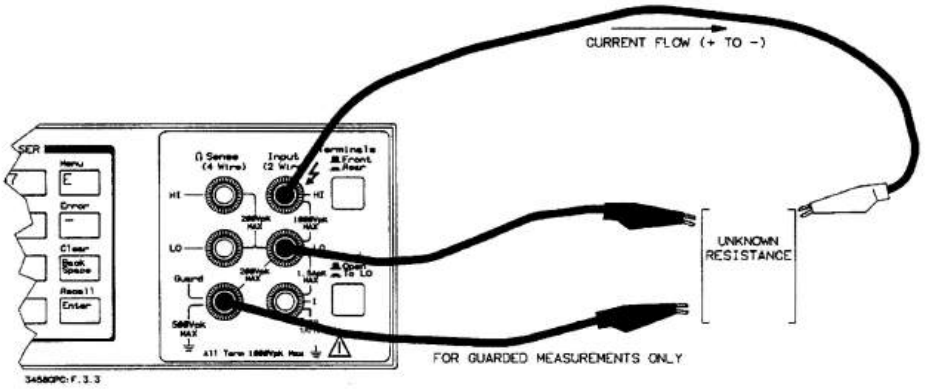

Figure 3-3 2-Wire ohms measurement connections

4-wire ohms

The 4-wire ohms mode eliminates the measurement error caused by test lead resistance. In 2-wire ohms, the voltage measurement is made across the combined resistance of the test leads and the unknown resistance. In 4-wire ohms, the voltage is measured across the unknown resistance only, not the combined resistance. This is important when the test lead resistance is high in comparison to the resistance being measured. Figure 3-4 shows the front connections for 4-wire ohms measurements. You specify 4-wire ohms measurements using the OHMF command. For example, to specify 4-wire ohms measurements on the 10 MΩ range, send:

```
OUTPUT 722; "OHMF 10E6"
```

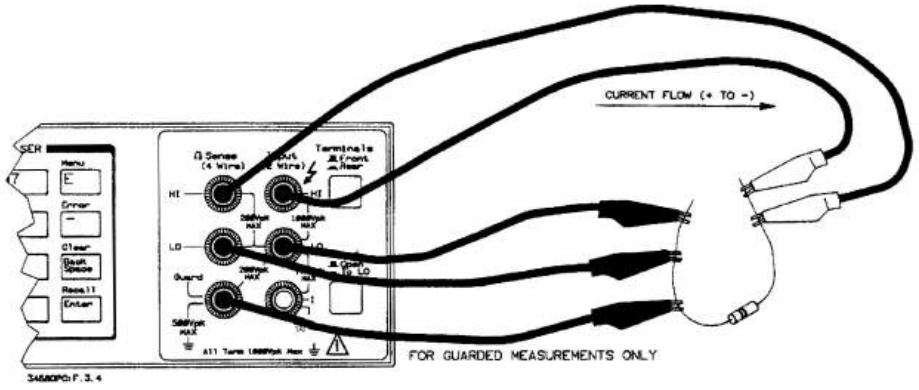

Figure 3-4 4-Wire ohms measurement connections

Configuring the A/D converter

The A/D converter's configuration determines the measurement speed, resolution, accuracy, and normal mode rejection[1] for DC or ohms measurements. The factors that affect the A/D converter's configuration are the reference frequency, the specified integration time, and the specified resolution.

The reference frequency

When power is applied, the multimeter measures the power line frequency, rounds the value to 50 Hz or 60 Hz, and sets the A/D converter's *reference* frequency to the rounded value. (For a 400 Hz power line frequency, the multimeter uses 50 Hz as the *reference frequency*, which is a subharmonic of 400 Hz.) For DC or ohms measurements, the multimeter achieves normal mode rejection (NMR) for noise at the reference frequency when the integration time is ≥1 power line cycle. See Setting the integration time (following) for more information.

[1] Normal mode rejection (NMR) is the multimeter's ability to reject noise at the power line frequency from DC or ohms measurements.

Changing the reference frequency

For most operating conditions, the power-on reference frequency allows for excellent NMR. However, for maximum NMR you should set the reference frequency to the exact power line frequency. (If your power line frequency is subject to drift, you may have to periodically correct the reference frequency.) The following command measures the power line frequency and sets the reference frequency to the exact measured value (for a
400 Hz line frequency. the multimeter divides the measured value by 8 and uses that as the reference frequency).

```
OUTPUT 722;"LFREQ LINE”
```

You can also use the LFREQ command to directly specify the reference frequency. This is particularly useful when the multimeter has a different power line frequency than the device being measured. Suppose, for example, the multimeter has a power line frequency of 60 Hz and the device being measured has a power line frequency of 50 Hz. For this application you can achieve NMR by setting the reference frequency to 50 Hz as follows:

```
OUTPUT 722;"LFREQ 50"
```

Remember that whenever power is cycled or the front panel **Reset** key is pressed, the reference frequency returns to the rounded value of 50 or 60 Hz.

Setting the integration time

Integration time is the period of time that the A/D converter measures the input signal. For DC or ohms measurements, the integration time determines the measurement speed, accuracy, maximum digits of resolution, and the amount of NMR for noise at the A/D converter's reference frequency, You can specify integration time in terms of power line cycles (PLCs) using the NPLC command or directly (in seconds) using the APER command. Since the NPLC and APER commands both set the integration time, executing either will cancel the integration time previously established by the other.

Specifying power line cycles

The multimeter achieves NMR for noise at the A/D converter's reference frequency when the integration time is ≥1 power line cycles. You can specify integration time in terms of power line cycles (PLCs) using the NPLC command. The multimeter multiplies the specified number of PLCs by the period of the A/D converter's reference frequency (LFREQ command) to determine the integration time. For example, the period of a 50 Hz power line is 1/50 = 20 msec. If you

specify 10 PLCs, the integration time is 200 msec. In the power-on state, integration time is set to 10 PLCs. In the PRESET NORM state, integration time is set to 1 PLC. To set the integration time for the fastest measurements (with the lowest accuracy, lowest resolution. and no NMR), send:

```
OUTPUT 722; "NPLC 0"
```

To specify the most accuracy, highest resolution, and 80 dB of NMR for DC or ohms measurements (with the slowest measurement speed), send:

```
OUTPUT 722;"NPLC 1000"
```

You can specify power line cycles in the following ranges:

- 0 - 1 PLC (in .000006 PLC steps for 60 Hz ref. frequency or .000005 PLC steps for 50 Hz ref. frequency)
- 1- 10 PLC in 1 PLC steps
- 10 - 1000 PLCs in 10 PLC steps

NOTE **For integration times greater than 10 PLCs, the multimeter averages a number of readings made using 10 PLCs of integration time. For example, if you specify 60 PLCs, the multimeter averages six 10 PLC readings.**

The wide range of PLC settings provides flexibility in the selection of measurement speed. accuracy, resolution, and NMR. Typically, you should select the integration time that provides adequate speed while maintaining an acceptable amount of resolution and NMR. The specifications tables in Appendix A show the relationship of integration time to digits of resolution and NMR for DC and ohms measurements.

Specifying integration time directly

For DC or ohms measurements, you can specify the integration time directly (in seconds) using the APER (aperture) command. For example, to specify 22 ms of integration time, send:

```
OUTPUT 722;"APER.022"
```

NOTE When using the APER command, the multimeter does not average readings for long integration times as it does with the NPLC command. For example, if you specify 60 = PLCs (1 second of integration time at a 60 Hz = line frequency) using the NPLC command, the multimeter averages six 10 PLC readings. If you specify 1 second of integration time using the APER command, the multimeter integrates a single reading for 1 second.

With the APER command, you can specify integration time from 500 ns to 1 s in increments of 100 ns. The APER command is most commonly used when sampling a specific part of a signal (such as a pulse) or for digitizing. You can also use the APER command to reject a noise signal of a specific frequency from the input signal. To do this, set the integration time equal to an integral multiple of the period of the signal to be rejected. For example, to reject noise at 100 Hz (period = 10 ms), specify an integration time of 10 ms, 20 ms, 30 ms, etc.

Specifying resolution

You specify the measurement resolution as the last parameter of a function command (FUNC, ACV, DCV, etc.) or the RANGE command.[1] This parameter is called *%_ resolution* since you specify it as a percentage of the command's *max._input* parameter (see Specifying the range earlier in this chapter). The multimeter multiplies the specified *%_resolution* parameter times the *max._input* parameter to determine the measurement resolution. To compute the *%_resolution* parameter, use the equation:

%_ resolution = (actual resolution/maximum input) × 100

For example, suppose the maximum expected input is 10 VDC and you need 1 mVDC of resolution. The equation evaluates to:

%_ resolution = (0.001/10) × 100 = 0.01

If you default the *%_resolution* parameter, the integration time will be that specified by the last APER or NPLC command executed.

For DC or ohms measurements (and analog AC measurements), resolution is determined by the A/D converter's integration time. When you specify a resolution, you are actually indirectly specifying an integration time. Since the

[1] You can also specify resolution using the RES command. Refer to the RES command in Chapter 6 for examples showing its usage.

APER or NPLC command can also specify an integration time, an interaction occurs when you specify resolution as follows:

- If you send the APER or NPLC command *before* specifying resolution, the multimeter satisfies the command that specifies greater resolution (more integration time).
- If you send the APER or NPLC command *after* specifying resolution. the multimeter uses the integration time specified by the APER or NPLC command, and any previously specified resolution is ignored.

When to specify resolution

For DC or ohms measurements, you should specify resolution when the resolution provided by the NPLC or APER command is not sufficient. For example, in the following program, line 10 specifies 1 PLC of integration time which provides 60 dB of NMR and 7½ digits of resolution. This produces an actual resolution of 1 µV on the 10 V range. For this application, 100 nV of resolution is required with a *max._input* of 10 V. The preceding equation produces a *%_resolution* parameter of 0.000001 (1E-6). This is specified in line 20.

```
10 OUTPUT 722;"NPLC 1"
20 OUTPUT 722;"DCV 10, 1E-6"
30 END
```

Autozero

The autozero function ensures that any offset errors internal to the multimeter are nulled from subsequent DC or ohms measurements. The autozero function is controlled using the AZERO command. With AZERO ON, the multimeter internally disconnects the input signal and makes a zero reading following every measurement. It then algebraically subtracts the zero reading from the preceding measurement. With AZERO OFF or ONCE, the multimeter takes one zero reading and algebraically subtracts this from subsequent readings. After you execute AZERO OFF or AZERO ONCE, the multimeter takes the autozero measurement when the first trigger arm event occurs for all events except TARM EXT which causes an autozero measurement when the TARM EXT command is executed. (The trigger arm event is discussed in Chapter 4.) The autozero measurement is updated whenever the measurement function, range, or integration time is changed (this update is made when the trigger arm event occurs or TARM EXT is executed). In the power-on/PRESET NORM state, AZERO is set to ON. You can change it by sending:

```
OUTPUT 722;"AZERO OFF"
```

NOTE You should leave autozero on (AZERO ON command) for 4-wire ohms measurements. If you must disable autozero (AZERO OFF or ONCE), be sure to make all measurement connections before disabling autozero and ensure that the lead resistance will not change. If you disable autozero before making the 4-wire connections, or if you have a varying lead resistance with autozero disabled (such as when scanning), you may get inaccurate 4-wire ohms measurements.

Offset compensation

Because a resistance measurement involves measuring the voltage induced across the resistance, any external voltage present (offset voltage) will affect the measurement accuracy. With offset compensation enabled, the multimeter corrects resistance measurements by canceling the effects of the offset voltage. To do this, the multimeter first measures the input voltage with its current source on. The current source is then disabled and the input voltage measured again, The true induced voltage is the difference between the two measured voltages. You can use offset compensation for both 2-wire and 4-wire ohms measurements. The multimeter can only perform offset compensation on the 10 Ω through 100 kΩ ranges; offset compensation does not function on the other ranges. In the power-on/PRESET NORM state, offset compensation is disabled. To enable offset compensation, send:

```
OUTPUT 722:"OCOMP ON"
```

Refer to the Appendix A for specifications concerning the maximum series offset voltage for offset compensated ohms measurements.

Fixed input resistance

When making DC voltage measurements, you can fix the multimeter's input resistance using the FIXEDZ command. This is useful to prevent a change in input resistance (caused by changing ranges) from affecting the measurements. Table 3-4 shows the input resistances with FIXEDZ OFF. With FIXEDZ ON, the input resistance is a constant 10 MΩ for all DC voltage ranges. In the power-on/PRESET NORM state, fixed resistance is disabled (OFF). To enable fixed resistance, send:

```
OUTPUT 722; "FIXEDZ ON"
```

To disable fixed resistance, send:

```
OUTPUT 722;"FIXEDZ OFF"
```

Configuring for AC Measurements

This section describes how to configure the multimeter for making AC or AC+DC voltage, AC or AC+DC current, frequency, or period measurements.

AC or AC+DC voltage

The multimeter can make true RMS AC voltage or AC+DC voltage measurements using one of three methods: analog RMS conversion, random sampling conversion, or synchronous sampling conversion. Each measurement method has six ranges: 10 mV, 100 mV, 1 V, 10 V, 100 V and 1000 V, and a maximum resolution of 6½ digits on any range.

Table 3-7 shows the measurement characteristics and signal requirements for each measurement method. Figure 3-1 shows the front terminal connections for all types of voltage measurements.

For AC voltage measurements, the multimeter measures only the AC component of the input signal. For AC+DC voltage measurements, the multimeter measures the DC component and the AC component within the frequency ranges shown in Table 3-7. Notice that when measuring AC+DC voltage using the analog method, for example, any AC components below 10 Hz are not included in the measurement.

NOTE **When taking measurements on the 10 mV and 100 mV ranges using any AC measurement method, it is possible for radiated noise (such as transients caused large motors turning on and off) to cause inaccurate readings. For accurate readings on these ranges, ensure that your nearby environment is electrically "quiet" and use shielded test leads.**

Table 3-7 AC and AC+DC voltage measurement methods

ACV/ACDCV measurement method	Frequency range	Best accuracy	Repetitive signal required	Readings per second	
				Min.	Max.
Synchronous	1 Hz - 10 MHz	0.01%	Yes	0.025	10
Analog	10 Hz - 2 MHz	0.03%	No	0.8	50
Random	20 Hz - 10 MHz	0.10%	No	0.025	45

Synchronous sampling conversion

The synchronous sampling conversion calculates the true RMS value from samples, but requires that the input signal be repetitive (periodic). Synchronous sampling has excellent, linearity and is the most accurate of the three methods. Synchronous sampling is useful for measuring periodic waveforms in the frequency range of 1 Hz to 10 MHz.

Synchronous sampling remarks

- For synchronous sampling, the multimeter uses the LEVEL sync source event (default mode) to synchronize sampling to the input signal. If the input signal is removed during a reading and does not return within a certain amount of time, (the time limits are determined primarily by the AC bandwidth setting which is discussed later in this section) the measurement method changes to random sampling so that a measurement can be made. You can prevent the measurement method from changing using the SSRC command. You can also pace synchronous sampling to a signal on the Ext Trig connector using the SSRC command. Refer to the SSRC command in Chapter 6 for more information and example programs.
- When using the LEVEL sync source, it is possible for noise on the input signal to produce false level triggers and to cause inaccurate readings. For accurate readings, ensure that your nearby environment is electrically “quiet” and use shielded test leads. Enabling level filtering (LFILTER ON command) reduces the sensitivity to this noise. Refer to the LFILTER command in Chapter 6 for more information.
- The input signal is always DC-coupled for synchronous sampling regardless of the specified ACV or ACDCV measurement function. When ACV is specified, the DC components are mathematically subtracted from the reading. This is

important to consider since the combined AC and DC voltage levels may cause an overload condition even though the AC voltage alone normally would not.

Analog RMS conversion

The analog RMS conversion directly integrates the input signal and is the method selected when power is applied. This method works well for measuring signals in the frequency range of 10 Hz to 2 MHz and can provide the fastest reading rate of the three methods.

Random sampling conversion

The random sampling conversion takes numerous samples of the input signal for each reading generated. Samples are spaced randomly by an internal time base generator and the signal's true RMS value is calculated statistically. Random sampling does not require a repetitive input signal (as does synchronous sampling) making it suitable for applications such as wideband noise measurements. This method has excellent linearity, good accuracy, and is particularly suited to low-level (<1/10 of full scale) measurements. The measurement bandwidth for random sampling is 20 Hz to 10 MHz.

Specifying the AC voltage method

When power is applied, the multimeter selects the analog RMS conversion. In the power-on state, you can make measurements using the analog RMS conversion simply by selecting AC or AC+DC voltage measurements as follows:

```
OUTPUT 722;"ACV"
!SELECTS AC-COUPLED AC VOLTAGE MEASUREMENTS
```

or

```
OUTPUT 722; "ACDCV"
!SELECTS DC-COUPLED AC VOLTAGE MEASUREMENTS
```

The SETACV command allows you to specify the AC voltage measurement method. For example, to specify the random sampling conversion, send:

```
OUTPUT 722;"SETACV RNDM"
```

To select the synchronous sampling conversion, send:

```
OUTPUT 722;"SETACV SYNC"
```

To return to the analog RMS conversion, send:

```
OUTPUT 722;"SETACV ANA"
```

The specified AC voltage measurement method remains in effect until power is cycled, the multimeter is reset, or another method is specified. Whenever you select AC or AC+DC voltage measurements, the last specified (or power-on) measurement method will be used.

AC or AC+DC current

The multimeter measures current by placing an internal shunt resistor across the input terminals, measuring the voltage across the resistor, and calculating the current (current =voltage/resistance). Unlike AC or AC+DC voltage measurements, AC or AC+DC current measurements can be made using the analog method (direct integration) only. The multimeter's front and rear current inputs are protected by 1 A, 1000 V fuses. Figure 3-2 shows the front terminal connections for all types of current measurements.

The multimeter measures AC or AC+DC current on any of five ranges. For AC current measurements, the multimeter measures only the AC component of the input signal, For AC+DC current measurements, the multimeter measures the DC component and the AC component with frequencies >10 Hz. Notice that when measuring AC+DC current, any AC components below 10 Hz are not included in the measurement. The maximum resolution for AC or AC+DC current is 6½, digits. Table 3-8 shows each current range and its full scale reading, maximum resolution, and the shunt resistor used. (Resolution is a function of the specified integration time; refer to Setting the integration time, later in this section, for more information.) You specify AC current measurements using the ACI command or AC+DC current measurements using the ACDCI command. For example to specify AC current measurements on the 100 µA range, send:

```
OUTPUT 722;"ACI 100E-6"
```

To specify AC+DC current measurements on the 10 mA range, send:

```
OUTPUT 722;"ACDCI 10E-3"
```

Table 3-8 AC and AC+DC current ranges and resolution

ACI range	Full scale reading	Maximum resolution	Shunt resistor
100 µA	120.0000 µA	lOO pA	730 Ω
1 mA	1.200000 mA	1 nA	100 Ω
10 mA	12.00000 mA	10 nA	10 Ω
100 mA	120.0000 mA	100 nA	1 Ω
1 A	1.050000 A	1 µA	0.1 Ω

Frequency or period

The multimeter's frequency and period counter accepts AC voltage or AC current inputs. The maximum resolution is 7 digits[1] for both frequency and period measurements. (Refer to Specifying resolution later in this section, for more information).

You specify frequency measurements using the FREQ command or period measurements using the PER command. For frequency or period measurements you must also specify whether the input signal is from a voltage source or a current source and whether the measurements will be AC or DC coupled. This is done using the FSOURCE command (the power-on/default value is ACV). Table 3-9 shows the FSOURCE parameters, the type of input specified by each, and the measurement capabilities of each. The terminal connections for frequency or period measurements from a voltage source are shown in Figure 3-1. The terminal connections for frequency or period measurements from a current source are shown in Figure 3-1.

NOTE **The LEVEL command affects the zero crossing threshold and the input signal coupling for frequency and period measurements. Refer to the LEVEL command in Chapter 6 for more information.**

[1] The leftmost digit, which is a ½ digit for most measurement functions is a full digit (0-9) for frequency and period measurements.

Table 3-9 FSOURCE parameters

FSOURCE parameter	Definition	Measurement capabilities	
		Frequency	Period
ACV	AC-coupled AC voltage input	1 Hz – 10 MHz	100 ns – 1 s
ACDCV	DC-coupled AC voltage input	1 Hz – 10 MHz	100 ns – 1 s
ACI	AC-coupled AC current input	1 Hz – 100 kHz	10 µs – 1 s
ACDCI	DC-coupled AC current input	1 Hz – 100 kHz	10 µs – 1 s

The following program configures the multimeter for frequency measurements on the 10 V range from a voltage Source. The input signal is AC-coupled.

```
10 OUTPUT 722;"FREQ 10"
20 OUTPUT 722;"FSOURCE ACV"
30 END
```

The following program configures the multimeter for period measurements on the 10 mA range from a current source. The input signal is DC-coupled.

```
10 OUTPUT 722;"PER 10E-3"
20 OUTPUT 722;"FSOURCE ACDCI"
30 END
```

NOTE You can reduce high-frequency noise above 75 kHz for frequency or period measurements by enabling the level filter. Refer to the LFILTER command in Chapter 6 for details.

Specifying bandwidth

The ACBAND command specifies the frequency content of the input signal for all AC and AC+DC measurements. Specifying the frequency content allows the multimeter to make accurate measurements and to configure itself for the fastest possible measurements. The ACBAND command's first parameter specifies the lowest expected frequency component (the power-on/PRESET NORM value is 20 Hz). The second parameter specifies the highest expected frequency

component (the power-on/PRESET NORM value is 2 MHz). For example, suppose the input signal has a frequency range of 750 Hz to 2 kHz; you should send:

```
OUTPUT 722;"ACBAND 750,2000"
```

Refer to the "Appendix A: Specifications" on page 415 for accuracy specifications (and reading rate specifications for analog AC measurements) based on the frequency components of the input signal.

NOTE **For synchronous AC or AC + DC voltage measurements, the bandwidth parameters are used by the multimeter to calculate time-out values and sampling parameters. For frequency or period measurements with autorange enabled, the bandwidth parameters are used to determine the amount of time needed for autoranging. For these measurements, it is very important that the specified bandwidth (particularly the specified low frequency) corresponds to the frequency content of the input signal.**

Setting the integration time

Integration time is the period of time that the A/D converter measures the input signal. For analog AC measurements, the integration time determines the maximum digits of resolution and, along with the specified bandwidth affects the measurement speed. (Integration time also has a minor affect on analog AC measurement accuracy). Analog AC measurements are defined as AC or AC+DC voltage measurements made using the analog conversion method (SETACV ANA command) only, and AC or AC+DC current measurements. With longer integration times, the measurement resolution and accuracy increases, but measurement speed decreases.

NOTE **The integration time has no effect on frequency or period measurements. For sampled AC voltage measurements (SET ACV SYNC or SET ACV RNDM) the A/D converter's integration time is selected automatically and the multimeter achieves the specified resolution (Specifying resolution is discussed in the next section) by varying the number of samples taken.**

For analog AC measurements, you can specify integration time in terms of power line cycles (PLCs) using the NPLC command. (You can also use the APER command to specify integration time although it is primarily intended for DC

measurements; refer to the APER command in Chapter 6 for more information.) The multimeter multiplies the specified number of PLCs by the period of the A/D converter's reference frequency (LFREQ command) to determine the integration time. For example, the period of a 50 Hz power line is 1/50 = 20 msec. If you specify 10 PLCs, the integration time is 200 msec. In the power-on state, integration time is set to 10 PLCs. In the PRESET NORM state, integration time is set to 1 PLC. To set the integration time for the fastest measurements (with the lowest accuracy and 4½, digits of resolution), send:

```
OUTPUT 722; "NPLC 0"
```

To specify the most accuracy and Highest resolution (6½ digits),with the slowest measurement speed, send:

```
OUTPUT 722; "NPLC 1000"
```

You can specify power line cycles in the following ranges:

- 0 - 1 PLC (in .000006 PLC steps for 60 Hz ref. frequency or .000005 PLC steps for 50 Hz ref. frequency)
- 1- 10 PLC in 1 PLC steps
- 10 - 1000 PLCs in 10 PLC steps

NOTE **For integration times greater than 10 PLCs, the multimeter averages a number of readings made using 10 PLCs of integration time. For example, if you specify 60 PLCs of integration time, the multimeter averages six 10 PLC readings.**

Typically, you should select the integration time that provides adequate speed while maintaining an acceptable amount of accuracy and resolution. Table 3-10 shows the relationships between integration time and digits of resolution for analog AC measurements.

Table 3-10 Analog AC A/D converter relationships

Digits of resolution	Power line cycles (NPLC command)	
	LFREQ = 60 Hz	LFREQ = 50 Hz
4.5	0 – .000030	0 – .000025
5.5	.000036 – .000360	.000030 – .000300
6.5	.000366 – 1000	.000305 – 1000

Specifying resolution

You can specify the measurement resolution as the last parameter (*%_resolution* parameter) of a function command (FUNC,ACV, ACI, etc.) or the RANGE command.[1]

For all analog AC voltage and current measurements *%_resolution* is specified as a percentage of the command's *max._input* parameter. The multimeter multiplies the specified *%_resolution* parameter times the *max._input* parameter to determine the measurement resolution. To determine the value of the *%_resolution* parameter, use the equation:

%_ resolution = (actual resolution/maximum input) × 100

For example, suppose your maximum expected input is 10 VAC and you need 1 mVAC of resolution. The equation evaluates to:

%_ resolution = (0.001/10) × 100 = 0.01

For analog AC measurements, resolution is determined by the A/D converter's integration time. When you specify a resolution, you are actually indirectly specifying an integration time. Since the NPLC command can also specify an integration time, an interaction occurs when you specify resolution as follows:

- If you send the NPLC command *before* specifying resolution, the multimeter satisfies the command that specifies greater resolution (more integration time).
- If you send the NPLC command *after* specifying resolution, the multimeter uses the integration time specified by the NPLC command, and the previously specified resolution is ignored.

[1] You can also specify resolution using the RES command. Refer to the RES command in chapter 6 for examples showing its usage.

For analog AC measurements, if you default, the %_ *resolution* parameter, the integration time will be that specified by the last NPLC command executed.

For sampled ACV or ACDCV, random sampling (SETACV RNDM) has a fixed resolution of 4.5 digits that cannot be changed. For synchronous sampling (SETACV SYNC) a *%_resolution* parameter of 0.001 = 7.5 digits; 0.01 = 6.5 digits: 0. 1= 5.5 digits: and 1 = 4.5 digits.

For frequency and period measurements, %_ *resolution* specifies the gate time and the digits of resolution as shown in Table 3-11. For example, the following program specifies frequency measurements from a voltage input using the 10 V range. The *%_resolution* parameter in line 20 (.00001) specifies a gate time of 1 second and 7 digits of resolution.

```
10 OUTPUT 722; "FSOURCE ACV"
20 OUTPUT 722;"FREQ 10,.00001"
30 END
```

If you default the *%_resolution* parameter for FREQ or PER measurements, the multimeter sets *%_resolution* to .00001 which selects a gate time of 1 second and 7 digits of resolution.

Table 3-11 Frequency/Period gate time and resolution

%_resolution parameter	Selects gate time	Digits of resolution
.00001	1 s	7
.0001	100 ms	7
.001	10 ms	6
.01	1 ms	5
.1	100 µs	4

When to specify resolution

For analog ACV or ACDCV (SETACV ANA), ACI, and ACDCI measurements, you should specify resolution when you need more resolution than that provided by the NPLC command. For example, in the following program, line 10 specifies 0.0001 PLC of integration time, which selects 5½, digits of resolution resulting in an actual resolution of 100 µV on the 10 V range. However, for this application, 10 µV of resolution is required with a *max._input* of 10 V. The preceding equation

produces a *%_resolution* parameter of 0.0001 (1E-4) which is specified in line 30 (for this resolution, a reading takes about 40 seconds).

```
10 OUTPUT 722;"NPLC .0001"
20 OUTPUT 722;"SETACV ANA"
30 OUTPUT 722;"ACV 10,1E-4"
40 END
```

For synchronous sampled ACV or ACDCV (SETACV SYNC), FREQ, and PER measurements specifying resolution is the only way to change the actual resolution. For these measurements, the integration time is fixed and no interaction occurs between the NPLC command and the *%_resolution* parameter. The multimeter achieves the specified resolution for sampled AC voltage by varying the number of samples taken. (If you default the *%_resolution* parameter, the multimeter sets the *%_resolution* to 0.01 percent for the synchronous conversion method or 0.4 percent for the random conversion method.) The following program selects AC voltage measurements using the synchronous sampling conversion. The maximum expected input voltage is 10 volts and a *%_resolution* parameter of .1 selects 5.5 digits resulting in an actual resolution of 0.1 mV.

```
10 OUTPUT 722; "SETACV SYNC"
20 OUTPUT 722;"ACV 10, .1"
30 END
```

Configuring for Ratio Measurements

For ratio measurements, the multimeter measures a DC reference voltage applied to the Ω Sense terminals and a signal voltage applied to the Input terminals. The multimeter then computes the ratio as:

$$\text{Ratio} = \frac{\text{Signal Voltage}}{\text{DC Reference Voltage}}$$

The signal voltage measurement function can be DC voltage, AC voltage, or AC+DC voltage. (For AC or AC+DC voltage, any of the three measurement methods ANA, RNDM, or SYNC may be used.) The reference voltage measurement function is always DC voltage and has a maximum measurable input of ±12 VDC. Figure 3-5 shows the front connections for ratio measurements.

NOTE **The Ω Sense LO and the Input LO terminals must have a common reference and cannot have a voltage difference greater than 0.25 V.**

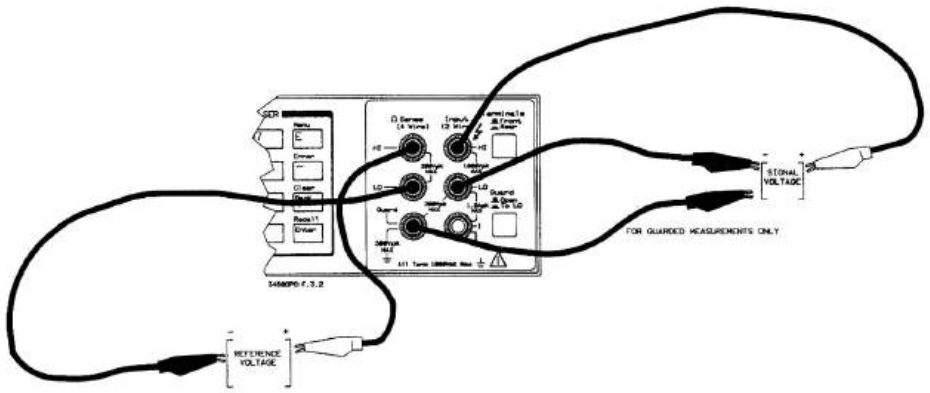

Figure 3-5 Ratio measurement connections

Specifying ratio measurements

To specify ratio measurements, you first select the measurement function for the signal measurement (and the measurement method for AC or AC+DC voltage) and then enable ratio measurements using the RATIO command. For example, the following program specifies AC voltage ratio measurements (on the 10 V range) using the synchronous sampling conversion.

```
10 OUTPUT 722;"ACV 10"
20 OUTPUT 722; "SETACV SYNC"
30 OUTPUT 722;"RATIO ON"
40 END
```

Later, to disable ratio measurements, send:

```
OUTPUT 722;"RATIO OFF"
```

For ratio measurements, the specified measurement range applies to the signal voltage measurement only (Input terminals). The reference voltage measurement (Ω Sense terminals) is always set to autorange. Ranging is discussed in detail earlier in this chapter under General Configuration.

Using Subprogram Memory

The multimeter can store command strings as subprograms. This allows you to execute frequently used command strings while keeping bus/controller interaction to a minimum. Since stored subprograms are compiled, the multimeter executes a subprogram much faster than it could execute the equivalent commands sent over the GPIB. The multimeter has 14k-bytes of memory that are shared by subprograms and states (discussed later). When subprogram/state memory becomes full, the multimeter generates the *Memory Error* (bit 7 in the error register).

NOTE **The status register contains a subprogram complete bit that can be used to determine when a subprogram has finished executing. Refer to Using the Status Register later in this chapter, for more information.**

Storing a subprogram

You store a subprogram using the SUB and SUBEND commands. The SUB command indicates the start of the subprogram and its identifying name. A subprogram name may contain up to 10 characters. The name can be all alpha characters or a combination of alpha and numeric characters (the characters ? and _ can also be included in the name). When using an alphanumeric name, the first character must be alpha. Alpha or alphanumeric subprogram names must not be the same as multimeter commands or parameters or the name of a stored state.

Following the SUB command, enter the subprogram commands in the order you want them executed. Use the SUBEND command to indicate the end of the subprogram. All subprograms are stored in continuous memory (remain intact when power is removed) unless the subprogram is compressed (see Compressing subprograms later in this chapter). For example, the following program stores the commands in lines 20 through 60 as a subprogram entitled DCCUR1.

```
10 OUTPUT 722;"SUB DCCUR1"
20 OUTPUT 722;"MEM FIFO"
30 OUTPUT 722;"TRIG HOLD"
40 OUTPUT 722;"DCI 1,.01"
50 OUTPUT 722; "NRDGS 5, AUTO"
```

```
60 OUTPUT 722;"TRIG SGL"
70 OUTPUT 722; "SUBEND"
80 END
```

If you create a new subprogram using the same name as an existing subprogram, the new subprogram overwrites the old subprogram.

Executing a subprogram

To execute a stored subprogram, issue the CALL command along with the subprogram's name. For example, to execute the preceding subprogram, send:

```
OUTPUT 722;"CALL DCCUR1"
```

NOTE **When the input buffer (discussed later in this chapter) is off, the multimeter does not release the GPIB until the completion of the subprogram or a PAUSE command (discussed below) is encountered. Refer to Using the Input Buffer, later in this chapter for information on how to release the bus immediately after calling a subprogram. To abort subprogram execution, send the GPIB Device Clear command.**

From the front panel, you can view all stored subprogram names by accessing the CALL command and pressing the up or down arrow key. Once you have found the correct subprogram, press the **Enter** key to execute the subprogram.

Suspending subprogram execution

You can temporarily suspend subprogram execution by including the PAUSE command in the stored subprogram. The multimeter executes subprograms on a command-by-command basis. When it encounters the PAUSE command, subprogram execution is suspended and, if the subprogram was called from remote, the GPIB bus is released. For example, the following program has a PAUSE command in line 60.

```
10 OUTPUT 722; "SUB 2"
20 OUTPUT 722;"MEM FIFO"
30 OUTPUT 722;"TRIG HOLD"
40 OUTPUT 722;"DCV 10"
```

```
50 OUTPUT 722;"NRDGS 5,AUTO"
60 OUTPUT 722;"PAUSE"
70 OUTPUT 722;"TRIG SGL"
80 OUTPUT 722;"SUBEND"
90 END
```

When you call the above subprogram, the commands will be executed up to the PAUSE command and then program execution ceases. To resume subprogram execution, send:

```
OUTPUT 722;"CONT"
```

Subprogram execution can also be resumed by sending the GPIB Group Execute Trigger (this does not in itself trigger a reading: it merely resumes subprogram operation).

Nested subprograms

You can use a subprogram to call another subprogram (nested subprograms). For example, when the following subprogram is called (CALL 1 command), it takes 10 DC voltage readings and then calls the previously stored subprogram *DCCUR1*.

```
10 OUTPUT 722; "SUB 1"
20 OUTPUT 722;"TRIG HOLD"
30 OUTPUT 722;"NRDGS 10,AUTO"
40 OUTPUT 722;"DCV 10"
50 OUTPUT 722;"TRIG SGL"
60 OUTPUT 722; "CALL DCCUR1"
70 OUTPUT 722; "SUBEND"
80 END
```

A subprogram containing a PAUSE command cannot be called from another subprogram. The multimeter allows you to nest up to 10 subprograms; that is having subprogram 1 call subprogram 2 which calls 3, which calls 4 ... which calls subprogram 10.

Autostart subprogram

When you entitle a subprogram 0, that subprogram will be executed whenever the multimeter completes its power-on sequence or it is reset using the front panel **Reset** key. This is particularly useful to automatically return the multimeter to its previous state following a power failure. Whenever a power failure is detected, the multimeter stores its present state as state 0 (states are discussed later in this chapter). The following program stores an autostart program that returns the multimeter to its power-down state and also sets the A/D converter's reference frequency to the exact power line frequency (see Changing the reference frequency earlier in this chapter for details).

```
10 OUTPUT 722; "SUB 0"
20 OUTPUT 722;"RSTATE 0"
30 OUTPUT 722;"LFREQ LINE"
40 OUTPUT 722; "SUBEND"
50 END
```

You can also call the autostart subprogram (CALL 0 command) if you need to execute the subprogram without having to cycle the multimeter's power.

Compressing subprograms

When you store a subprogram, the multimeter stores the ASCII text in continuous memory and a compiled version of the subprogram in volatile memory. When you call a subprogram, the multimeter executes the compiled version (this is why a subprogram executes faster than the equivalent commands sent over the bus). When power is removed, only the ASCII text is saved. When power is reapplied, the multimeter uses the ASCII text to generate a compiled subprogram. You can compress subprograms using the COMPRESS command. Compressing a subprogram removes the ASCII text from continuous memory leaving only the compiled version in volatile memory. This makes more continuous memory space available but removes the subprogram from continuous memory (all record of the subprogram will be destroyed when power is removed or the front panel **Reset** key is pressed). The following program statement compresses the previously stored subprogram named *DCCUR1*.

```
OUTPUT 722; "COMPRESS DCCUR1"
```

Deleting subprograms

The DELSUB command deletes a particular subprogram. For example, to delete the subprogram named *DCCUR1* send:

```
OUTPUT 722; "DELSUB DCCUR1"
```

You can also delete all stored subprograms and all stored states using the SCRATCH command.

Using State Memory

You can store the multimeter's present configuration (measurement function. range, resolution, integration time, etc.) as a particular state in state memory. Subprograms, readings, and the contents of some math registers (see the SSTATE command in Chapter 6 for details) are not included as part of a stored state. In the event of a power loss, the multimeter stores its present configuration in state 0, if you store a state in location 0, it will be overwritten with the present configuration when power is removed. The multimeter has 14k-bytes of memory which are used for both states and subprograms. Each state occupies about 300 bytes. If no subprograms are in memory, the multimeter can store a maximum of 46 states. When subprogram/state memory becomes full, the multimeter generates the *Memory Error* (bit 7 in the error register).

Storing states

The SSTATE command stores the multimeter's present state with an identifying name. A state name may contain up to 10 characters. The name can be all alpha characters or a combination of alpha and numeric characters (the characters ? and _ can also be included in the name). You can also use an integer in the range of 0 to 127 as the name (this is primarily for front panel operation). When using an alphanumeric name, the first character must be alpha. Alpha or alphanumeric state names must not be the same as multimeter commands or parameters or the name of a stored subprogram. When using an integer state name, the multimeter assigns the prefix *STATE* to the integer when the state is stored. This differentiates an integer state name from an integer subprogram name. For example, a state stored with the name 8 will be recorded as *STATE8*. The state can be recalled later using either the name 8 or *STATE8*.

All states are stored in continuous memory (remain intact when power is removed). The multimeter compiles the state as it is stored. This means that when the state is recalled, the multimeter configures itself much faster than could be done by executing the individual commands that were used to create the state. To store the present multimeter state as a state named *ACST1*, send:

```
OUTPUT 722; "SSTATE ACST1"
```

Recalling states

The RSTATE command recalls a state from memory and configures the multimeter to the recalled state. For example, to recall state ACSTl send:

```
OUTPUT 722;"RSTATE ACST1"
```

From the front panel, you can view all stored state names by accessing the RSTATE command and pressing the up or down arrow key. Once you have found the correct state, press Enter to recall the state.

Deleting states

You can delete a single stored state using the PURGE command. For example, to purge the state *ACST1*, send:

```
OUTPUT 722;"PURGE ACST1"
```

You can also use the SCRATCH command to delete all stored states and all subprograms from memory.

Using the Input Buffer

In the multimeter's power-on/PRESET NORM state, the input buffer is disabled. The means the multimeter must process each GPIB command individually and wait until the command is executed before releasing the GPIB bus or accepting another command. In most cases, the controller must wait until the bus is released before it can continue, which ensures synchronization between the controller and the instrument. This is most noticeable on commands that take a long time to execute. For example, if you run the complete self-test from remote (TEST command), the multimeter does not release the GPIB bus until the self test is complete, approximately 50 seconds.

With the input buffer enabled, the multimeter temporarily stores commands in the buffer and immediately releases the GPIB bus. The multimeter then retrieves and executes the commands in the order received, one by one, from the input buffer. This allows the controller to perform other operations while the multimeter is executing commands. The following program enables the input buffer prior to executing the TEST command.

```
10 OUTPUT 722;"INBUF ON"
20 OUTPUT 722; "TEST"
30 END
```

The input buffer holds a maximum of 255 characters. If you send more characters than the input buffer can hold, the multimeter holds the bus until buffer space becomes available. When space is available, the remaining characters are accepted into the input buffer and the bus is released.

When using the input buffer, it may be necessary to know when all buffered commands have been executed. The multimeter provides this information by setting bit 4 (ready for instructions) in the status register (discussed next). If the status register is properly enabled, it drives the GPIB's SRQ (service request) line true. Your controller will acknowledge this if previously programmed to accept SRQ as an interrupt.

Using the Status Register

The status register monitors the following multimeter status information:

- Subprogram complete
- High or low limit exceeded
- SRQ command executed
- Power turned-on
- Ready for instructions
- Error
- Service requested
- Data available.

When one of these events occurs, it sets a corresponding bit, in the status register. The following list defines the meaning of each bit in the status register:

Bit 0 (weight = 1) Subprogram Complete--a stored subprogram has been executed.

Bit 1 (weight = 2) High or Low Limit Exceeded--one or more readings have exceeded the high/low limits specified for the Pass/Fail math operation. This bit applies to both real-time and post-process math. (See Pass/Fail in Chapter 4.)

Bit 2 (weight = 4) SRQ Command Executed--the multimeter's SRQ command has been executed.

Bit 3 (weight = 8) Power-On--a power-on sequence has occurred.

Bit 4 (weight = 16) Ready for Instructions--the multimeter has completed execution of any previous commands and is ready to accept more commands. (When using TRIG SGL or TARM SGL to initiate a group of readings with the input buffer off, this bit can be used to monitor when all readings are complete.)

Bit 5 (weight = 32) Error--one or more errors have been logged in the error/auxiliary register. Refer to Reading the error registers earlier in this chapter for more information.

NOTE **You can prevent any or all errors from setting the error bit in the status register using the EMASK command. Refer to the EMASK command in Chapter 6 for more information.**

Bit 6 (weight = 64) Service Request--service is requested and the GPIB SRQ line is set true. This bit will be set when any other bit of the status register is set and has been enabled to assert SRQ by the RQS command. It is possible for bit 6 to be the only bit set such as when an error set a bit in the error register which, in turn, set bit 6. Later, the error register was read which removed the error bit but left bit 6 set,

Bit 7 (weight = 128) Data Available--a reading or query response is available in the output buffer.

Reading the status register

The STB? query command reads the status register and returns the weighted sum of all set bits. The STB? command does not clear the status register. The following program uses the STB? command to read the contents of the status register.

```
10 OUTPUT 722."STB?"
20 ENTER 722; A
30 PRINT A
40 END
```

For example, assume bit 3 (weight = 8) and bit 7 (weight = 128) are set. The above program returns the sum of the two weights (136).

The STB? command will never reveal bit 4 (Ready for Instructions) set because the multimeter is busy processing the STB? command and, therefore, is not ready. If you intend to monitor the ready bit, you must use the GPIB Serial Poll command to read the status register. If the SRQ line is true, the Serial Poll command clears all status register bits.* The SRQ line is also returned to false if bit 6 is cleared. If the SRQ line is false during Serial Poll, the register's contents are not changed. The following program shows how to read the status register using the Serial Poll command.

```
10 P=SPOLL(722)
20 DISP P
30 END
```

To clear the status register,[1] send:

```
OUTPUT 722; "CSB"
```

[1] Bits 4, 5, and 6 are not cleared if the condition(s) that set the bit(s) still exist.

Interrupts

When a bit of the status register is set and has been enabled to assert SRQ (RQS command), the multimeter sets the GPIB SRQ line true. This can be used to alert the controller to interrupt its present operation and find out what service the multimeter requires. (Refer to your controller-operating manual for information on how to program it to respond to the interrupt.)

To allow any of the status register bits to set the SRQ line true, you must first enable the bit(s) with the RQS command. For example, suppose your application requires an interrupt when a high or low limit is exceeded (bit 1), power is cycled (bit 3), or when an error occurs (bit 5). The decimal equivalents of these bits are 2, 8, and 32, respectively. The decimal sum is 42. You can enable these bits to assert SRQ by sending:

```
OUTPUT 722;"RQS 42"
```

Now, whenever one of the events associated with bits 1, 3, or 5 occurs, it will set bit 6 in the status register and assert SRQ. Notice that the bits that are not enabled still respond to their corresponding conditions. They do not, however, set bit 6 or assert SRQ. The following program is an example of interrupts using Keysight Series 200/300 BASIC.

```
10 !HI/LO LIMIT EXCEEDED,ERROR, POWER CYCLED INTERRUPT
20 OUTPUT 722;"PRESET NORM"
30 OUTPUT 722; "CSB"
40 ON INTR 7 GOTO 90
50 ENABLE INTR 7;2
60 OUTPUT 722;"RQS 42;MATH PFAIL;SMATH MIN -5;SMATH MAX 5"
70 OUTPUT 722;"TRIG AUTO"
80 GOTO 80
90 OUTPUT 722; "STB?"
100 ENTER 722;A
110 IF BINAND (A,2) THEN PRINT "HI/LO LIMIT EXCEEDED"
120 IF BINAND (A,8) THEN PRINT "POWER WAS CYCLED"
130 IF BINAND (A,32) THEN PRINT "ERROR OCCURRED"
140 END
```

Line 20 presets the multimeter, which suspends triggering. Line 30 clears the status register. Line 40 instructs the controller to go to line 90 should an interrupt occur. Line 50 enables SRQ interrupts on the GPIB interface. Line 60 enables the hi/lo limit, power-on, and error bits to assert SRQ. Line 60 also enables the real-time pass/fail math operation with the values of –5 for the low limit and +5 for the hi limit. Line 70 enables automatic triggering. Line 80 causes the controller to wait for an interrupt. Lines 90 through 130 read the status register and print which condition(s) caused the interrupt.

4 Making Measurements

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Introduction

This chapter discusses the methods for triggering measurements, the reading formats, how to use reading memory, and how to transfer readings across the bus. This chapter also discusses how to increase the reading rate and GPIB bus transfer speed, how to measure the reading rate, how to use the multimeter's EXTOUT signal, and how to use the math operations.

Triggering Measurements

Before the multimeter will take readings, three separate events must occur in the proper order. These events are (1) the trigger arm event, (2) the trigger event, and (3) the sample event. Sub-sampling (discussed in Chapter 5) and multiple trigger arming (discussed in this chapter) are the only exceptions to this triggering hierarchy. As shown in Figure 4-1, when all three events have occurred in the order listed, the multimeter begins to make the specified reading(s). In the power-on state, the multimeter is configured so that it makes readings automatically; that is, all three events are set to AUTO. For most applications, you will need to use only one or two of these events and leave the other event(s) set to AUTO. This section describes the various events that can be used to satisfy the trigger arm, trigger, and sample event requirements and contains examples showing how to use these events.

NOTE The examples in this manual are intended for Hewlett-Packard Series 200/300 computers using BASIC language. They assume a GPIB interface select code of 7 and a device address of 22 resulting in a combined GPIB address of 722. Some of the examples in this section store readings in memory while others transfer readings to the controller. Reading destination is discussed in detail later in this chapter under Using Reading Memory and Sending Readings Across the Bus.

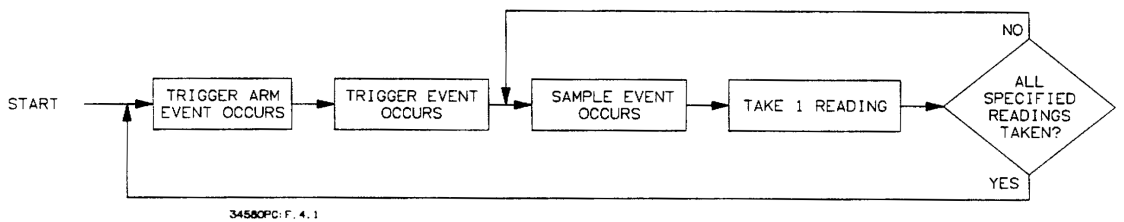

Figure 4-1 Triggering hierarchy

The trigger arm event

When the specified trigger arm event occurs, it arms the multimeter's triggering mechanism. That is, the trigger arm event enables a subsequent trigger event. You specify the trigger arm event using the TARM command.

The trigger event

When the specified trigger event occurs (and the trigger arm event has already occurred), it enables a subsequent sample event. You specify the trigger event using the TRIG command.

The sample event

When the sample event occurs (and the trigger arm and trigger events have already occurred), the multimeter makes a reading. The multimeter will then make one reading per sample event until the specified number of readings are taken. The first parameter of the NRDGS (number of readings) command specifies how many readings are to be taken per trigger event. The second parameter specifies the event (sample event) that initiates each reading.

Event choices

You can select from a variety of events to use as the trigger arm, trigger, and sample events. Table 4-1 describes the event parameters and shows the commands to which they apply.

Table 4-1 Event parameters

Event parameter	Used with: TARM	Used with: TRIG	NRDGS	Event description
AUTO	?	?	?	Occurs automatically (whenever required)
EXT	?	?	?	Occurs on negative edge transition on the multimeter's external trigger input
HOLD	?	?		Suspends measurements
LEVEL[a]		?	?	Occurs when the specified voltage is reached on the specified slope of the input signal

Table 4-1 Event parameters (continued)

Event parameter	Used with: TARM	Used with: TRIG	NRDGS	Event description
LINE[b]		?	?	Occurs when the power line voltage crosses zero volts
SGL	?	?		Occurs once (upon receipt of TARM SGL or TRIG SGL command, then becomes HOLD)
SYN	?	?	?	Occurs when the multimeter's output buffer is empty, reading memory is off or empty, and the controller requests data
TIMER[b]			?	Occurs automatically with a time interval between readings

[a] The LEVEL trigger or sample event can be used only for DC voltage or direct-sampled digitizing.

[b] The TIMER or LINE event cannot be used for AC or AC+DC voltage measurements using the synchronous or random method, or for frequency or period measurements.

Making continuous readings

In the power-on state, the multimeter's trigger arm, trigger, and sample events are all set to AUTO. This causes the multimeter to take readings continuously. Typically, continuous readings should be suspended before configuring the multimeter using either the TARM HOLD or TRIG HOLD command or by setting the multimeter to one of the PRESET states (see Suspending readings in Chapter 3). After configuring the multimeter, you can resume continuous readings (assuming the other triggering events have not been changed) by sending:

```
OUTPUT 722;"TARM AUTO”
!Resumes readings suspended by TARM HOLD, PRESET FAST, or PRESET DIG
```

or

```
OUTPUT 722; "TRIG AUTO"
!Resumes readings suspended by TRIG HOLD or PRESET NORM
```

Making single readings

The NRDGS command specifies the number of readings made per trigger event and the sample event that initiates each reading. In the power-on, RESET, PRESET NORM, or PRESET FAST state, the number of readings per trigger is set to 1 and the sample event is AUTO (NRDGS 1,AUTO). In any of these states, you can initiate a single reading by executing the TARM SGL or TRIG SGL command (depending on which event, if any, is suspending readings). For example, the following program resets the multimeter and suspends readings by setting the trigger arm event to HOLD. The configuration is changed (lines 30-50) and line 60 initiates a single reading, which is transferred to the controller and displayed. After the single reading, the trigger arm event becomes HOLD, which suspends readings.

```
10 OUTPUT 722;"RESET"!RESET, ALL TRIGGERING EVENTS AUTO
20 OUTPUT 722;"TARM HOLD"!SUSPEND READINGS
30 OUTPUT 722;"DCV 10"!DC VOLTAGE, 10 V RANGE
40 OUTPUT 722;"NPLC 1"!1 PLC INTEGRATION TIME
50 OUTPUT 722;"AZERO OFF"!AUTOZERO OFF
60 OUTPUT 722;"TARM SGL"!TRIGGER 1 READING
70 ENTER 722;A!ENTER READING
80 PRINT A!PRINT READING
90 END
```

In the PRESET NORM state, readings are suspended because the trigger event is set to SYN (the SYN event is discussed later in this chapter). In this state, you can initiate a single reading using the TRIG SGL command. For example, in the following program, line 10 suspends readings by setting the trigger event to SYN. Line 20 initiates a single reading and the reading is transferred to the controller and displayed. Following execution of the TRIG SGL command, the trigger event becomes HOLD which suspends readings.

```
10 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, NRDGS 1,AUTO
20 OUTPUT 722;"TRIG SGL"!GENERATE SINGLE TRIGGER
30 ENTER 722;A!ENTER READING
40 PRINT A!PRINT READING
50 END
```

Making multiple readings

You can use the NRDGS command to specify more than one reading per trigger event. For example, the following program takes 10 readings per trigger event (one reading is taken per sample event) and transfers them to the controller. Notice that the input buffer is enabled (line 40). This is because, with the input buffer disabled, the SGL event (line 60) holds the GPIB bus until all specified readings are complete. This would prevent line 70 from transferring all but the last reading to the controller. Enabling the input buffer prevents the TRIG SGL command from holding the bus and allows each reading to be transferred as it becomes available.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(10)!DIMENSION ARRAY FOR 10 READINGS
30 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE
40 OUTPUT 722;"INBUF ON"!ENABLE INPUT BUFFER
50 OUTPUT 722;"NRDGS 10, AUTO"!10 READINGS/TRIGGER, AUTO SAMPLE EVENT
60 OUTPUT 722;"TRIG SGL"!TRIGGER READINGS
70 ENTER 722;Rdgs(*)!ENTER READINGS
80 PRINT Rdgs(*)!DISPLAY READINGS
90 END
```

Multiple trigger arming

The second parameter of the TARM command allows you to specify multiple trigger arming. When multiple trigger arming is specified, a single occurrence of the trigger arm event arms the multimeter the specified number of times. (The trigger arm event must be SGL for multiple arming.) This causes the multimeter to make multiple groups of readings as shown in Figure 4-2.

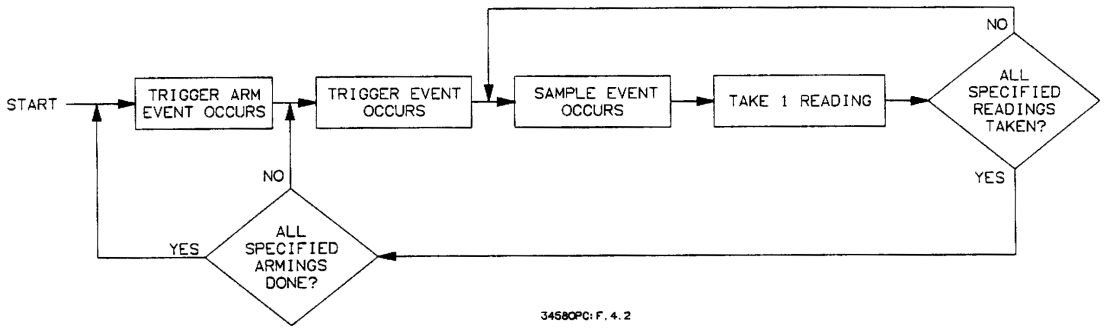

Figure 4-2 Multiple trigger arming

In the following program, the NRDGS command selects 10 readings per trigger event. The second parameter of the TARM command specifies 5 armings. This program stores 5 groups of ten readings for a total of 50 readings.

```
10  OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20  DIM Rdgs(50)!DIMENSION ARRAY FOR 50 READINGS
30  OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE
40  OUTPUT 722;"TARM HOLD"!HOLD TRIGGER ARM EVENT
50  OUTPUT 722;"TRIG AUTO"!AUTO TRIGGER EVENT
60  OUTPUT 722;"INBUF ON"!ENABLE INPUT BUFFER
70  OUTPUT 722;"NRDGS 10,AUTO"!10 READINGS/TRlGGER, AUTO SAMPLE EVENT
80  OUTPUT 722;"TARM SGL,5"!ARM TRIGGERING 5 TIMES
90  ENTER 722;Rdgs(*)!ENTER READINGS
100 PRINT Rdgs(*)!PRINT READINGS
110 END
```

Making synchronous readings

You can synchronize the multimeter to the controller by setting the trigger arm, trigger, and/or sample event to synchronous (SYN). The synchronous event occurs whenever the multimeter's output buffer is empty, reading memory is off or empty, and the controller requests data. This means that measurements are made whenever the controller wants them. This is a very important feature for remote operation, especially when the multimeter is in the high-speed mode.

In the high-speed mode, the synchronous event ensures that the controller is ready to accept readings and will not slow the reading rate. Refer to High-speed

mode later in this chapter for more information. In the following program, the PRESET NORM command sets the trigger event to synchronous. Line 40 specifies 15 readings per synchronous trigger event. Line 50 requests data from the multimeter. This satisfies the synchronous trigger event and initiates the readings. Notice that line 50 requests data from the multimeter 15 times. When multiple readings are specified and SYN is used as the trigger or trigger arm event, the multimeter does not recognize the multiple data requests as individual SYN events. That is, in this program the SYN trigger event occurs once, not 15 times.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs (15)!DIMENSION ARRAY FOR 15 READINGS
30 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE, MEM OFF
40 OUTPUT 722;"NRDGS 15,AUTO"!15 READINGS/TRIGGER, AUTO SAMPLE EVENT
50 ENTER 722;Rdgs(*)!GENERATE SYN EVENT, ENTER READINGS
60 PRINT Rdgs(*)!DISPLAY READINGS
70 END
```

The following program uses the synchronous event as the sample event. Line 60 requests data from the multimeter 15 times. When SYN is used as the sample event, each request for data is recognized as a SYN event. That is, in this program the SYN event occurs 15 times.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(15)!DIMENSION ARRAY FOR 15 READINGS
30 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE
40 OUTPUT 722;"NRDGS 15,SYN"!15 READINGS PER TRIGGER, SYN SAMPLE EVENT
50 OUTPUT 722;"TRIG AUTO"!AUTO TRIGGER EVENT
60 ENTER 722;Rdgs(*)!SYN EVENT, ENTER EACH READING
70 DISP Rdgs(*)!PRINT READINGS
80 END
```

Making timed readings

When making multiple readings per trigger, you can use the TIMER sample event to place a specified time interval between readings. This interval is the amount of time from the beginning of one reading to the beginning of the next reading. You specify the interval in seconds using the TIMER command. (If the specified interval is less than the time required to make each reading, the multimeter generates the TRIG TOO FAST error). The following program specifies 8 readings per trigger with 1 second between readings (this is shown in Figure 4-3).

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(8)!DIMENSION ARRAY FOR 8 READINGS
```

```
30 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE
40 OUTPUT 722;"NRDGS 8, TIMER"!8 READINGS/TRIGGER, TIMER SAMPLE EVENT
50 OUTPUT 722;"TIMER 1"!1 SECOND TIMER INTERVAL
60 ENTER 722;Rdgs(*)!SYN EVENT,ENTER EACH READING
70 PRINT Rdgs(*)!PRINT READINGS
80 END
```

You can also use the SWEEP command to replace the NRDGS n,TIMER command and the TIMER command. The SWEEP command's first parameter specifies the interval between readings and its second parameter specifies the number of readings. (The SWEEP and NRDGS commands are interchangeable: the multimeter uses whichever was specified last in the programming.) For example, the following program also takes 8 readings with a 1 second interval between readings (this is shown in Figure 4-3).

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(8)!DIMENSION ARRAY FOR 8 READINGS
30 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE
40 OUTPUT 722;"SWEEP 1,8"!1 SECOND INTERVAL, 8 READINGS/TRIGGER
50 ENTER 722; Rdgs(*)!SYN EVENT,ENTER EACH READING
60 PRINT Rdgs(*)!PRINT READINGS 80 END
70 END
```

NOTE When using the TIMER sample event or the SWEEP command, autorange is disabled. You cannot use TIMER or SWEEP for AC or AC+DC voltage measurements using the synchronous or random methods (SETACV SYNC or RNDM), or for frequency or period measurements.

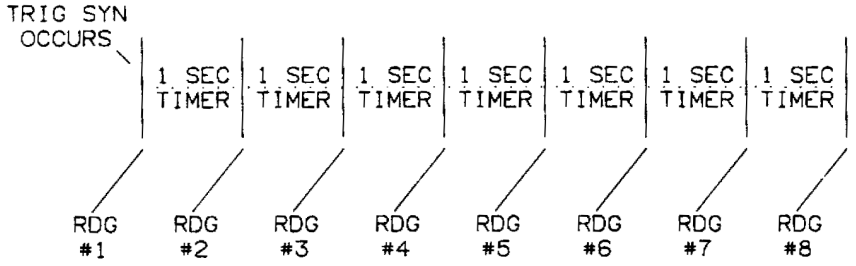

Figure 4-3 TIMER or SWEEP interval

Making delayed readings

The DELAY command allows you to specify a time interval that is inserted between the trigger event and the first sample event. For example, in the following program, the specified delay interval is 2 seconds and the SWEEP interval is 1 second. Line 40 specifies 8 readings per trigger event. Figure 4-4 shows that the delay occurs between the trigger event (TRIG SGL) and the first reading. The SWEEP interval then occurs between each successive reading. In this example, the amount of time added to the total measurement is 9 seconds.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(8)!DIMENSION ARRAY FOR READINGS
30 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE
40 OUTPUT 722;"SWEEP 1,8"!1 SECOND INTERVAL, 8 READINGS/TRIGGER
50 OUTPUT 722;"DELAY 2"!2 SECOND DELAY
60 ENTER 722;Rdgs(*)!ENTER READINGS
70 PRINT Rdgs(*)!PRINT READINGS
80 END
```

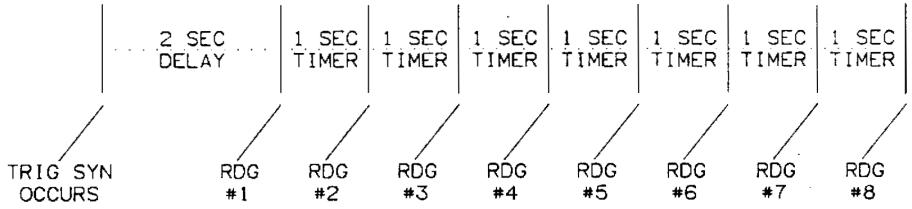

Figure 4-4 DELAY with SWEEP (or TIMER)

Default delays

If you have not specified a delay interval, the multimeter automatically determines a delay time (default delay time) based on the present measurement function, range, resolution, and the AC bandwidth setting. This delay time is actually the settling time allowed before readings, which ensures accurate measurements. The default delay time is updated automatically whenever the function range, resolution, or AC bandwidth changes. However, once you specify a delay time value, the value does not change until you execute RESET or a PRESET command, cycle power, specify another delay value, or default the delay parameter (DELAY -1 command which returns to the automatic delay). The following program uses

the DELAY? query command to respond with the delay time for the PRESET NORM state.

```
10 OUTPUT 722;"PRESET NORM"
20 OUTPUT 722;"DELAY?"
30 ENTER 722;A$
40 PRINT A$
50 END
```

External triggering

The external (EXT) event allows the multimeter to be triggered from an external source. This event can be used as the trigger arm, the trigger event, and/or the sample event. The EXT event occurs on a negative edge transition of a TTL pulse applied to the multimeter's rear panel Ext Trig connector. The minimum pulse width recognized is 250 ns. The bandwidth of the external trigger circuitry is 5 MHz.

The following program uses the EXT event as the trigger event. The sample event is AUTO; the number of readings per trigger event is set to 1. Upon the arrival of a negative edge transition on the Ext Trig terminal, the multimeter takes a reading, which is transferred, to the controller. A second negative edge transition initiates the second reading, which is transferred to the controller. This sequence continues until all 20 readings are completed and transferred to the controller.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(20)!DIMENSION ARRAY FOR READINGS
30 OUTPUT 722;"PRESET NORM"!TARM AUTO,TRIG SYN, NRDGS 1,AUTO,
50 OUTPUT 722;"TRIG EXT"!TRIGGER EACH READING
60 ENTER 722;Rdgs(*)!ENTER READINGS
70 PRINT Rdgs(*)!PRINT READINGS
80 END
```

The following example uses EXT as the sample event. The trigger event is synchronous (selected by the PRESET NORM command). The number of readings per trigger event is set to 10. When the controller executes line 50, the synchronous event occurs which enables the sample event (EXT). Upon the arrival of a negative edge transition on the Ext Trig terminal, the multimeter takes a single reading, which is transferred, to the controller. A second negative edge transition initiates the second reading, which is transferred to the controller. This sequence continues until all 10 readings are completed and transferred to the controller.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(10)!DIMENSION ARRAY FOR READINGS
30 OUTPUT 722;"PRESET NORM"!TARM AUTO, TRIG SYN, DCV AUTORANGE
40 OUTPUT 722;"NRDGS 10,EXT"!10 READINGS/TRIGGER, EXTERNAL SAMPLE EVENT
50 ENTER 722;Rdgs(*)!ENTER READINGS
60 PRINT Rdgs(*)!PRINT READINGS
70 END
```

NOTE Refer to the “EXTOUT Signal” later in this chapter, for examples showing how to synchronize the multimeter to an external scanning device.

External trigger buffering

Trigger buffering corrects for an error (TRIGGER TOO FAST) that can occur when using the external (EXT) trigger arm, trigger, or sample event. With trigger buffering disabled, any external trigger signal that occurs during a rending generates the TRIGGER TOO FAST error and the trigger(s) are ignored. With trigger buffering enabled, the first external trigger that occurs during a reading is stored and no error is generated by this or any successive triggers. After the reading is complete, the stored trigger satisfies the EXT event if the multimeter is so programmed. Trigger buffering is useful when you are using an external scanning device synchronized to the multimeter's EXTOUT signal using the input complete (ICOMP) event. Since the ICOMP pulse occurs before each reading is finished, it is possible for the scanner to close the next channel and generate its channel closed pulse (which is used to trigger the multimeter) before the reading is complete. (Refer to Input complete, later in this chapter, for more information.) In the multimeter's power-on state, trigger buffering is disabled. To enable trigger buffering, send:

```
OUTPUT 722;"TBUFF ON"
```

To disable trigger buffering, send:

```
OUTPUT 722; "TBUFF OFF"
```

Event combinations

You can specify many combinations of the trigger arm, trigger, and sample events to suit your application. Table 4-2 shows, all possible combinations of these events and describes the resultant triggering sequence for each.

Table 4-2 Event combinations

Trigger arm event	Trigger event	Sample event	Description
AUTO	AUTO	Any	One reading is taken per sample event (if the sample event is AUTO, readings are taken continuously).
AUTO	EXT	AUTO, EXT, TIMER, LINE, LEVEL	After a negative edge transition on the Ext Trig input, one reading is taken per sample event until the specified number of readings are completed.
AUTO	EXT	SYN	Illegal
AUTO	LEVEL	AUTO, EXT, TIMER, LEVEL	After the LEVEL event[a] occurs, one reading is taken per sample event, until the specified number of readings are completed.
AUTO	LEVEL	SYN, LINE	Illegal
AUTO	LINE	AUTO, EXT, TIMER, LINE	After the power line voltage crosses zero volts, one reading is taken per sample event until the specified number of readings are completed.
AUTO	LINE	SYN, LEVEL	Illegal
AUTO	SGL	Any	After executing the TRIG SGL command, one reading is taken per sample event until the specified number of readings are completed. The trigger event then becomes HOLD. When using the SYN sample event, the input buffer must be enabled or you must suppress cr lf when sending the TRIG SGL command.
AUTO	SYN	SYN	After the controller requests data,[b] both SYN events are satisfied and the first reading is taken. One reading is then taken per SYN event until the specified number of readings are completed.
AUTO	SYN	AUTO, EXT, LEVEL, LINE, TIMER	After the controller requests data,[b] one reading is taken per sample event until the specified number of readings are completed.

Table 4-2 Event combinations (continued)

Trigger arm event	Trigger event	Sample event	Description
EXT	AUTO	Any	After a negative edge transition on the Ext Trig input, one reading is taken per sample event until the specified number of readings are completed.
EXT	EXT	AUTO, EXT, TIMER, LINE, LEVEL	After two negative edge transitions on the Ext Trig input, one reading is taken per sample event until the specified number of readings are completed.
EXT	EXT	SYN	Illegal
EXT	LEVEL	AUTO, EXT, TIMER, LEVEL	After a negative edge transition on the Ext Trig input followed by the occurrence of the LEVEL event[a], one reading is taken per sample event until the specified number of readings are completed.
EXT	LEVEL	SYN, LINE	Illegal
EXT	LINE	AUTO, EXT, TIMER, LINE	After a negative edge transition on the Ext Trig input followed by the power line voltage crossing zero volts, one reading is taken per sample event until the specified number of readings are completed.
EXT	LINE	SYN, LEVEL	Illegal
EXT	SGL	ANY	Illegal
EXT	SYN	SYN	After a negative edge transition on the Ext Trig input followed by the controller requesting data[b] (which satisfies both SYN events), the first reading is taken. One reading is then taken per SYN event until the specified number of readings are completed.
EXT	SYN	AUTO, EXT, TIMER, LINE, LEVEL	After a negative edge transition on the Ext Trig input, followed by the controller requesting data[b] one reading is taken per sample event, until the specified number of readings are completed.
HOLD	Any	Any	No readings taken until the trigger arm event is changed.
AUTO, EXT, SGL, SYN	HOLD	Any	No readings taken until the trigger event is changed. When using the SGL trigger arm event and the SYN sample event, the input buffer must be enabled or you must suppress cr lf when sending the TARM SGL command.

Table 4-2 Event combinations (continued)

Trigger arm event	Trigger event	Sample event	Description
SGL	AUTO	Any	After executing the TARM SGL command, one reading is taken per sample event until the specified number of readings are completed. The trigger arm event then becomes HOLD. When using the SYN sample event, the input buffer must be enabled or you must suppress cr lf when sending the TARM SGL command.
SGL	EXT	AUTO, EXT, TIMER, LINE, LEVEL	After executing the TARM SGL command followed by a negative edge transition on the Ext Trig input, one reading is taken per sample event, until the specified number of readings are completed. The trigger arm, event then becomes HOLD.
SGL	EXT	SYN	Illegal
SGL	LEVEL	AUTO, EXT, TIMER, LEVEL	After executing the TARM SGL command followed by the occurrence of the LEVEL event,[a] one reading is taken per sample event until the specified number of readings are completed. The trigger arm event then becomes HOLD.
SGL	LEVEL	SYN, LINE	Illegal
SGL	LINE	AUTO, EXT, TIMER, LINE	After executing the TARM SGL command followed by the power line voltage crossing zero volts, one reading is taken per sample event until the specified number of readings are completed. The trigger arm event then becomes HOLD.
SGL	LINE	SYN, LEVEL	Illegal
SGL	SGL	Any	Illegal
SGL	SYN	SYN	After executing the TARM SGL command, followed by the controller requesting data[b], which satisfies both SYN events, the first reading is taken. One reading is then taken per SYN event until the specified number of readings are completed.[c] The trigger arm event then becomes HOLD.
SGL	SYN	AUTO, EXT, TIMER, LINE, LEVEL	After executing the TARM SGL command, followed by the controller requesting data,[b] one reading is taken per sample event until the specified number of readings are completed.[c] The trigger arm event then becomes HOLD.

Table 4-2 Event combinations (continued)

Trigger arm event	Trigger event	Sample event	Description
SYN	AUTO	SYN	After the controller requests data,[b] (which satisfies both SYN events) the first reading is taken. One reading is then taken per SYN event until the specified number of readings are completed.
SYN	AUTO	AUTO, EXT, TIMER, LINE, LEVEL	After the controller requests data,[b] one reading is taken per sample event until the specified number of readings are completed.
SYN	EXT	AUTO, EXT, TIMER, LINE, LEVEL	After the controller requests data,[b] followed by a negative edge transition on the Ext Trig input, one reading is taken per sample event until the specified number of readings are completed.
SYN	EXT	SYN	Illegal
SYN	LEVEL	AUTO, EXT, TIMER, LEVEL	After the controller requests data,[b] followed by the occurrence of the LEVEL event,[a] one reading is taken per sample event until the specified number of readings are completed
SYN	LEVEL	SYN, LINE	Illegal
SYN	LINE	AUTO, EXT, TIMER, LINE	After the controller requests data,[b] followed by the power line voltage crossing zero volts, one reading is taken per sample event until the specified number of readings are completed.
SYN	LINE	SYN, LEVEL	Illegal
SYN	SGL	Any	Illegal
SYN	SYN	SYN	After the controller requests data,[b] all three events are satisfied and the first reading is taken. One reading is then taken per SYN event until the specified number of readings are completed.
SYN	SYN	AUTO, EXT, TIMER, LINE, LEVEL	After the controller requests data,[b] both SYN events are satisfied. One reading is then taken per sample event until the specified number of readings are completed.

[a] The LEVEL event occurs when the specified voltage is reached on the specified slope of the input signal. The LEVEL trigger event or sample event can only be used for DC voltage or direct-sampled measurements.

[b] The output buffer must be empty and reading memory must be OFF or empty for the SYN event to occur.

[c] The input buffer must be enabled or you must suppress cr lf when sending the TARM SGL command.

Reading Formats

This section discusses the ASCII, single integer (SINT), double integer (DINT). single real (SREAL), and double real (DREAL) formats that can be used for storing readings or for outputting readings on the GPIB. Storing readings in memory is described later in this chapter under Using Reading Memory; outputting readings on the GPIB is discussed later in this chapter under Sending Readings Across the Bus.

ASCII

The ASCII format is 15 bytes per reading encoded in scientific notation in standard units of volts, amps, ohms, hertz, or seconds as follows:

SD.DDDDDDDDESDD

Where:
S = sign (+ or -)
D = 0-9
E = delimiter between mantissa and base 10 exponent

Single and double integer

The single integer (SINT) format has 2 bytes per reading and the double integer (DINT) format has 4 bytes per reading. Both formats use two's complement coding.

NOTE **When using the SINT or DINT memory/output format, the multimeter applies a scale factor to the readings. The scale factor is based on the multimeter's measurements function, range, A/D converter setup, and enabled math operations. You should not use the SINT or DINT format for frequency or period measurements; when a real-time or post-process math operation is enabled (except STAT or PFAIL); or when autorange is enabled.**

Two's complement binary coding

Two's complement binary coding is a method that allows a binary number to represent both positive and negative integers. Two's complement coding is done by changing the sign and, in effect, the decimal equivalent of the most significant bit (MSB). When the MSB is set (1), in a 1 byte two's complement number, its value is $1 \times -(2^7) = -128$. When the MSB is reset (0), its value is $0 \times -(2^7) = 0$. Note that the range of an 8 bit, 1 byte two's complement number is -128 to 127, not 0 to 255.

The following example resolves the decimal equivalent of this two's complement word:

10110101 10010110

This two's complement word is equivalent to:

$-(2^{15}) + 2^{13} + 2^{12} + 2^{10} + 2^8 + 2^7 + 2^4 + 2^2 + 2^1$

Which evaluates to: –19050

Single real

The single real (SREAL) format conforms to IEEE-754 specifications. This format has 32 bits, 4 bytes per reading as follows:

```
S EEE EEEE  E MMM MMMM  MMMM MMMM  MMMM MMMM
  byte 0     byte 1     byte 2    byte 3
```

Where:

S = sign bit (1 = negative 0 = positive)
E = base two exponent biased by 127 (to “decode” these 8 bits, subtract 127 from their decimal equivalent).
M = mantissa bits (those right of the radix point). There is an implied most significant bit (MSB) to the left of the radix point. This bit is always assumed to be “1”. This provides an effective precision of 24 bits with the least significant bit (right most) weighted 2^{-23}. Another way to evaluate this mantissa is to convert these 24 bits (MSB assumed “1”) to an integer and then multiply by 2^{-23}.

The value of a number in the SREAL format is calculated by:

$(-1)^S \times (\text{mantissa}) \times 2^{(\text{exponent})}$

SREAL example

This example resolves the decimal equivalent of the following SREAL formatted number:

```
SEEEEEEE EMMMMMMM MMMMMMMM MMMMMMMM
10111011 11001000 01001000 10010000
```

The sign bit “S” is set “1,” this indicates that the number is negative.

The base two's exponent (01110111) evaluates to:

$2^6 + 2^5 + 2^4 + 2^2 + 2^1 + 2^0 = 119$

Since the exponent is biased by 127, the real value is:

exponent - 127 = 119 - 127 = -8

The mantissa [1.10010000100100010010000 (MSB assumed “1”)] evaluates to:

$1 + 2^{-1} + 2^{-4} + 2^{-9} + 2^{-12} + 2^{-16} + 2^{-19} = 1.56471443177$

Evaluating the mantissa at the byte level instead of the bit level:

```
 byte 1   byte 2   byte 3 = byte 1  byte 2  byte 3
11001000 01001000 10010000   200     72       144
```

mantissa $= 200 \times 2^{-7} + 72 \times 2^{-15} + 144 \times 2^{-23} = 1.56471443177$

or

mantissa $= (200 \times 2^{16} + 72 \times 2^{8} + 144) \times 2^{-23} = 1.56471443177$

The SREAL number is then calculated by:

$-1 \times 2^{-8} \times 1.56471443177 = -6.1121657491E-3$

Double real

The double real (DREAL) format conforms to IEEE-754 specifications and contains 64 bits (8 bytes) per reading as follows:

```
   byte 0     byte 1    byte 2     byte 3
S EEE EEEE  EEEE MMMM  MMMM MMMM  MMMM MMMM
   byte 4     byte 5    byte 6     byte 7
MMMM MMMM   MMMM MMMM  MMMM MMMM  MMMM MMMM
```

Where:

S = sign bit (1 = negative 0 = positive)
E = base two exponent biased by 1023 (to decode these 11 bits, subtract 1023 from their decimal equivalent).
M = mantissa bits (those right of the radix point). There is an implied most significant bit (MSB) to the left of the radix point. This bit is always “1”. This provides an effective precision of 53 bits with the least significant bit (right most) weighted 2^{-52}. Another way to evaluate this mantissa is to convert these 53 bits (MSB = “1”) to an integer and then multiply by 2^{-52}.

The value of a number in the DREAL format is calculated by:

$(-1)^{S} \times (\text{mantissa}) \times 2^{(\text{exponent})}$

Using Reading Memory

The multimeter stores readings in memory whenever readings are being taken and reading memory is enabled. Reading memory has a FIFO (first-in-first-out) mode and a LIFO (last-in-first-out) mode. In the FIFO mode, the first reading stored is the first reading returned when you recall readings without specifying reading numbers (implied read method which is discussed later in this chapter). If you fill the reading memory in the FIFO mode, all stored readings remain intact and new readings are not stored.

In the LIFO mode, the last reading stored is the first reading returned when you recall readings without specifying reading numbers. If you fill reading memory in the LIFO mode, the oldest readings are replaced by the newest readings. You enable reading memory and specify the mode using the MEM command. (Specifying a reading memory mode erases any previously stored readings.) For example, to specify reading memory using the LIFO mode, send:

```
OUTPUT 722."MEM LIFO"
```

The multimeter is now enabled to store readings. After storing readings, you can disable reading memory and leave all stored readings intact by sending:

```
OUTPUT 722;"MEM OFF"
```

Later, you can resume the previous mode to store additional readings without clearing any stored readings by sending:

```
OUTPUT 722;"MEM CONT"
```

Memory formats

Readings can be stored in one of five formats: ASCII, single integer (SINT), double integer (DINT), single real (SREAL), or double real (DREAL). The memory space required for each format is:

```
ASCII - 16 bytes per reading[1]
SINT - 2 bytes per reading
DINT - 4 bytes per reading
SREAL - 4 bytes per reading
DREAL - 8 bytes per reading
```

[1] The ASCII format is actually 15 bytes for the reading plus 1 byte per reading for a null character which is used to separate stored ASCII readings only.

To determine how many readings can be stored using a particular format, divide the reading memory size (first response returned by the MSIZE? command) by the number of bytes per reading shown above.

– Single Integer (SINT) or Double Intcgcr (DINT) Use the SINT memory format when making low-resolution measurements (3.5 or 4.5 digits) at the fastest possible rate on a fixed range (autorange disabled). (Since the SINT format is only 2 bytes per reading, you can store more readings using SINT than in any other memory format.) Use the DINT memory format when making high-resolution measurements (5.5 digits or greater) at the fastest possible rate on a fixed range.

NOTE

When using the SINT or DINT memory format, the multimeter applies a scale factor to the readings. The scale factor is based on the multimeter's configuration (measurement function, range, A/D converter setup, and enabled math operations). When recalling readings, the multimeter calculates the scale factor based on its present configuration. If the configuration was changed since the readings were stored, a different scale factor may be used which produces incorrect readings. When recalling stored readings, it is very important that the multimeter be configured as it was when the readings were stored. You should not use the SINT or DINT format for frequency or period measurements; when a realtime or post-process math operation is enabled (except STAT or PFAIL); or when autorange is enabled.

– Single Real (SREAL) or Double Real (DREAL) Unlike the SINT and DINT formats, readings stored in SREAL or DREAL format are not scaled and can be used with any measurement function/multimeter configuration. (Since there is no scale factor, the SREAL and DREAL formats are ideal when auto ranging and/or a math function is enabled). Use the SREAL format for measurements with ≤6.5 digits of resolution. Use the DREAL format for measurements with >6.5 digits of resolution.

– ASCII This memory format can be used for any measurement function/ multimeter configuration. Since ASCII has the greatest. number of bytes per reading, you should use it only when the output format is ASCII, measurement speed is not critical, and the number of readings to be stored is not great.

The MFORMAT command specifies the reading memory format (the power-on and default format is SREAL). For example, to select the single integer format, send:

```
OUTPUT 722; "MFORMAT SINT"
```

Overload indication

The multimeter indicates an overload condition (input greater than the present range can measure) by storing the value ± 1E+38 in reading memory instead of a reading. When overload values are recalled to the display, the value ± lE+38 is displayed. When overload values are transferred from reading memory to the GPIB output buffer, they are converted to the overload numbers for the specified output format. Refer to Sending Readings Across the Bus later in this chapter for more information.

Recalling readings

You can recall readings from memory using the reading number or by a method called “implied read”. Regardless of the specified reading memory format, recalled readings are output in the format specified in the OFORMAT command (refer to Sending Readings Across the Bus later in this chapter for more information). Before recalling readings, you may want to determine the number of readings stored. This can be done using the MCOUNT? query command. The following program returns the total number of stored readings.

```
10 OUTPUT 722;"MCOUNT?"
20 ENTER 722;A
30 PRINT A
40 END
```

Using reading numbers

The multimeter assigns a number to each reading in reading memory. The most recent reading is assigned the lowest number (1) and the oldest reading is assigned the highest number. Reading numbers are always assigned in this manner regardless of whether the LIFO or FIFO mode is used. The RMEM command allows you to use the reading number(s) to copy a reading or group of readings from memory to the output buffer. The RMEM command does not destroy readings in memory: it merely copies the reading(s) to the output buffer.

The RMEM command turns reading memory OFF. This means all previously stored readings remain intact and new readings are not stored. The first parameter in the RMEM command specifies the beginning reading (first parameter). The second parameter (count) specifies the number of readings to be recalled, starting with first. The third parameter (record) specifies the record from which to recall readings. Records correspond to the number of readings specified in the NRDGS or SWEEP command. For example, if you have specified four readings in the

NRDGS command, each record in reading memory contains four readings. The following program specifies 10 readings per trigger (NRDGS 10) and uses the TARM SGL command to take 8 groups of 10 readings (multiple trigger arming). This will place a total of 80 readings in memory.

```
10 OUTPUT 722;"TARM HOLD"!SUSPEND READINGS
20 OUTPUT 722."DCV 1"!DC VOLTAGE, 1 V RANGE
30 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
40 OUTPUT 722;"TRIG AUTO"!AUTO TRIGGER EVENT
50 OUTPUT 722;"NRDGS 10,AUTO"!10 READINGS/TRIGGER, AUTO SAMPLE EVENT
60 OUTPUT 722;"TARM SGL,8"!ARM TRIGGERING 8 TIMES
70 END
```

The stored readings can now be accessed by individual reading number (1 through 80) or by record/reading number (e.g. the 3rd reading in record 2 is also reading number 13). For example, the following program returns and displays reading number 50 (the 31st reading taken by the above program).

```
10 OUTPUT 722;"RMEM 50"!RECALL READING NUMBER 50
20 ENTER 722;A!ENTER READING
30 PRINT A!PRINT READING
40 END
```

The following program uses the first parameter and the count parameter to return and display the readings numbered 12 through 17.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(6)!DIMENSION ARRAY FOR 6 READINGS
30 OUTPUT 722;"RMEM 12,6"!RECALL 6 READINGS, STARTING WITH #12
40 ENTER 722;Rdgs(*)!ENTER READINGS
50 PRINT Rdgs(*)!PRINT READINGS
60 END
```

You can also use record numbers when recalling readings. The multimeter assigns the lowest record number (1) to the most recent record and the highest number to the oldest record. The following program returns the 3rd and 4th reading in record number 6 {in this case, readings numbered 53 and 54, respectively).

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(2)!DIMENSION ARRAY FOR READINGS
30 OUTPUT 722;"RMEM 3,2,6"!RECALL 3rd & 4th READINGS FROM RECORD #6
40 ENTER 722;Rdgs(*)!ENTER READINGS
50 PRINT Rdgs(*)!PRlNT READINGS
60 END
```

When executing RMEM from the front panel, after recalling a reading by reading number, you can use the up or down arrow keys to scroll through the other readings in memory. (The RMEM command is the only way to retrieve stored readings from the front panel.)

Using implied read

When the controller requests data from the multimeter and its output buffer is empty with reading memory enabled, a reading is removed from memory, placed in the output buffer, and transferred to the controller. This is the "implied read" method of recalling readings. Unlike the RMEM command, the implied read removes readings from memory. In the LIFO mode, the most recent reading is returned. In the FIFO mode, the oldest reading is returned. The following program makes 200 readings, places them in reading memory, and uses the implied read to transfer the readings to the controller.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(200) !DIMENSION ARRAY FOR 200 READINGS
30 OUTPUT 722;"PRESET NORM" !TARM AUTO, TRIG SYN, DCV AUTORANGE
40 OUTPUT 722;"NRDGS 200,AUTO" !200 READINGS/TRIGGER, AUTO SAMPLE EVENT
50 OUTPUT 722;"MEM FIFO" !ENABLE READING MEMORY, FIFO MODE
60 OUTPUT 722;"TRIG SGL" !TRIGGER READINGS
70 PAUSE !PAUSE PROGRAM, PRESS CONTINUE TO RESUME
80 ENTER 722;Rdgs(*) !ENTER READINGS
90 PRINT Rdgs(*) !PRINT READINGS
100 END
```

Sending Readings Across the Bus

This section describes the output formats for readings and how to transfer readings from the multimeter to the controller.

Output formats

The multimeter sends readings to the GPIB output buffer whenever readings are being taken and reading memory is not enabled (MEM OFF command). (In the power-on. RESET, or any of the PRESET states, reading memory is not enabled.) The five output formats and the number of bytes per reading are:

```
ASCII-- 15bytes per reading
SINT -- 2per reading
DINT -- 4bytes per reading
SREAL-- 4bytes per reading
DREAL-- 8bytes per reading
```

– ASCII This is the most commonly used output format because it has no scale factor and requires no special handling by the controller to convert the data. Since ASCII uses the greatest number of bytes per reading, use this format when measurement speed is not critical.

NOTE

When using the ASCII format, 2 additional bytes are required for the carriage-return, line-feed (cr, lf) end of line sequence. The cr, lf is used only for the ASCII format and normally follows each reading output in ASCII format. However, when using the ASCII output format and multiple readings are recalled from reading memory using the RMEM command, the multimeter places a comma between readings (comma = 1 byte). In this case, the cr, lf occurs only once, following the last reading in the group being recalled. Commas are not used when readings are output directly to the bus (reading memory disabled), when readings are recalled using "implied read", or when using any other output format.

– Single Integer (SINT) or Double Integer (DINT) Use the SINT format when making low-resolution measurements (3.5 or 4.5 digits) at the highest possible rate on a fixed range (autorange disabled). (Since the SINT format is only 2 bytes per reading, readings can be transferred across GPIB faster using SINT than any other format.) Use the DINT format when making high-resolution

measurements (5.5 digits or greater) at the highest possible speed on a fixed range.

NOTE **When using the SINT or DINT memory/output format, the multimeter applies a scale factor to the readings. The scale factor is based on the multimeter's measurement function, range, A/D converter setup, and enabled math operations. You should not use the SINT or DINT format for frequency or period measurements; when a real-time or post-process math operation is enabled (except STAT or PFAIL); or when autorange is enabled.**

– Single Real (SREAL) or Double Real (DREAL) Unlike the SINT and DINT formats, readings output in SREAL or DREAL format are not scaled and can be used with any measurement function/multimeter configuration. (Since there is no scale factor, the SREAL and DREAL formats are ideal when autoranging and/or a math function is enabled.) The DREAL format has the added advantage that no conversion is necessary by the controller. Use the SREAL, format for measurements with ≤6.5 digits of resolution. Use the DREAL format for measurements with >6.5 digits of resolution.

The OFORMAT command specifies the output format for readings (the power on and default format is ASCII). For example, to select the double integer format, send:

```
OUTPUT 722;"OFORMAT DINT"
```

Overload indication

The multimeter indicates an overload condition (input greater than the present range can measure) by outputting the largest number possible for the particular output format as follows.

```
SINT format: +32767 or -32768 (unscaled)
DINT format: +2.147483647E+9 or -2.147483648E+9 (unscaled)
ASCII, SREAL, DREAL: +/-1.OE+38
```

Output termination

Each reading output to the GPIB in ASCII format is normally followed by *cr lf* (carriage return, line feed). The *cr lf* indicates the end of transmission to most controllers. Readings output in any other format do not have the *cr lf* end of line sequence. With any output format, you can enable the GPIB EOI (End Or Identify) function to mark the end of transmission. Refer to the END command in Chapter 6 for more information.

Using the SINT or DINT output format

The ISCALE? command returns the scale factor (in ASCII format) for readings output in the SINT or DINT format. (After the controller retrieves the scale factor, the output format returns to the specified SINT or DINT format.) You can retrieve the scale factor after the multimeter is configured but before readings are triggered, or after all readings are completed and transferred to the controller. (If a reading is in the output buffer when the ISCALE? command is executed, the reading will be overwritten by the scale factor.)

SINT example

The following program outputs 10 readings in SINT format, retrieves the scale factor and multiplies the scale factor times each reading. The readings are transferred to the controller using the TRANSFER statement (this command is specific to Hewlett-Packard 200/300 controllers using BASIC language). The TRANSFER statement is the fastest way to transfer readings across the GPIB, especially when used with the direct memory access (DMA) GPIB interface. You should use the TRANSFER statement whenever measurement/transfer speed is important.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20INTEGER Num_readings!DECLARE VARIABLE
30INTEGER Int_rdgs (1: 10) BUFFER!CREATE INTEGER BUFFER ARRAY
40REAL Rdgs(1:10)!CREATE REAL ARRAY
50Num_readings=10!NUMBER OF READINGS = 10
60ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
70 ASSIGN Int_rdgs TO BUFFER Int_rdgs(*)!ASSIGN BUFFER I/O PATH NAME
80 OUTPUT @Dvm;"PRESET NORM;OFORMAT SINT;NPLC 0;NRDGS ";Num_readings
85  !TARM AUTO, TRIG SYN, SINT OUTPUT FORMAT, MIN. INTEGRATION TIME
90TRANSFER @Dvm TO @Int_rdgs;WAIT!SYN EVENT,TRANSFER READINGS INTO
91!INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
```

```
95!SINT,NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
100OUTPUT @Dvm;"I SCALE?"!QUERY SCALE FACTOR FOR SINT FORMAT
110ENTER @Dvm;S!ENTER SCALE FACTOR
120FOR I=1 TO Num_readings
130Rdgs(I)=Int_rdgs(I)!CONVERT EACH INTEGER READING TO REAL
135 !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
140R=ABS(Rdgs(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
150IF R>=32767 THEN PRINT "OVLD"!IF OVLD,PRINT OVERLOAD MESSAGE
160Rdgs(I)=Rdgs(I)*S!MULTIPLY READING TIMES SCALE FACTOR
170Rdgs(I)=DROUND(Rdgs(I),4)!ROUND TO 4 DIGITS
180NEXT I
190END
```

DINT example

The following program is similar to the preceding program except that it takes 50 readings and transfers them to the computer using the DINT format.

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20INTEGER Num_readings,L,J,K!DECLARE VARIABLES
30Num_readings= 50! NUMBER OF READINGS = 50
40ALLOCATE REAL Rdgs(1:Num_readings)!CREATE ARRAY FOR READINGS
50ASSIGN @Dvm TO 722!ASSlGN MULTIMETER ADDRESS
60ASSIGN @Buffer TO BUFFER[4*Num_readings]!ASSIGN BUFFER I/O PATH NAME
70OUTPUT @Dvm;"PRESET NORM;RANGE 10;FORMAT DINT;NRDGS";Num_readings
75TARM AUTO, TRIG SYN,DCV 10 V RANGE,DINT OUTPUT FORMAT,NRDGS 50,AUTO
80TRANSFER @Dvm TO @Buffer;WAIT!SYN EVENT, TRANSFER READINGS
90OUTPUT @Dvm;"1 SCALE?"!QUERY SCALE FOR DINT
100ENTER @Dvm;S!ENTER SCALE FACTOR
110FOR I=1 TO Num_readings
120ENTER @Buffer USING "#,W,W";J,K!ENTER ONE 16-BIT 2's COMPLEMENT
121!WORD INTO EACH VARIABLE J AND K(# = STATEMENT TERMINATION NOT
125!REQUIRED; W = ENTER DATA AS 16-BIT 2'S COMPLEMENT INTEGER)
130Rdgs(I)=(J*65536.+K+65536.*(K<0))!CONVERT TO REAL NUMBER
140R=ABS(Rdgs(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
150IF R>2147483647 THEN PRINT "OVLD"!IF OVERLOAD OCCURRED, PRINT
MESSAGE
160Rdgs(I)=Rdgs(I)*S!APPLY SCALE FACTOR
170Rdgs(I)=DROUND(Rdgs(I),8)!ROUND CONVERTED READING
180PRINT Rdgs(I)!PRINT READINGS
190NEXT I
200END
```

Using the SREAL output format

The following program shows how to convert 10 readings output in the SREAL format.

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20INTEGER Num_readings!DECLARE VARIABLE
30Num_readings=10!NUMBER OF READINGS = 10
40ALLOCATE REAL Rdgs(1:Num_readings)!CREATE ARRAY FOR READINGS
50ASSIGN @Dvm TO 722!ASSlGN MULTIMETER ADDRESS
60ASSIGN @Buffer TO BUFFER [4*Num_readings]    !ASSIGN BUFFER I/O PATH
NAME
70OUTPUT @Dvm;"PRESET NORM;OFORMAT SREAL;NRDGS";Num_readings
75!TRlG SYN, SREAL OUTPUT FORMAT, 1 PLC, DCV AUTORANGE, 10 READINGS
80TRANSFER @Dvm TO @Buffer;WAIT!SYN EVENT; TRANSFER READINGS
90FOR I=1 TO Num_readings
100ENTER @Buffer USING "#,B";A,B,C,D!ENTER ONE 8-BIT BYTE INTO
101!EACH VARIABLE, (# =STATEMENT TERMINATION NOT REQUIRED, B = ENTER ONE
105!8-BIT BYTE AND INTERPRET AS AN INTEGER BETWEEN 0 AND 255)
110S=1!CONVERT READING FROM SREAL
120IF A>127 THEN S=-1!CONVERT READING FROM SREAL
130IF A>127 THEN A=A-128!CONVERT READING FROM SREAL
140A=A*2- 127!CONVERT READING FROM SREAL
150IF B>127 THEN A=A+1!CONVERT READING FROM SREAL
160IF B<=127 THEN B=B+128!CONVERT READING FROM SREAL
170Rdgs(I)=S*(B*65536.+C*256.+D)*2^(A-23)!CONVERT READING FROM SREAL
180Rdgs(I)=DROUND(Rdgs(I),7)!ROUND READING TO 7 DIGITS; YOU
181!MUST DO THIS WITH SREAL TO ENSURE ANY OVLD VALUES ARE ROUNDED TO
185!1.E+38 (WITHOUT ROUNDING, THE VALUE MAY BE SLIGHTLY LESS)
190IF ABS(Rdgs(I))=1.E+38 THEN!IF OVERLOAD OCCURRED:
200PRINT "Overload Occurred"!PRINT OVERLOAD MESSAGE
210ELSE!IF NO OVERLOAD OCCURRED:
220PRINT Rdgs(I)!PRINT READING
230END IF
240NEXT I
250END
```

Using the DREAL output format

The following program uses the DREAL output format. Notice that no conversion is necessary using this format since DREAL is the same format that the controller uses as its internal data format (8-bytes/word).

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20REAL Rdgs(1:10) BUFFER!CREATE BUFFER ARRAY
30ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
40ASSIGN @Rdgs TO BUFFER Rdgs(*)!ASSIGN BUFFER I/O PATH NAME
50OUTPUT @Dvm;1'PRESET NORM;NPLC 10;OFORMAT DREAL;NRDGS 10"
55!TRIG SYN, 10 PLCs, DCV AUTORANGE, DREAL OUTPUT FORMAT, 10 RDGS/TRIG.
60TRANSFER @Dvm TO @Rdgs;WAIT!SYN EVENT, TRANSFER READINGS
70FOR I=1 TO 10
80IF ABS(Rdgs(I))=1.E+38 THEN!IF OVERLOAD OCCURRED:
90PRINT "OVERLOAD OCCURRED"!PRINT OVERLOAD MESSAGE
100ElSE!IF NO OVERLOAD:
110Rdgs(I)=DROUND(Rdgs(I),8)!ROUND READINGS
120PRINT Rdgs(I)!PRINT READINGS
130END IF
140NEXT I
150END
```

The preceding program used the TRANSFER statement to get readings from the multimeter. The following program uses the ENTER statement to transfer readings to the computer using the DREAL format. The ENTER statement is easier to use since no I/O path is necessary but is much slower than the TRANSFER statement. Also when using the ENTER statement, you must use the FORMAT OFF command to instruct the controller to use its internal data structure instead of ASCII.

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT
20Num_readings=20!NUMBER OF READINGS = 20
30ALLOCATE REAL Rdgs(1:Num_readings)!CREATE ARRAY FOR READINGS
40ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
50OUTPUT @Dvm;"PRESET NORM;OFORMAT DREAL;NPLC 10;NRDGS";Num_readings
55!TRIG SYN, DCV AUTORANGE, DREAL OUTPUT FORMAT, 10 PLC, 20 READINGS/
TRIG
60ASSIGN @Dvm;FORMAT OFF!USE 8-BYTE/WORD DATA STRUCTURE
70FOR I=1 TO Num_readings
80ENTER @Dvm;Rdgs(I)!ENTER EACH READING
90IF ABS(Rdgs(I))=1.E+38 THEN!IF OVERLOAD OCCURRED:
100PRINT "OVERLOAD OCCURRED"!PRINT OVERLOAD MESSAGE
110ELSE!IF NO OVERLOAD OCCURRED
```

```
120Rdgs(I)=DROUND(Rdgs(1),8)!ROUND READINGS TO 8 DIGITS
130PRINT Rdgs(I)!PRINT READINGS
140END IF
150NEXT I
160END
```

Increasing the Reading Rate

This section discusses the multimeter's high-speed mode and the factors that affect the reading rate. It contains program examples that show how to increase the reading rate, how to transfer readings at high-speed directly to the controller, how to perform high-speed transfers from reading memory to the controller, and how to determine the reading rate.

High-speed mode

For DC voltage, DC current, 2- or 4-wire ohms, and direct- or sub-sampled measurements,[1] the multimeter enters the high-speed mode when readings are initiated, the integration time is less than 10 PLCs, and the following commands have been executed:

```
ARANGE OFF
DISP OFF
MATH OFF
MFORMAT SINT or DINT (only required when reading memory is enabled)
OFORMAT SINT or DINT (only required when reading memory is not enabled)
```

While readings are being taken in the high-speed mode, the multimeter becomes completely dedicated to the measurement process. This means that it will not process any commands until the specified readings are completed. When readings are being sent directly to the output buffer in the high-speed mode, the multimeter waits until each reading is removed from the output buffer before placing the next reading in the output buffer. This ensures that readings will not be lost because of bus/controller speed limitations. (When not in the high-speed mode, the multimeter will write-over any reading in the output buffer when a new reading is available.)

If reading memory is enabled in the FIFO mode and reading memory becomes full in the high-speed mode, the trigger arm event becomes HOLD which stops readings and removes the multimeter from the high-speed mode. After removing some or all of the readings from memory, you can resume measurements by changing the trigger arm event (TARM command). In the LIFO mode, when reading memory becomes full, the oldest readings are replaced with the newest readings regardless of whether in high-speed mode or not.

[1] Refer to Chapter 5 for more information on direct- and sub-sampled measurements.

NOTE In the high-speed mode, the input buffer is temporarily disabled while readings are being made. Also, if END ALWAYS was specified (specifies the GPIB EOI mode), the EOI mode changes to END ON while the readings are being made. Following completion of the readings, the input buffer mode and the EOI mode return to that previously specified.

In the high-speed mode, the multimeter will respond only to the GPIB CLEAR command (Device Clear). If for some reason you must remove the multimeter from the high-speed mode, send the following:

```
CLEAR 722
```

The CLEAR command suspends measurements which removes the multimeter from the high-speed mode. Refer to Appendix B for more information on the GPIB CLEAR command.

Configuring for fast readings

The PRESET FAST command executes a series of commands that configure for fast readings. In addition, the reading rate is affected by the integration time and/or resolution; triggering setup: delay time; AC bandwidth (for AC measurements only): and, for resistance measurements only, the offset compensation mode.

NOTE In addition to the commands discussed in this section, the DEFEAT command can be used to speed throughput by disabling the multimeter's input protection algorithm and some syntax and error checking algorithms. With these algorithms disabled, the multimeter can change to a new measurement configuration faster than it can with them disabled. Refer to the DEFEAT command in Chapter 6 for details and a CAUTION statement concerning its use.

PRESET FAST command

The PRESET FAST command disables many functions that slow the reading rate and configures the multimeter for fast reading transfer to memory and to the GPIB. Table 4-3 shows the speed-related commands executed by PRESET FAST and the reason for executing each.

Table 4-3 Commands executed by PRESET FAST

Command	Reason
DCV 10	Selects DC voltage measurements on the 10 V range, which disables autorange. The autorange function samples the input before each reading, taking more time per reading than readings made on a fixed range. The disadvantage of a fixed range is lower resolution for signals that are less than 10% of full scale and the possibility of an overload condition for readings greater than full scale.
AZERO OFF	With autozero enabled, a zero measurement is made following each reading (for DC measurements only), which increases the time per reading.
DISP OFF	The time required for the multimeter to update its display slows the reading rate.
MATH OFF	Any enabled real-time math operation(s) slow the reading rate. If you must perform math operations on readings, use the post-process math (MMATH command). Refer to Math Operations later in this chapter for more information.
MFORMAT DINT	Readings come from the A/D converter in either SINT or DINT format (the format used depends on the specified measurement resolution;[a] in the configuration selected by PRESET FAST, the A/D converter uses DINT). The fastest way to transfer readings to reading memory is to have the memory format (MFORMAT) match the A/D converter's format so that no conversion is necessary. (Refer to Reading Formats earlier in this chapter for information on when to use SINT or DINT).
OFORMAT DINT	Readings come from the A/D converter in either SINT or DINT format (the format used depends on the specified measurement resolution;[a] in the configuration selected by PRESET FAST, the A/D converter uses DINT). The fastest way to transfer readings to the output buffer is to have the output format (OFORMAT) match the A/D converter's format so that no conversion is necessary. In addition, when the output format matches the reading memory format, no conversion is required to recall readings from memory. Remember to use the ISCALE? command to retrieve the scale factor when using the SINT or DINT output format. (Refer to Reading Formats earlier in the chapter for information on when to use SINT or DINT.)

[a] For direct-sampled digitizing, the format used depends on the amplitude of the input signal. Refer to Chapter 5 for details.

Integration time and resolution

DC, ohms, and analog AC measurements: The specified integration time and/or resolution have a major effect on the reading rate for DC voltage; DC current: 2-wire or 4-wire ohms; AC or AC+DC current: and AC or AC+DC voltage (using the SETACV ANA method only). The longer the integration time (or the greater the resolution), the slower the reading rate. The specifications in Appendix A show selected reading rates for each of these measurements based on integration time.

Sampled AC voltage measurements: For AC or AC+DC voltage measurements using SETACV SYNC or SETACV RNDM, the integration time is fixed and cannot be changed. For these measurements, the specified resolution has a major effect on the reading rate. The specifications in Appendix A show selected reading rates for sampled AC measurements based on the specified resolution.

Frequency or period measurements: The integration time does not affect frequency or period measurements. For these measurements, the specified resolution (which also selects gate time) has a major effect on the reading rate. The specifications in Appendix A show reading rates for frequency and period measurements based on the specified resolution.

Triggering setup

To ensure the fastest triggering configuration, set the trigger arm, trigger, and sample events to AUTO, You can also use the TIMER sample event (or the SWEEP command). Assuming you do not generate the TRIGGER TOO FAST error, the reading rate is the reciprocal of the TIMER or SWEEP interval.

Delay time

Under normal operation, the multimeter automatically determines a delay time (default delay) based on the present measurement function, range, resolution, and for AC measurements, the AC bandwidth setting. This delay time is actually the settling time inserted before the first reading, which ensures accurate readings. The default delay has a large affect on the reading rate for analog AC measurements and a minimal affect on the reading rate for sampled AC voltage or DC measurements. For analog AC measurements, you can achieve a faster reading rate by specifying a shorter delay than the default value. However, the resulting settling time may not produce accurate measurements.

AC bandwidth

For the fastest AC measurements, specify the AC bandwidth (ACBAND command) to match the frequency content of the input signal. The specifications in Appendix A show the reading rates for AC measurements based on the frequency components of the input signal.

Offset compensation

For 2- and 4-wire ohms measurements with offset compensation enabled, an offset voltage measurement is made before each resistance reading. This requires more time than with offset compensation disabled (OCOMP OFF).

High-speed DCV example

The following program measures DC voltage at the fastest. possible rate (>100k readings per second). The readings are stored in reading memory.

```
10 OUTPUT 722;"PRESET FAST"!DCV, 10 V RANGE, TARM SYN, TRIG AUTO
20 OUTPUT 722;"APER 1.4E-6"!LONGEST INTEGRATION TIME POSSIBLE FOR
25 !>100K READINGS PER SECOND
30 OUTPUT 722;"MFORMAT SINT"!SINT MEMORY FORMAT
40 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY
50 OUTPUT 722;"NRDGS 10000,AUTO!10000 READINGS/TRIGGER, AUTO SAMPLE
EVENT
60 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
70 END
```

High-speed OHM (or OHMF) example

The following program measures 2-wire ohms at the fastest possible rate (>100k readings per second). This program can be adapted to 4-wire ohms by using the OHMF command instead of the OHM command in line 50.

```
10 OUTPUT 722;"PRESET FAST"!DCV 10 V RANGE, TARM SYN, TRIG AUTO
20 OUTPUT 722;"APER 1.4E-6"!LONGEST INTEGRATION TIME POSSIBLE FOR
25 !>100K READINGS PER SECOND
30 OUTPUT 722;"MFORMAT SINT"!SINT MEMORY FORMAT
40 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY
50 OUTPUT 722;"OHM 100E3"!2-WIRE OHMS, 100 K(Ω) RANGE
60 OUTPUT 722;"NRDGS 10000,AUTO"!10000 READINGS/TRIGGER, AUTO SAMPLE
EVENT
70 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
80 END
```

High-speed DCI example

The following program measures DC current at the fastest possible rate.

```
10 OUTPUT 722;"PRESET FAST"!DCV, 10 V RANGE, TARM SYN, TRIG AUTO
20 OUTPUT 722;"APER 1.4E-6"I!LONGEST INTEGRATION TIME POSSIBLE FOR
25 !MAXIMUM READING RATE
30 OUTPUT 722;"MFORMAT SINT"!SINT MEMORY FORMAT
40 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY
50 OUTPUT 722;"DCI 100E-3"!DC CURRENT, 100 mA RANGE
60 OUTPUT 722;"NRDGS 5000 AUTO"!5000 READINGS/TRIGGER, AUTO SAMPLE
EVENT
70 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
80 END
```

Fast synchronous ACV/ACDCV example

The following program measures AC voltage using the synchronous method at the fastest possible rate (approximately 10 readings per second). This program can be adapted to AC+DC voltage by using the ACDCV command instead of the ACV command in line 50.

```
10 OUTPUT 722;"PRESET FAST"!TARM SYN, TRIG AUTO
20 OUTPUT 722;"MFORMAT SINT"!SINT MEMORY FORMAT
30 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY
40 OUTPUT 722;"SETACV SYNC"!SYNCHRONOUS AC MEASUREMENT METHOD
50 OUTPUT 722;"ACV 10,2"!AC VOLTS, 10 V RANGE, 2% RESOLUTION
60 OUTPUT 722;"ACBAND 5E3,8E3"!SIGNAL BETWEEN 5 kHz AND 8 kHz
70 OUTPUT 722;"NRDGS 20, AUTO"!20 READINGS/TRIGGER, AUTO SAMPLE EVENT
80 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
90 END
```

Fast random ACV/ACDCV example

The following program measures AC voltage using the random method at the fastest possible rate (approximately 45 readings per second). This program can be adapted to AC+DC voltage by using the ACDCV command instead of the ACV command in line 50.

```
10 OUTPUT 722;"PRESET FAST""!TARM SYN, TRIG AUTO
20 OUTPUT 722;"MFORMAT SINT!SINT MEMORY FORMAT
30 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY
40 OUTPUT 722;"SETACV RNDM"!RANDOM AC MEASUREMENT METHOD
50 OUTPUT 722;"ACV 10 6"!AC VOLTS, 10 V RANGE, 6% RESOLUTION
60 OUTPUT 722;"ACBAND 10E3,20E3”!SIGNAL BETWEEN 10 kHz AND 20 kHz
```

```
70 OUTPUT 722;"NRDGS 100, AUTO”!100 READINGS/TRIGGER, AUTO SAMPLE EVENT
80 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
90 END
```

Fast analog ACV/ ACDCV example

The following program measures AC voltage using the analog method at a fast rate. This program uses the default delay time. You can achieve faster reading rates by specifying a shorter delay time; the resulting settling time, however, may not produce accurate measurements. You can also achieve unspecified faster reading rates by specifying less integration time in line 60. This program can be adapted to AC+DC voltage by using the ACDCV command instead of the ACV command in line 50.

```
10 OUTPUT 722;"PRESET FAST""!TARM SYN, TRIG AUTO
20 OUTPUT 722;"MFORMAT SINT!SINT MEMORY FORMAT
30 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
40 OUTPUT 722;"SETACV ANA"!ANALOG AC MEASUREMENT METHOD
50 OUTPUT 722;"ACV 10"!AC VOLTS, 10 V RANGE
60 OUTPUT 722;"NPLC 0.1""!0.1 PLC INTEGRATION TIME
70 OUTPUT 722;"ACBAND 10E3,20E3"!SIGNAL BETWEEN 10 kHz AND 20 kHz
80 OUTPUT 722;"NRDGS 100, AUTO"!100 READINGS/TRIGGER, AUTO SAMPLE EVENT
90 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
100 END
```

Fast ACI/ ACDCI example

The following program measures AC current at a fast rate. This program uses the default delay time. You can achieve faster reading rates by specifying a shorter delay time; the resulting settling time, however, may not produce accurate measurements. You can also achieve unspecified faster reading rates by specifying less integration time in line 50. This program can be adapted to AC+DC current by using the ACDCI command instead of the ACI command in line 40.

```
10 OUTPUT 722;"PRESET FAST"!TARM SYN, TRIG AUTO
20 OUTPUT 722;"MFORMAT SINT"!SINT MEMORY FORMAT
30 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
40 OUTPUT 722;"ACI 100E-3"!AC CURRENT, 100 mV RANGE
50 OUTPUT 722;"NPLC 0.1"!0.1 PLC INTEGRATION TIME
60 OUTPUT 722;"ACBAND 10E3,20E3"!SIGNAL BETWEEN 10 kHz AND 20 kHz
70 OUTPUT 722;"NRDGS 100,AUTO"!100 READINGS/TRIGGER, AUTO SAMPLE EVENT
80 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
90 END
```

Fast FREQ (or PER) example

The following program measures frequency at a fast rate. This program can be adapted to measure period by using the PER command instead of the FREQ command in line 40.

```
10 OUTPUT 722;"PRESET FAST"!TARM SYN, TRIG AUTO
20 OUTPUT 722;"MFORMAT SREAL"!SINGLE REAL MEMORY FORMAT
30 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
40 OUTPUT 722;"FREQ 10, .1"!FREQUENCY, 10 V RANGE, 100 µs GATE TIME
50 OUTPUT 722;"ACBAND 10E3,20E3"!SIGNAL BETWEEN 10 kHz AND 20 kHz
60 OUTPUT 722;"NRDGS 100, AUTO"!100 READINGS/TRIGGER, AUTO SAMPLE EVENT
70 OUTPUT 722;"TARM SGL"!TRIGGER READINGS
80 END
```

High-speed transfer across GPIB

Configuring the output format (OFORMAT command) to match the format used by the A/D converter (either SINT or DINT) ensures the fastest. transfer of readings to the controller. This is because no format conversion is required in the multimeter. For high-speed, low-resolution readings (3.5 or 4.5 digits) made on a fixed range, use the SINT output format. (Because the SINT format uses only 2 bytes per reading, multiple readings can be transferred across the bus faster using the SINT output format than any other format.) For the fastest transfer of high resolution readings (5.5 digits or greater) made on a fixed range, use the DINT output format.

The multimeter is capable of taking readings and outputting them to the controller at >100k readings per second. Using the SINT output format at this reading rate, the GPIB and controller must be able to transfer data at >200k bytes per second. For Hewlett-Packard Series 200/300 Computers, this requires a direct memory access (DMA) card. In addition, devices that slow the operation of the GPIB bus and any unnecessary lengths of GPIB cable must be removed to achieve maximum transfer rate.

The following program transfers readings directly to the controller at the fastest possible rate. This program configures the multimeter to take readings at its maximum rate of >100k readings per second. Readings are output using the SINT format. If the bus/controller cannot transfer readings at >200k bytes per second, the reading rate will be slower.This is because, in the high-speed mode, the multimeter waits until each reading is removed from its output buffer before placing the next reading in the output buffer. In the following program, the SYN

trigger arm event is used to trigger the readings (TRIG SYN could also be used). The SYN event is very important for high-speed operation since it ensures the controller will be ready to accept the first reading output by the multimeter. The TRANSFER statement (line 120) satisfies the SYN event and is the fastest way to transfer readings across the GPIB, especially when used with the direct memory access (DMA) GPIB interface.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_readings!DECLARE VARIABLE
30 INTEGER Int_rdgs(1:30000) BUFFER!CREATE INTEGER ARRAY FOR BUFFER
40 REAL Rdgs(1:30000)!CREATE REAL ARRAY
50 Num_readings=30000!NUMBER OF READINGS = 30000
60 ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
70 ASSIGN Int_rdgs TO BUFFER Int_rdgs(*)!ASSIGN BUFFER I/O PATH NAME
80 OUTPUT @Dvm; "PRESET FAST"!TARM SYN,TRIG AUTO, DCV 10 V
90 OUTPUT @Dvm;"APER 1.4E-6"!1.4 µs INTEGRATION TIME
100 OUTPUT @Dvm; "OFORMAT SINT"!SINT OUTPUT FORMAT
110 OUTPUT @Dvm; "NRDGS"; Num_readings !30000 READINGS/TRIGGER, AUTO
115 !SAMPLE EVENT (DEFAULT VALUE)
120 TRANSFER @Dvm TO @Int rdgs;WAIT!SYN EVENT, TRANSFER READINGS INTO
121 !INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
125 !SINT,NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
130 OUTPUT @Dvm; "ISCALE?"!QUERY SCALE FACTOR FOR SINT FORMAT
140 ENTER @Dvm;S!ENTER SCALE FACTOR
150 FOR I=1 TO Num_readings
160 Rdgs(I)=Int_rdgs(I)!CONVERT EACH INTEGER READING TO REAL
165!FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT LINE)
170 R=ABS(Rdgs(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
180 IF R>=32767 THEN PRINT "OVLD"!IF OVLD, PRINT OVERLOAD MESSAGE
190 Rdgs(I)=Rdgs(I)*S!MULTIPLY READING TIMES SCALE FACTOR
200 Rdgs(I)=OROUND(Rdgs(I),4)!ROUND TO 4 DIGITS
210 NEXT I
220 END
```

High-speed transfer from memory

Configuring the reading memory format (MFORMAT command) to match the output format (OFORMAT command) helps to ensure command) to match the fastest transfer of readings from reading memory to the controller. This is because no conversion is necessary when the readings are recalled from memory. For high-speed, low resolution readings (3.5 or 4.5 digits) made on a fixed range, use the SINT format. (Because the SINT format uses only 2 bytes per reading, multiple readings can be stored in memory and transferred across the bus faster using the SINT output format than any other format.) For the fastest transfer of high resolution readings (5.5 digits or greater) made on a fixed range, use the DINT format. Whenever autorange is enabled and transfer speed is critical, use the SREAL format (for readings of 6.5 digits or less) or the DREAL format (for readings of 7.5 or 8.5 digits). Disabling the display and any math operations will also ensure the fastest transfer from reading memory to the controller.

The following program is an example of transferring readings from reading memory to the controller at the fastest possible rate. The program stores 5000 readings in reading memory using the SINT format. The readings are removed from memory using the “implied read” and transferred to the controller (in the SINT format) using the TRANSFER statement (line 130). The controller then retrieves the scale factor, multiplies the scale factor times each reading, and stores the corrected readings in the *Rdgs* array.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_readings!DECLARE VARIABLE
30 INTEGER Int_rdgs(1:30000) BUFFER!CREATE INTEGER ARRAY FOR BUFFER
40 REAL Rdgs(1:30000)!CREATE REAL ARRAY
50 Num_readings=30000!NUMBER OF READINGS = 30000
60 ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
70 ASSIGN Int_rdgs TO BUFFER Int_rdgs(*)!ASSIGN BUFFER I/O PATH NAME
80 OUTPUT @Dvm; "PRESET FAST"!TARM SYN,TRIG AUTO, DCV 10 V
90 OUTPUT @Dvm;"APER 1.4E-6"!1.4 µs INTEGRATION TIME
100 OUTPUT @Dvm; "OFORMAT SINT"!SINT OUTPUT FORMAT
110 OUTPUT @Dvm; "NRDGS"; Num_readings !30000 READINGS/TRIGGER, AUTO
115 !SAMPLE EVENT (DEFAULT VALUE)
120 TRANSFER @Dvm TO @Int rdgs;WAIT!SYN EVENT, TRANSFER READINGS INTO
121 !INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
125 !SINT,NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
130 OUTPUT @Dvm; "ISCALE?"!QUERY SCALE FACTOR FOR SINT FORMAT
140 ENTER @Dvm;S!ENTER SCALE FACTOR
150 FOR I=1 TO Num_readings
```

```
160 Rdgs(I)=Int_rdgs(I)!CONVERT EACH INTEGER READING TO REAL
165!FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT LINE)
170 R=ABS(Rdgs(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
180 IF R>=32767 THEN PRINT "OVLD"!IF OVLD, PRINT OVERLOAD MESSAGE
190 Rdgs(I)=Rdgs(I)*S!MULTIPLY READING TIMES SCALE FACTOR
200 Rdgs(I)=OROUND(Rdgs(I),4)!ROUND TO 4 DIGITS
210 NEXT I
220 END
```

Determining the reading rate

When using the TIMER sample event or the SWEEP command, the reading rate is simply the reciprocal of the specified interval between readings (assuming the TRIGGER TOO FAST error does not occur). For example, if the TIMER interval is specified as 1E-4, the reading rate is 1/1E-4 = 10,000 readings per second. When using another sample event, you can determine the reading rate by specifying a large number of readings per trigger specifying an output pulse after each reading (EXTOUT RCOMP command), and connecting an electronic frequency counter to the multimeter's Ext Out connector. The frequency displayed on the counter is the reading rate expressed in readings per second.

Another method uses the controller to time a number of readings initiated by the TARM SGL or TRIG SGL command. With the input buffer disabled (INBUF OFF), the SGL event holds the GPIB bus until the readings are complete. This means that the time required to execute the TARM SGL or TRIG SGL command is the total time of the measurement. For example, the following program stores readings in reading memory, times TARM SGL for 10000 readings, divides 10000 by the total time, and displays readings per second. The TIMEDATE command (lines 90 and 110) applies to Hewlett-Packard Series 200/300 computers using BASIC language. Refer to your computer operating manuals for more information on how to use you computer's timer.

```
10 REAL Num_readings!CREATE ARRAY
20 Num_readings=10000!NUMBER OF READINGS = 10000
30 ASSIGN @Dvm to 722!ASSIGN MULTIMETER ADDRESS
40 OUTPUT @Dvm;"PRESET FAST"!DCV 10 V RANGE, DINT MEM FORMAT, FAST
45 !READINGS, TARM SYN, TRIG AUTO
50 OUTPUT @Dvm;"NPLC 0"!MINIMUM INTEGRATION TIME (500 ns)
60 OUTPUT @Dvm;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
70 OUTPUT @Dvm;"MFORMAT SINT"!SINT MEMORY FORMAT
80 OUTPUT @Dvm;"NRDGS"; Num_readings ,"AUTO" ! 10000 READINGS/TRIGGER,
AUTO
```

```
85 !SAMPLE EVENT
90 TO=TIMEDATE!START TIMER
100 OUTPUT @Dvm;"TARM SGL"!TRIGGER READINGS
110 T1=TIMEDATE!STOP TIMER
120 PRINT "Readings per second = ";Num_readings/(T1-T0)
125 !PRINT READINGS PER SECOND
130 END
```

If you are transferring multiple readings across the bus instead of using reading memory, you can use the SYN (synchronous) trigger arm or trigger event (which also holds the bus until all readings are complete and transferred) and time the controller's ENTER or TRANSFER statement. This is shown in the following program (the synchronous trigger arm event is selected by the PRESET FAST command in line 50).

```
10 REAL Num_readings!CREATE ARRAY
20 Num_readings=300000!NUMBER OF READINGS = 300000
30 ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
40 ASSIGN @Buffer TO BUFFER [2*Num_readings] !ASSIGN BUFFER I/O PATH
NAME
50 OUTPUT @Dvm; "PRESET FAST"!DCV 10 V RANGE, DINT OUTPUT FORMAT,
55!TARM SYN, TRIG AUTO
60 OUTPUT @Dvm;"NPLC 0"!MINIMUM INTEGRATION TIME
70 OUTPUT @Dvm;"OFORMAT SINT"!SINT OUTPUT FORMAT
80 OUTPUT @Dvm; "NRDGS "; Num_readings, "AUTO"
85 !300000 READINGS/TRIGGER, AUTO SAMPLE EVENT
90 TO=TIMEDATE!BEGIN TIMING READINGS
100 TRANSFER @Dvm TO @Buffer;WAIT!SYN EVENT, TRANSFER READINGS
110 T1=TIMEDATE!STOP TIMING READINGS
120 PRINT "READINGS PER SECOND = 11;Num_readings/(T1/T0)
125!PRINT READINGS PER SECOND
130 END
```

NOTE The time required to retrieve the scale factor (which is necessary to convert the readings output in SINT format) is not included in the above program.

The EXTOUT Signal

You can program the multimeter to output a TTL-compatible signal on its Ext Out connector when a specified A/D converter event occurs; when the multimeter generates a GPIB service request; or when the EXTOUT ONCE command is executed. This signal can be used to synchronize external equipment to the multimeter. The EXTOUT command's first parameter specifies the event that generates the signal and its second parameter specifies the signal's polarity: NEG = low-going, POS = high-going. The events that can generate a signal on the Ext Out connector are:

- Reading complete
- Burst of readings complete
- Input complete
- Aperture waveform
- Service Request
- Executing the EXTOUT ONCE command

Most of the above events apply to the multimeter's A/D converter. Figure 4-5 shows the relationship of these events to the A/D converter activity.

NOTE **The apparent time intervals shown in Figure 4-5 are for the illustration purposes only. They are not meant to indicate the actual intervals produced by the multimeter.**

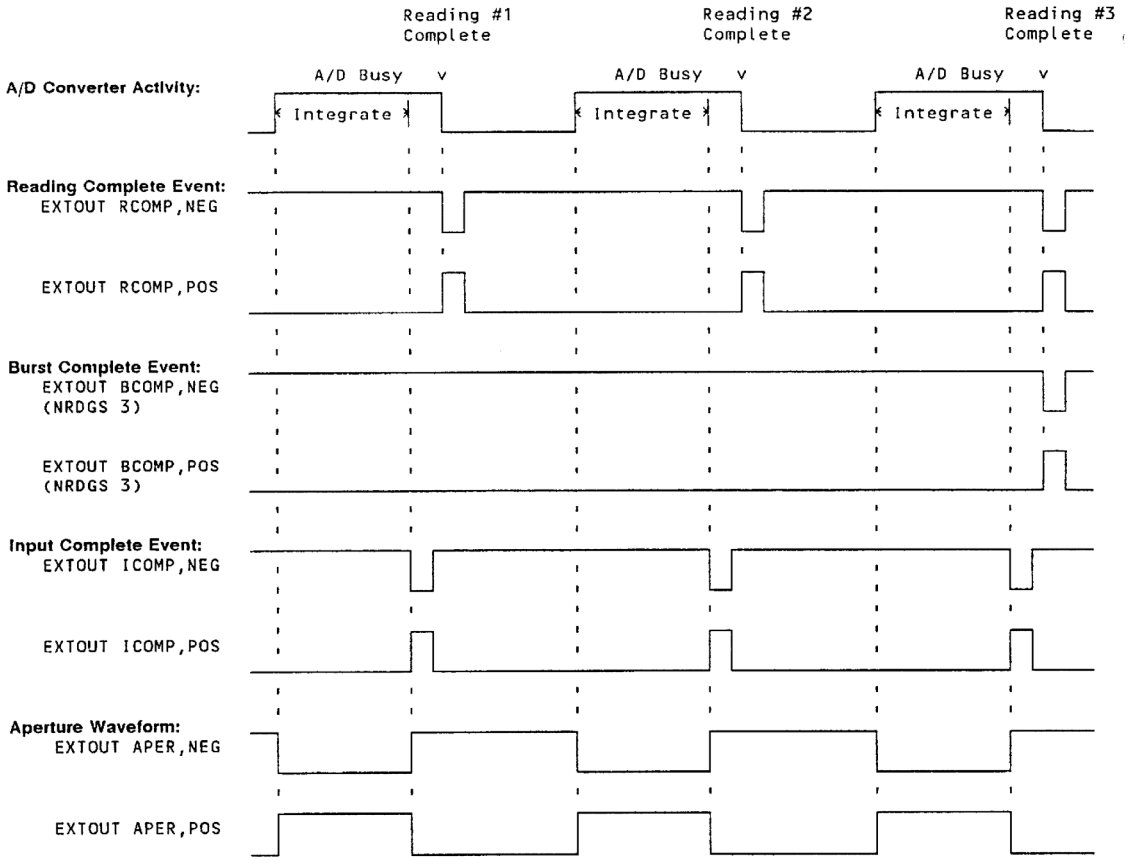

Figure 4-5 A/D Converter event relationships

Reading complete

When specified, the reading complete event (RCOMP event) produces a 1 µs pulse following each reading for any measurement function. For sampled AC voltage measurements (SETACV SYNC or RNDM) a pulse is output after each computed reading, not after each sample in the measurement process. This event can be used to synchronize an external scanner to the multimeter when making one reading per scanner channel.

The following program uses the RCOMP event to synchronize the multimeter to a scanner (the example uses a 3235 Switch/Test Unit with a scanning module in slot 200). Measurement connections are shown in Figure 4-6. The scanner is programmed to output a low-going pulse after each channel closure (line 60). This pulse is connected to the multimeter's Ext Trig connector and triggers each reading. After each reading, the multimeter's EXTOUT signal causes the scanner to advance to the next channel. The channel closure generates a signal which in turn triggers the next reading. This sequence repeats until all 6 channels have been scanned. Readings are stored in the multimeter's reading memory.

```
10 OUTPUT 722;"PRESET NORM"!DCV,NRDGS,1,AUTO, TARM AUTO, TRIG SYN
20 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
30 OUTPUT 722;"TRIG EXT"!TRIGGER EVENT = EXTERNAL
40 OUTPUT 722;"EXTOUT RCOMP,NEG" !READING COMPLETE EXTOUT, LOW-GOING
TTL
45!CONFIGURE EXTERNAL SCANNER
50 OUTPUT 709;"SADV EXTIN"!ADVANCE SCANNER ON MULTIMETER'S EXTOUT
SIGNAL
60 OUTPUT 709;"CHCLOSED EXT"!OUTPUT LOW-GOING PULSE AFTER EACH CLOSURE
70 OUTPUT 709;"SCAN 201- 206"!SCAN CHANNELS 01- 06 ON SCANNER IN SLOT
200
75 !AND ADVANCE TO CHANNEL 01, STARTING THE SCAN
80 END
```

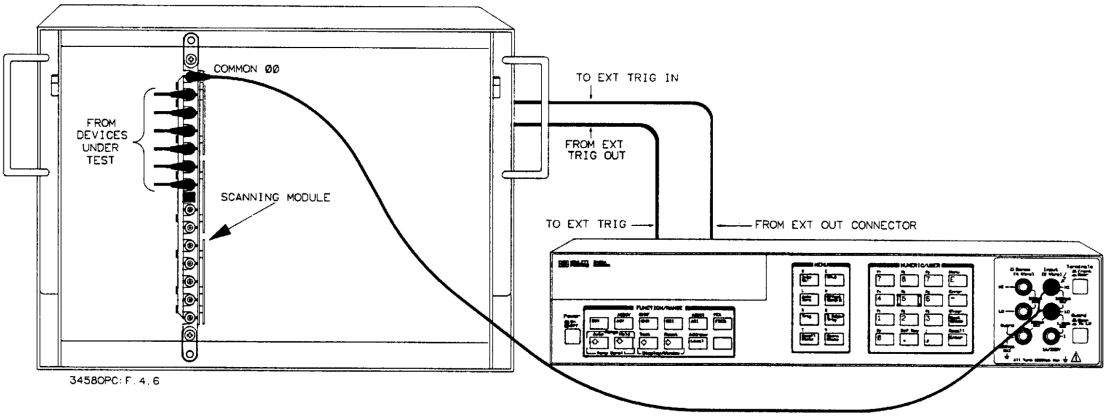

Figure 4-6 Using an external scanner

Burst complete

When specified, the burst complete event (BCOMP event) produces a 1 µs pulse following completion of a group of readings. The number of readings in a group is specified by the NRDGS or SWEEP command. The BCOMP event can be used to synchronize an external scanner to the multimeter when making multiple readings per scanner channel. The following program is similar to the preceding program except that it uses the BCOMP event and makes 15 readings on each scanner channel. Connections for this example are shown in Figure 4-6.

```
10 OUTPUT 722;"PRESET NORM"!DCV, NRDGS 1,AUTO, TARM AUTO, TRIG SYN
20 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
30 OUTPUT 722;"TRlG EXT"!TRIGGER EVENT = EXTERNAL
40 OUTPUT 722;"EXTOUT BCOMP, NEG"!BURST COMPLETE EVENT, LOW-GOING TTL
50 OUTPUT 722;"NRDGS 15, AUTO"!15 READINGS PER CHANNEL
55!CONFIGURE EXTERNAL SCANNER
60 OUTPUT 709;"SADV EXTIN"!ADVANCE SCANNER ON MULTIMETER'S EXTOUT
SIGNAL
70 OUTPUT 709;"CHCLOSED EXT"!OUTPUT LOW-GOING PULSE AFTER EACH CLOSURE
80 OUTPUT 709;"SCAN 201- 206"!SCAN CHANNELS 01 - 06 ON SCANNER IN SLOT
200
```

```
85!AND ADVANCE TO CHANNEL 01, STARTING THE SCAN
90 END
```

Input complete

The input complete event (ICOMP event) is similar to the RCOMP event in that it produces a 1 µs pulse for each reading. However, when the ICOMP event is specified, the pulse occurs when the A/D converter has finished integrating the input signal but before the reading is complete (see Figure 4-5). The ICOMP event can be used with an external scanner when making a single reading per scanner channel. This event is especially important when using a slower (relay type) scanner. Since the ICOMP event occurs before the reading is complete, it advances the scanner sooner than would the RCOMP event. The following program uses the ICOMP event to make one reading on each of 6 scanner channels. Notice that line 40 enables trigger buffering. This prevents the multimeter from generating the TRIGGER TOO FAST error should the scanner output a channel closed pulse before the present reading is complete. Connections for this example are shown in Figure 4-6.

```
10 OUTPUT 722;"PRESET NORM"!DCV, NRDGS,1,AUTO, TARM AUTO, TRIG SYN
20 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
30 OUTPUT 722;"TRIG EXT"!TRIGGER EVENT = EXTERNAL
40 OUTPUT 722;"TBUFF ON"!ENABLE TRIGGER BUFFERING
50 OUTPUT 722 "EXTOUT ICOMP,NEG"!INPUT COMPLETE EXTOUT, LOW-GOING TTL
55!CONFIGURE EXTERNAL SCANNER
60 OUTPUT 709;"SADV EXTIN"!ADVANCE SCANNER ON MULTIMETER'S EXTOUT
SIGNAL
70 OUTPUT 709;"CHCLOSED EXT"!OUTPUT LOW-GOING PULSE AFTER EACH CLOSURE
80 OUTPUT 709;"SCAN 201- 206"!SCAN CHANNELS 01 - 06 ON SCANNER IN SLOT
200
85!AND ADVANCE TO CHANNEL 01 STARTING THE SCAN
90 END
```

Aperture waveform

When specified, the aperture waveform event (APER event) outputs a waveform indicating when the A/D converter is measuring the input signal. In addition to showing when a reading is being measured, the aperture waveform also shows any autozero and autorange measurements being made. This waveform can be used to synchronize external switching equipment to the multimeter. For example, to ensure an electrically quiet environment for high-accuracy measurements, it

may be necessary to suspend the operation of external switching equipment while the A/D converter is integrating each reading. This can be done by enabling the APER event and by programming the external switching to occur only when the aperture waveform indicates that the A/D converter is not integrating the input signal. To following program line enables the APER event with positive polarity (see Figure 4-5):

```
OUTPUT 722;"EXTOUT APER,POS"
```

Service request

When specified, the service request event (SRQ event) produces a 1 µs pulse whenever the multimeter generates a GPIB service request. This event can be used to indicate to external equipment (especially equipment that cannot be connected to GPIB) that one or more specified events have occurred and have generated a service request (refer to Using the Status Register in Chapter 3, for information on service requests).

NOTE **When a status event sets the SRQ bit in the register, that bit remains set until cleared (CSB command, for example). When specified, the EXTOUT SRQ pulse occurs whenever any status event occurs that has been enabled to assert SRQ (RQS command). The EXTOUT SRQ pulse does not necessarily occur whenever the SRQ bit is set; it occurs whenever an enabled status event occurs.**

The following program uses the SRQ event to synchronize the multimeter to external equipment. The program downloads a subprogram to the multimeter. When the subprogram is called by the controller (line 120), it configures the multimeter for high-accuracy temperature measurements using a 10 k(Ω) thermistor. After the subprogram has been called and executed, bit 0 is set in the status register (program memory execution completed). This asserts a GPIB SRQ (enabled by line 30) and causes a pulse on the Ext Out connector (specified by line 40). This pulse signals external equipment that the multimeter is configured and ready to make measurements.

```
10 OUTPUT 722;"SUB EXTSRQ"! STORE SUBPROGRAM NAMED "EXTSRQ"
20 OUTPUT 722;-"PRESET NORM"! PRESET,TRIG SYN, TARM AUTO, NRDGS 1,AUTO
30 OUTPUT 722;"RQS 1"!ENABLE SUBPROGRAM EXECUTION COMPLETE BIT
40 OUTPUT 722;"EXTOUT SRQ,POS"!SRQ EXTOUT EVENT, HI-GOING PULSE
50 OUTPUT 722;"OHMF 10E3"!2-WIRE OHMS, 10 kΩ RANGE
60 OUTPUT 722;"NPLC 100"!100 PLCS INTEGRATION TIME
```

```
70 OUTPUT 722;"OCOMP ON"!ENABLE OFFSET COMPENSATION
80 OUTPUT 722;"TRIG EXT"!EXTERNAL TRIGGER EVENT
90 OUTPUT 722;"MATH CTHRM10K"!ENABLE 10 kΩ THERMISTOR MATH OPERATION
100 OUTPUT 722;"CSB"!CLEAR STATUS REGISTER
110 OUTPUT 722;"SUBEND"!END OF SUBPROGRAM
120 OUTPUT 722;"CALL EXTSRQ"!CALL SUBPROGRAM
130 END
```

EXTOUT ONCE

Executing the EXTOUT ONCE command produces a single 1 µS pulse on the multimeter's Ext Out connector. After executing EXTOUT ONCE, the mode reverts to OFF (the EXTOUT signal is disabled). As shown in the following program. EXTOUT ONCE is useful in subprograms to indicate the completion of the subprogram, or a segment of the subprogram, to external equipment.

```
10 OUTPUT 722;"SUB EXTONCE"!STORE SUBPROGRAM NAMED "EXTONCE"
20 OUTPUT 722;"EXTOUT ONCE"!SIGNAL EXTERNAL EQUIPMENT TO SWITCH
25!TO DC VOLTAGE SIGNAL
30 OUTPUT 722;"PRESET FAST!FAST READINGS, TARM SYN, TRIG AUTO"
40 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
50 OUTPUT 722;"NRDGS 20"!20 READINGS PER TRIGGER
60 OUTPUT 722;"TARM SGL"!TRIGGER 20 READINGS
70 OUTPUT 722;"EXTOUT ONCE"!SIGNAL EXTERNAL EQUIPMENT TO SWITCH TO
75!RESISTANCE MEASUREMENT
80 OUTPUT 722;"OCOMP ON"!ENABLE OFFSET COMPENSATION
90OUTPUT 722;"OHM 1E3"!2-WIRE OHMS, 1 KΩ RANGE
100 OUTPUT 722;"NRDGS 40"!40 READINGS PER TRIGGER
110 OUTPUT 722;"TARM SGL!TRIGGER 40 READINGS"
120 OUTPUT 722;"SUBEND"!END OF SUBPROGRAM
130 OUTPUT 722;"CALL EXTONCE"!CALL SUBPROGRAM
140END
```

Math Operations

Each math operation performs a specific mathematical operation on each reading and/or stores data on a series of readings. The multimeter can perform the null, scale, percent, dB, dBm, filter, RMS, or temperature-related math operations on readings. The statistics and pass/fail math operations do not alter readings but store information pertaining to readings. This section describes how to enable and disable math operations and discusses each math operation in detail.

Real-time vs. post-process

Math operations can be performed real-time or post-process. When a real-time math operation is enabled, the operation is performed on each reading immediately after the reading is taken. The result can then be stored in reading memory or output over the GPIB. When enabled, a post-process math operation (except STAT and PFAIL) is performed on each reading as it is removed or copied from reading memory to the display or the GPIB output buffer. (The readings in memory are not altered by any post-process math operation.) The STAT or PFAIL post-process math operations are performed using the readings in memory immediately after executing the MMATH command. For the statistics operation, results are stored in the statistics registers. For the pass/fail operation, an out of limit reading sets bit number 1 in the status register and displays either FAILED HIGH or FAILED LOW depending on whether the high or low limit was exceeded.

Enabling math operations

To enable a math operation, send the MATH command (for real-time) or the MMATH command (for post-process) followed by the operation parameter (DB, DBM, FILTER, NULL, PERC, PFAIL, RMS, SCALE, STAT, or one of the temperature-related parameters; refer to "Measuring Temperature, later in this section for a listing of the temperature-related parameters). After enabling a math operation, it remains enabled until you disable it, cycle power, execute RESET, or execute one of the PRESET commands. For example, to enable the NULL operation, send:

```
OUTPUT 722; "MATH NULL" !ENABLES REAL-TIME NULL OPERATION
```

or

```
OUTPUT 722; "MMATH NULL" !ENABLES POST-PROCESS NULL OPERATION
```

Up to two math operations can be enabled at the same time. The operations are performed on each reading in the order listed in the command. For example, to enable the NULL and SCALE operations, send:

```
OUTPUT 722;"MATH NULL, SCALE" !ENABLEs REAL-TIME NULL & SCALE
```

or

```
OUTPUT 722;"MMATH NULL, SCALE" !ENABLES POST-PROCESS NULL & SCALE
```

To disable all enabled math operations, send:

```
OUTPUT 722;"MATH OFF" !DISABLES ALL REAL-TIME MATH OPERATIONS
```

or

```
OUTPUT 722;"MMATH OFF" !DISABLES ALL POST-PROCESS MATH OPERATIONS
```

Later you can re-enable the operation(s) that were disabled by the MATH OFF or MMATH OFF command. To re-enable a single math operation (if two operations were previously enabled, this will enable only the first of those two operations), send:

```
OUTPUT 722;"MATH CONT" !RE-ENABLES ONE REAL-TIME MATH OPERATION
```

or

```
OUTPUT 722;"MMATH CONT" !RE-ENABLES ONE POST-PROCESS MATH OPERATION
```

To re-enable two previously enabled math operations send:

```
OUTPUT 722;"MATH CONT,CONT" !RE-ENABLES TWO REAL-TIME MATH OPERATIONS
```

or

```
OUTPUT 722;"MMATH CONT,CONT" !RE-ENABLES TWO POST-PROCESS MATH
OPERATIONS
```

Math registers

Table 4-4 shows the registers used by the real-time or post-process math operations.

Table 4-4 Math registers

Register name	Register contents
DEGREE	Time constant for FILTER and RMS
LOWER	Smallest reading in STATS
MAX	Upper limit for PFAIL operation
MEAN	Average of readings in STATS
MIN	Lower limit for PFAIL
NSAMP	Number of samples in STATS
OFFSET	Subtrahend in NULL and SCALE operations
PERC	Percent value for PERC operation
REF	Reference value for DB operation
RES	Reference impedance for DBM operation
SCALE	Divisor in the SCALE operation
SDEV	Standard deviation in STATS
UPPER	Largest reading in STATS
PFAILNUM	The number of readings that passed PFAIL before a failure was encountered

You can write a value to any math register (except SDEV) using the SMATH command. For example, to place the value of 22 in the DEGREE register, send:

```
OUTPUT 722;"SMATH DEGREE,22"
```

You can read the value in any math register using the RMATH command. For example, the following program reads and prints the value in the RES register.

```
10 OUTPUT 722;"RMATH RES"
20 ENTER 722;A
30 PRINT A
40 END
```

NULL

The NULL operation subtracts a value from each reading (following the first reading). The equation is:

Result = Reading - OFFSET

Where:

OFFSET is the value stored in the OFFSET register (typically the first reading).
Reading is any reading following the first reading.

After you select the NULL operation, the first reading made (real-time) or the first reading taken from memory (post-process) is stored in the OFFSET register. The value of this reading is then subtracted from all subsequent readings. If you do not want the first reading to be the null value, you can write another value to the OFFSET register using the SMATH command. You must wait, however, until after the first reading is made (real-time) or recalled (post-process) before changing the value.

A typical application of the NULL operation is in making more accurate 2-wire ohms measurements. To do this, select 2-wire ohms (OHM command) and short the ends of the test leads together. Now enable the NULL operation. The first reading taken (the lead resistance) is stored in the OFFSET register. Connect the test leads to the unknown resistance to be measured. The multimeter then subtracts the value in the OFFSET register from all subsequent readings until the math NULL operation is disabled. This method is not as accurate as 4-wire ohms because the resistance of the test leads connected together probably will not be the same as when they are connected to the unknown resistance. Also, the resistance of the test leads is checked only once for a series of measurements and the test lead resistance may change.

The following program performs the real-time NULL math operation on 20 readings. After executing the NULL command, the first reading is triggered by line 50. The value in the OFFSET register is then changed to 3.05. The 20 readings are triggered by line 90 and 3.05 is subtracted from each reading.

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(20)!DIMENSION ARRAY FOR 20 READINGS
30 OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10
40 OUTPUT 722;"MATH NULL"!ENABLE REAL-TIME NULL MATH OPERATION
50 OUTPUT 722;"TRIG SGL"!TRIGGER 1 READING, STORED IN OFFSET
60 OUTPUT 722;"SMATH OFFSET,3.05"!WRITE 3.05 TO OFFSET REGISTER
70 OUTPUT 722;"NRDGS 20"!20 READINGS PER TRIGGER
```

```
80 OUTPUT 722;"TRIG SYN"!SYN TRIGGER EVENT
90 ENTER 722;Rdgs(*)!SYN EVENT, ENTER NULL CORRECTED READINGS
100 PRINT Rdgs(*)!PRINT NULL CORRECTED READINGS
110 END
```

The following program performs the post-process NULL operation on 20 readings. After executing the MMATH NULL command, 21 readings are taken and stored in reading memory in FIFO mode. Line 80 recalls the first reading taken which is stored in the OFFSET register. The value in the OFFSET register is then changed to 3.05. The remaining 20 readings in memory are recalled and the NULL operation is performed on each.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(20)!DIMENSION ARRAY FOR 20 READINGS\
30 OUTPUT 722;"PRESET NORM"!PRESET,NRDGS 1,AUTO, DCV 10
40 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
50 OUTPUT 722;"MMATH NULL"!ENABLE POST-PROCESS NULL OPERATION
60 OUTPUT 722;"NRDGS 21"!21 READINGS PER TRIGGER
70 OUTPUT 722;"TRIG SGL"!TRIGGER READINGS
80 ENTER 722;A!RECALL FIRST READING USING IMPLIED READ
90 OUTPUT 722;"SMATH OFFSET,3.05"!WRITE 3.05 TO OFFSET REGISTER
100 ENTER 722;Rdgs(*)!RECALL READINGS USING IMPLIED READ,
105!PERFORM NULL OPERATION ON EACH
110 PRINT Rdgs(*)!PRINT NULL MODIFIED READINGS
120 END
```

SCALE

The SCALE operation modifies each reading by subtracting an offset and dividing by a scale factor. The equation is:

Result = (Reading - OFFSET)/SCALE

Where:

Reading is any reading.
OFFSET is the value stored in the OFFSET register (default = 0: notice that the first reading is not stored in OFFSET as it was for the NULL operation).
SCALE is the value stored in the SCALE register (default = 1).

Notice that the default values do not change the reading (they subtract 0 and divide by 1). You can change the values in the OFFSET register or the SCALE register using the SMATH command.

The following program uses the real-time scale operation to divide each of 20 readings by 2. The default value of 0 is left in the OFFSET register so no subtraction is done before the readings are scaled.

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(20)!DIMENSION ARRAY FOR 20 READINGS
30 OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
40 OUTPUT 722;"NRDGS 20"!20 READINGS PER TRIGGER
50 OUTPUT 722;"MATH SCALE"!ENABLE REAL-TIME SCALE OPERATION
60 OUTPUT 722;"SMATH SCALE 2"!WRITE 2 TO SCALE REGISTER
70 ENTER 722;Rdgs(*)!SYN EVENT, ENTER SCALED READINGS
80 PRINT Rdgs(*)!PRINT SCALED READINGS
90 END
```

The following program uses the post-process scale operation to subtract the value of 1 from each reading and then divide each reading by 2.

```
10  OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20  DIM Rdgs(20)!DIMENSION ARRAY FOR 20 READINGS
30  OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
40  OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
50  OUTPUT 722;"NRDGS 20"!20 READINGS PER TRIGGER
60  OUTPUT 722;"MMATH SCALE"!ENABLE POST-PROCESS SCALE OPERATION
70  OUTPUT 722;"SMATH OFFSET 1"!WRITE 1 TO OFFSET REGISTER
80  OUTPUT 722;"SMATH SCALE 2"!WRITE 2 TO SCALE REGISTER
90  OUTPUT 722;"TRIG SGL"!TRIGGER READINGS
100 ENTER 722;Rdgs(*)!!RECALL READINGS USING IMPLIED READ,
105!PERFORM SCALE OPERATION ON EACH
110 PRINT Rdgs(*)!PRINT MATH RESULTS
120 END
```

Percent

The PERC math operation determines the difference, in percent, between each reading and the value in the PERC register. The equation is:

Result = ((Reading - PERC)/PERC)·100

Where:

Reading is any reading.
PERC is the value stored in the PERC register (power-on value = 1).

You can use the PERC math operation to determine the difference (in percent) between an ideal value and the measured value. For example, the following

program determines the percent error of a 10 VDC voltage measurement. Line 60 enters the ideal value (10) into the PERC register. Line 70 triggers the 20 readings. If a reading is exactly 10 VDC, the value returned is 0. If a reading is, for example, 10.1 VDC, the value returned is:

Result = ((10.1 - 10)/10)·100 = 0.01·100 = 1

```
10 OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Perc(20)!DIMENSION ARRAY FOR 20 PRECENTAGES
30 OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
40 OUTPUT 722;"NRDGS 20"!20 READINGS PER TRIGGER
50 OUTPUT 722;"MATH PERC"!ENABLE REAL-TIME PERC OPERATION
60 OUTPUT 722;"SMATH PERC 10"!WRITE 10 TO PERC REGISTER
70 ENTER 722;Perc(*)!SYN EVENT, ENTER PERCENT DIFFERENCE
80 PRINT Perc(*)!PRINT PERCENT DIFFERENCE
90 END
```

The following program is similar to the preceding program except that it uses the post-process PERC operation.

```
10  OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20  DIM Perc(20)!DIMENSION ARRAY FOR 20 PERCENTAGES
30  OUTPUT 722;"PRESET NORM"!PRESET,NRDGS 1,AUTO, DCV 10, TRIG SYN
40  OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
50  OUTPUT 722;"NRDGS 20"!20 READINGS PER TRIGGER
60  OUTPUT 722;"MMATH PERC"!ENABLE POST-PROCESS PERC OPERATION
70  OUTPUT 722;"SMATH PERC 10"!WRITE 10 TO PERC REGISTER
80  OUTPUT 722;"TRIG SGL"!TRIGGER READINGS
90  ENTER 722;Perc(*)!RECALL READINGS USING IMPLIED READ,
95 !PERFORM PERC OPERATION
100 PRINT Perc(*)!PRINT PERCENT DIFFERENCE
110 END
```

DB

The DB math operation calculates a ratio in decibels. The equation is:

Result = $20 \cdot \log_{10}$,(Reading/REF)

Where:

Reading is any reading.
REF is the value in the REF register (default = 1).

You can change the value in the REF register using the SMATH command.

The following program uses the real-time DB operation to determine an amplifier's voltage gain. Line 40 stores the amplifier's input voltage (0.1 V) in the REF register. The amplifier's output voltage is measured and the gain of the amplifier is computed.

```
10 OUTPUT 722;"PRESET NORM"!PRESET,NRDGS 1,AUTO, DCV 10, TRIG SYN
20 OUTPUT 722;"ACV"!AC VOLTAGE MEASUREMENTS, AUTORANGE
30 OUTPUT 722;"SETACV ANA"!ANALOG ACV METHOD
40 OUTPUT 722;"SMATH REF 0.1"!WRITE 0.1 TO REF REGISTER
50 OUTPUT 722;"MATH DB"!ENABLE REAL-TIME DB OPERATION
60 ENTER 722;A!SYN EVENT, ENTER DB
70 PRINT A!PRINT DB
80 END
```

For example, if the input voltage is 0.1 V and the output voltage is 10 V, the gain is:

$$20 \cdot \log_{10}(10/0.1) = 20 \cdot \log_{10}100 = 40 \text{ dB}$$

The following program is similar to the preceding program except that it uses the post-process DB operation.

```
10  OUTPUT 722;"PRESET NORM"!PRESET,NRDGS 1,AUTO, DCV 10, TRIG SYN
20  OUTPUT 722;"ACV"!AC VOLTAGE MEASUREMENTS, AUTORANGE
30  OUTPUT 722;"SETACV ANA"!ANALOG ACV METHOD
40  OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
50  OUTPUT 722;"SMATH REF 0.1"!WRITE 0.1 TO REF REGISTER
60  OUTPUT 722;"MMATH DB"!ENABLE POST-PROCESS DB OPERATION
70  OUTPUT 722;"TRIG SGL"!TRIGGER READING
80  ENTER 722;A!RECALL READING USING IMPLIED READ,
85!PERFORM DB OPERATION
90  PRINT A!PRINT DB RESULT
100 END
```

DBM

The DBM math operation calculates the power delivered to a resistance referenced to 1 mW. The equation is:

$$\text{Result} = 10 \cdot \log_{10}(\text{Reading}^2/\text{RES}/1\text{ mW})$$

Where:

Reading is any voltage reading.
RES is the resistance value in the RES register (default = 50)

You can change the value in the RES register using the SMATH command.

The following program uses the real-time DBM operation to determine the input power to a loudspeaker. Line 40 stores the speaker's impedance in the RES register (for this example, 8 Ω). The input voltage to the speaker is then measured and the DBM operation is performed.

```
10 OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
20 OUTPUT 722;"ACV"!AC VOLTAGE MEASUREMENTS, AUTORANGE
30 OUTPUT 722;"SETACV ANA"!ANALOG ACV METHOD
40 OUTPUT 722;"SMATH RES 8"!WRITE 8 TO RES REGISTER
50 OUTPUT 722;"MATH DBM"!ENABLE REAL-TIME DBM OPERATION
60 ENTER 722;A!SYN EVENT, ENTER DBM
70 PRINT A!PRINT DBM
80 END
```

For example, if the input voltage is 10 V, the power is:

$$10 \cdot \log_{10}(10^2/8/1\ \text{mW}) = 40.97\ \text{dBm}$$

The following program is similar to the preceding program except that it uses the post-process DBM operation.

```
10  OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
20  OUTPUT 722;"ACV"!AC VOLTAGE MEASUREMENTS, AUTORANGE
30  OUTPUT 722;"SETACV ANA"!ANALOG ACV METHOD
40  OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
50  OUTPUT 722;"SMATH RES 8"!WRITE 8 TO RES REGISTER
60  OUTPUT 722;"MMATH DBM"!ENABLE POST-PROCESS DBM OPERATION
70  OUTPUT 722;"TRIG SGL"!TRIGGER READING
80  ENTER 722;A!RECALL READING USING IMPLIED READ,
85!PERFORM DBM OPERATION
90  PRINT A!PRINT DBM RESULT
100 END
```

Statistics

The STAT math operation performs five calculations on a group of readings and stores the results in five math registers. The calculations are: standard deviation, mean, number of samples, largest reading, and smallest reading. Table 4-5 shows the STAT registers and their contents. You can read any of the STAT registers using the RMATH command.

Table 4-5 STAT registers

Register	Stored result
SDEV	Standard deviation
MEAN	Average of the readings
NSAMP	Number of readings in this group of measurements
UPPER	Largest reading in this group of measurements
LOWER	Smallest reading in this group of measurements

The following program uses the real-time STAT operation to perform five running calculations on 20 DC voltage readings. After the readings are taken and transferred to the controller, the standard deviation is read and returned.

```
10  OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20  DIM Rdgs(20)!DIMENSION ARRAY FOR 20 READINGS
30  OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
40  OUTPUT 722"NRDGS 20"!20 READINGS PER TRIGGER
50  OUTPUT 722;"MATH STAT"!ENABLE REAL-TIME STAT OPERATION
60  ENTER  722 Rdgs(*)!SYN EVENT, ENTER READINGS
70  OUTPUT 722;"RMATH SDEV"!READ STANDARD DEVIATION
80  ENTER  722;S!ENTER STANDARD DEVIATION
90  PRINT S!PRINT STANDARD DEVIATION
100 END
```

The following program performs the post-process STAT operation on 20 readings stored in memory. The post,-process STAT operation is a batch operation. That is the readings do not have to be recalled from memory in order to perform the STAT operation. Also notice that the readings must be stored before enabling the post-process STAT operation (if not, the MEMORY ERROR will occur).

```
10 OUTPUT 722;"PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
20 OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
30 OUTPUT 722;"NRDGS 20"!20 READINGS PER TRIGGER
40 OUTPUT 722;"TRIG SGL"!TRIGGER READINGS
50 OUTPUT 722;"MMATH STAT"!PERFORM POST-PROCESS STAT OPERATION
60 OUTPUT 722;"RMATH SDEV"!READ STANDARD DEVIATION
70 ENTER  722;S!ENTER STANDARD DEVIATION
80 PRINT  S!PRINT STANDARD DEVIATION
90 END
```

Pass/Fail

The PFAIL math operation tests each reading against the limits set in the MAX and MIN registers. If a boundary is exceeded, the hi/low bit of the status register is set. Also, the number of readings that passed the PFAIL operation before a failure was encountered are logged in the PFAILNUM register. The default value is 0 for both the MAX and MIN registers. You can change the value in either register using the SMATH command.

The following program uses the real-time PFAIL operation to check 20 DCV readings against the high and low limits of 11 V and 9 V. After the readings have been triggered, the HI/LO LIMIT bit of the status register (bit 2) is checked. If one or more failures occurred, the PFAILNUM register is queried and its contents returned.

```
10  OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20  DIM Rdgs(20)!DIMENSION ARRAY FOR 20 READINGS
30  OUTPUT 722; "PRESET NORM"!PRESET, NRDGS 1,AUTO, DCV 10, TRIG SYN
40  OUTPUT 722;"MATH PFAIL"!ENABLE REAL-TIME PFAIL OPERATION
50  OUTPUT 722;"SMATH MIN 9"!LOWER LIMIT = 9(V)
60  OUTPUT 722;"SMATH MAX 11"!UPPER LIMIT = 11(V)
70  OUTPUT 722;"CSB"!CLEAR STATUS REGISTER
80  OUTPUT 722;"RQS 2"!ENABLE HI/LO STATUS REGISTER BIT
90  OUTPUT 722;"NRDGS 20"!20 READINGS/TRIGGER
100 ENTER 722;Rdgs(*)!SYN EVENT, ENTER READINGS
110 OUTPUT 722; "STB?"!QUERY SET BITS IN STATUS REGISTER
120 ENTER 722;A!ENTER QUERY RESPONSE
130 IF BINAND(A,2) THEN!IF BIT 2 IS SET:
140 PRINT "HI/LOW LIMIT TEST FAILED"!PRINT FAILURE MESSAGE
150 OUTPUT 722; "RMATH PFAILNUM"!QUERY PFAILNUM REGISTER
160 ENTER 722;B!ENTER QUERY RESPONSE
170 PRINT "NUMBER OF READINGS THAT PASSED BEFORE FAILURE WERE";B
175!PRINT PFAILNUM RESPONSE
```

```
180 ELSE!IF BIT 2 WAS NOT SET:
190 PRINT "HI/LOW LIMIT TEST PASSED"!PRINT TEST PASSED MESSAGE
200 END IF
210 END
```

The following program is similar to the preceding program except that it uses the post-process PFAIL operation on 20 readings stored in memory. The post process PFAIL operation is a batch operation. That is, the readings do not have to be recalled from memory in order to perform the PFAIL operation. Also notice that the readings must be stored before enabling the post process PFAIL operation (if not, the MEMORY ERROR will occur).

```
10  OUTPUT 722;"PRESET NORM"!PRESET,NRDGS 1,AUTO, DCV 10, TRIG SYN
20  OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
30  OUTPUT 722;"SMATH MIN 9"!LOWER LIMIT = 9(V)
40  OUTPUT 722;"SMATH MAX 11"!UPPER LIMIT = 11(V)
50  OUTPUT 722;"CSB" "!CLEAR STATUS REGISTER
60  OUTPUT 722;"RQS 2!ENABLE HI/LO STATUS REGISTER BIT
70  OUTPUT 722;"NRDGS 20"!20 READINGS/TRIGGER
80  OUTPUT 722;"TRIG SGL"!TRIGGER READINGS
90  OUTPUT 722;"MMATH PFAIL"!PERFORM POST-PROCESS PFAIL OPERATION
100 OUTPUT 722;"STB?";!QUERY SET BITS IN STATUS REGISTER
110 ENTER 722; A!ENTER QUERY RESPONSE
120 IF BINAND(A,2) THEN!IF BIT 2 IS SET:
130 PRINT "Hi/LOW LIMIT TEST FAILED"      !PRINT FAILURE MESSAGE
140 OUTPUT 722;"RMATH PFAILNUM"!QUERY PFAILNUM REGISTER
150 ENTER 722; B!ENTER QUERY RESPONSE
160 PRINT "NUMBER OF READINGS THAT PASSED BEFORE FAILURE WERE";B
165!PRINT PFAILNUM RESPONSE
170 ELSE!IF BIT 2 WAS NOT SET:
180 PRINT "HI/LOW LIMIT TEST PASSED"      !PRINT TEST PASSED MESSAGE
190 END IF
200 END
```

FILTER

The filter math operation simulates the output of a single pole, low pass, RC filter. This allows you to reduce the effects of random noise while preserving long term trends. The equation is:

Result = (Previous Result)×(DEGREE-1)/DEGREE + Reading/DEGREE

Where:

Previous Result is initially set to the value of the first reading and thereafter is set to the result of this FILTER operation.
Reading is any reading.
DEGREE selects the step response of the filter.

The value of DEGREE corresponds to the step response of the low-pass filter. That is, if 20 is the value of DEGREE, 20 readings are required for the step response to achieve 63% of its final value. You can achieve slower response or quieter readings by increasing the value of DEGREE. The actual time constant (R×C) of the filter can be determined by:

$$t = \frac{1}{f_s}\left[\frac{1}{ln\frac{DEGREE}{DEGREE-1}} - 1\right]$$

Where:

t = the time constant (R×C)
f_s = the sampling rate which is: 1/timer interval (when using the TIMER and NRDGS commands) or 1/effective interval {when using the SWEEP command). If you are not using the TIMER or SWEEP command, refer to "Determining the Reading Rate" earlier in this chapter.

If DEGREE is larger than 10, (R×C) can be approximated by:

$t \approx (1/f_s) \times DEGREE$

For example (using the first equation), if the reading rate is 200 Hz and the DEGREE is 20, the time constant is:

$$t = \frac{1}{200}\left[\frac{1}{ln\frac{20}{20-1}} - 1\right] = 0.092 \text{ Seconds}$$

Using the second equation with the same reading rate and DEGREE produces:

$t \approx (1/200) \times 20 = 0.1$ seconds

RMS

The RMS math operation can be used to compute the combined RMS value of the AC and DC components of digitized (using the DCV, DSAC, or DSDC command) low frequency signals.

NOTE

For repetitive AC signals of 1 Hz or greater, the synchronous AC measurement method can be used instead of the RMS math operation. If the AC signal is 10 Hz or greater, the analog AC method can be used. If the signal is 20 Hz or greater, the random method can be used. You can also determine the RMS value of the AC component of sinewaves by digitizing (using the DCV, DSAC, or DSDC command) and enabling the STATS math operation. After a number of readings, the result in the SDEV register is the RMS value of the AC component of the input signal.

The RMS math operation takes the square root of the preceding FILTER operation with the reading and the previous result first squared. The RMS math equation is:

$$\text{Result} = \sqrt{\frac{\text{PreviousResult}^2 \cdot (\text{DEGREE} - 1)}{\text{DEGREE} + \frac{\text{Reading}^2}{\text{DEGREE}}}}$$

Where:

Previous Result is initially set to the value of the first reading and thereafter is set to the result of this FILTER operation.
Reading is the latest reading taken.
DEGREE selects the step response of the filter.

Measuring temperature

The temperature-related math operations convert the measured resistance of a thermistor or RTD into a Fahrenheit or Celsius temperature reading. Table 4-6 describes each of the temperature-related math operations. The resistance measurement can be made in either 2-wire ohms (OHM command) or 4-wire ohms (OHMF command). For the greatest accuracy, use the 4-wire ohms mode. Conditions that affect the accuracy of a typical resistance measurement also affect the accuracy of temperature measurements (see Resistance and Calibration in Chapter 3).

Table 4-6 Temperature-related math operations

MATH operation	Description
CTHRM2K	Result = temperature (Celsius) of a 2 kΩ thermistor (40653A)
CTHRM	Result = temperature (Celsius) of a 5 kΩ thermistor (40653B)
CTHRM10K	Result = temperature (Celsius) of a 10 kΩ thermistor (40653C)
FTHRM2K	Result = temperature (Fahrenheit) of a 2 kΩ thermistor (40653A)
FTHRM	Result = temperature (Fahrenheit) of a 5 kΩ thermistor (40653B)
FTHRM10K	Result = temperature (Fahrenheit) of a 10 kΩ thermistor (40653C)
CRTD85	Result = temperature (Celsius) of 100 Ω RTD with alpha of 0.00385 (40654A or 406548)
CRTD92	Result = temperature (Celsius) of 100 Ω RTD with alpha of 0.003916
FRTD85	Result = temperature (Fahrenheit) of 100 Ω RTD with alpha of 0.00385 (40654A or 40654B)
FRTD92	Result = temperature (Fahrenheit> of 100 Ω RTD with alpha of 0.003916

The following example performs a temperature measurement using a 10 kΩ thermistor and returns the result in degrees Celsius.

```
10 OUTPUT 722;"PRESET NORM"!PRESETS MULTIMETER, SUSPENDS READINGS
20 OUTPUT 722;"OHMF 10E3"!SELECTS 4-WIRE OHMS, 10 kΩ RANGE
30 OUTPUT 722;"MATH CTHRM10K"!CELSIUS CONVERSION, 10 kΩ THERMISTOR
40 OUTPUT 722;"TRIG SGL"!TRIGGER READING
50 ENTER 722;A!ENTER RESULT
```

```
60 PRINT A!PRINT RESULT
70 END
```

5 Digitizing

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Introduction

Digitizing is the process of converting a continuous analog signal into a series of discrete samples (readings). Figure 5-1 shows the result of digitizing a sine wave. This chapter discusses the various ways to digitize signals. The importance of the sampling rate, and how to use level triggering.

NOTE As a supplement to the information in this chapter, Product Note 3458A-2 in Appendix D discusses the trigger and timebase errors that affect digitized measurements.

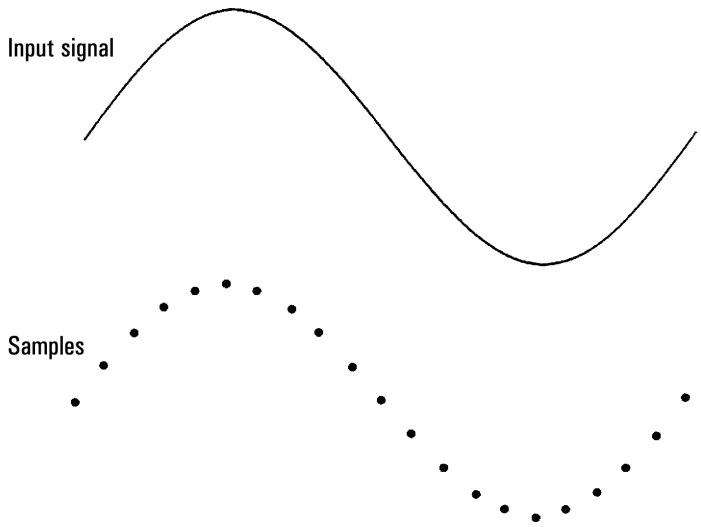

Figure 5-1 Digitized sine wave

Digitizing Methods

The multimeter can digitize signals by making DC voltage measurements, by direct-sampling, or by sub-sampling. Table 5-1 summarizes the characteristics of each digitizing method. Figure 5-2 shows a simplified block diagram of the multimeter's signal path for each digitizing method. Figure 5-3 and shows the front terminal connections for all methods of digitizing.

Table 5-1 Digitizing methods

Digitizing method	Maximum sampling rate	Bandwidth	Repetitive signal required
DCV	100 k/sec	DC - 150 kHz[a]	No
Direct-Sampling	50 k/sec	DC - 12 MHz	No
Sub-Sampling	100 M/sec[b]	DC - 12 MHz	Yes

[a] Range dependent. See the "Appendix A: Specifications" on page 415 for details.

[b] Effective sampling rate (refer to Sub-Sampling later in this chapter for details).

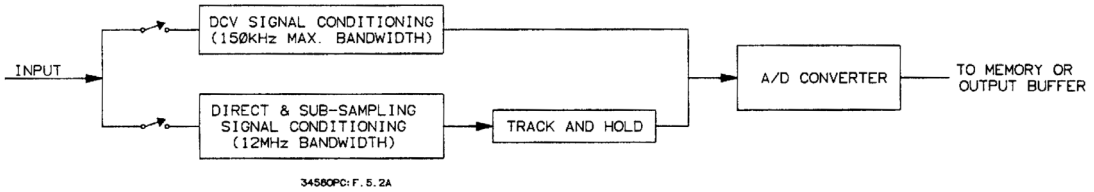

Figure 5-2 Digitizing signal paths

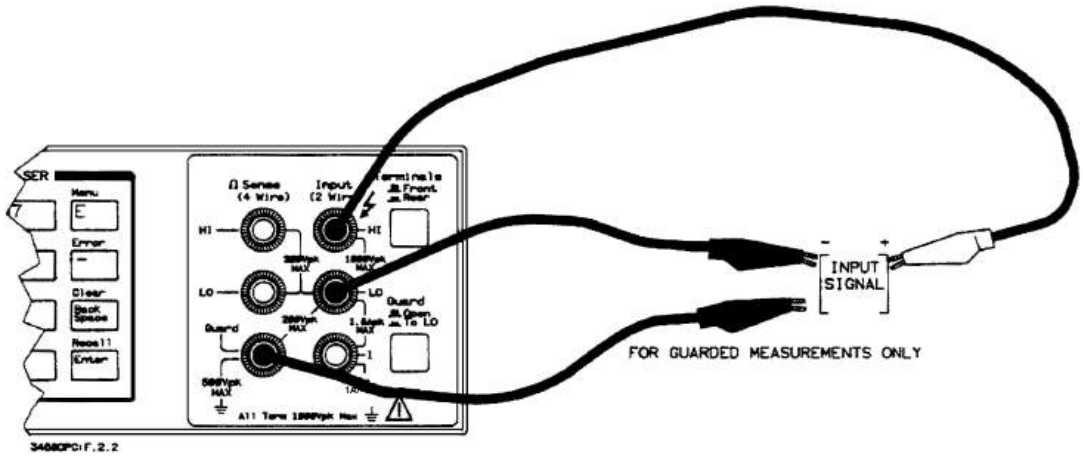

Figure 5-3 Digitizing measurement connections

For most digitizing applications, the multimeter enters its high-speed mode whenever sampling is initiated. In the high-speed mode, the multimeter becomes completely dedicated to taking samples. This means that it will not process any commands until the specified number of samples are completed. When samples are sent directly to the output buffer in the high-speed mode, the multimeter waits until each sample is removed from the output buffer before placing the next sample in the output buffer. This ensures that samples will not be lost because of bus/controller speed limitations. (When not in the high-speed mode, the multimeter writes-over any sample still in the output buffer when a new sample is available.) For more information, refer to High-speed mode in Chapter 4.

The Sampling Rate

The Nyquist or Sampling Theorem states:

> If a continuous, bandwidth-limited signal contains no frequency components higher than F, then the original signal can be recovered without distortion (aliasing) if it is sampled at a rate that is greater than 2F samples per second.

In practice, the multimeter's sampling rate must be *at least* twice the highest frequency component of the signal being measured. The sampling rate is the reciprocal of the time interval specified by the TIMER command or the *effective_interval* specified by the SWEEP command. For example, assume the *effective_interval* is specified as 20 µs. The sampling rate is then 1/20 µs = 50,000 samples per second.

Figure 5-4 shows a sine wave sampled at a rate slightly less than 2F. As shown by the dashed line, the result is an *alias frequency* which is much different than the frequency of the signal being measured.

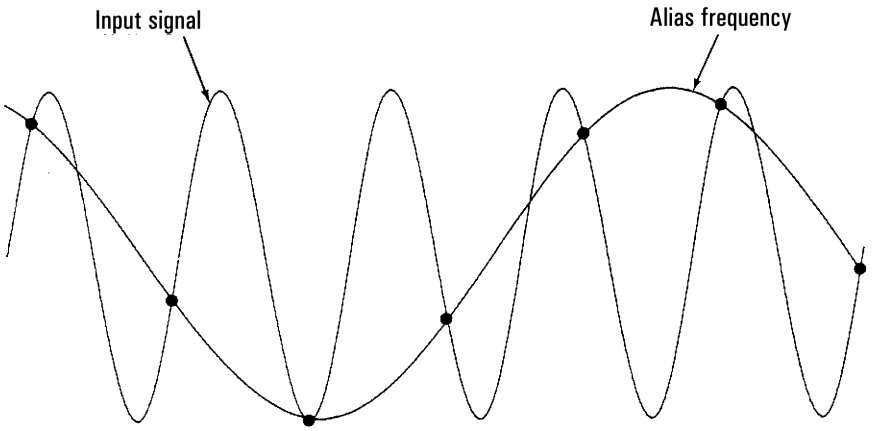

Figure 5-4 Aliasing caused by undersampling

Some digitizers have a built-in anti-aliasing low-pass filter with a sharp cutoff at a frequency equal to 1/2 the digitizer's sampling rate. This limits the bandwidth of the input signal so that aliasing cannot occur. Since the multimeter has a variable sample rate for DCV digitizing, and to preserve the upper bandwidth for high-frequency measurements, no anti-aliasing filter is provided in the multimeter. If you are concerned about aliasing, you should add an external antialiasing filter.

Level Triggering

When digitizing, it is important to begin sampling at some defined point on the input signal such as when the signal crosses zero volts or when it reaches the midpoint of its positive or negative peak amplitude. Level triggering allows you to specify when (with respect to voltage and slope) to begin sampling. For example, Figure 5-5 shows sampling beginning as the input signal crosses 0 V with a positive slope.

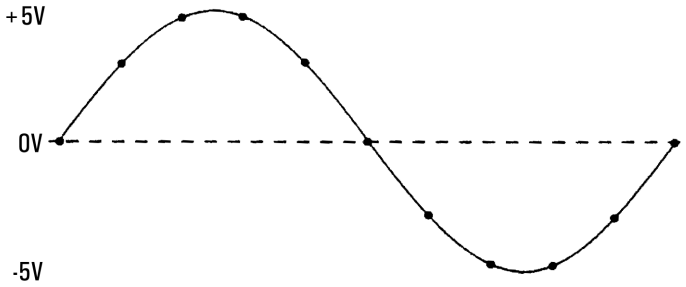

Figure 5-5 Level triggering at zero crossing, positive slope

Level triggering examples

For DCV and direct sampling, level triggering can be used as the trigger event (TRIG LEVEL command) or the sample event (NRDGS n, LEVEL command). For sub-sampling, level triggering can be used as the sync source event only (the sync source event is discussed later in this chapter under Sub-Sampling). The program examples in this section use the DCV method of digitizing and the 10 V range. Refer to DCV Digitizing, Direct-Sampling, and Sub-Sampling later in this chapter, for complete programs showing specific information on how to use level triggering with each digitizing method.

The LEVEL command specifies the level triggering voltage as a percentage of the measurement range. {The ranges are shown later in this chapter under the discussions for each digitizing method,) The LEVEL command also specifies the coupling (AC or DC) to the level detection circuitry.

NOTE The coupling of the input signal can affect the level trigger coupling. That is, if you select AC coupling for the input signal (e.g., DSAC or SSAC) the level trigger signal will also be AC coupled regardless of the specified level trigger coupling. When the input signal is DC coupled (e.g., DCV, DSDC, SSDC) however, you can control the coupling of the level trigger signal with the LEVEL command. The level trigger coupling does not affect the input signal coupling.

The SLOPE command specifies the slope of the signal to use. The power-on or default values for these commands specify a level percentage of 0% of the present range (trigger when the signal crosses zero volts}, positive slope, and AC-coupling to the level detection circuitry. So, in the power-on state, you can select the level triggering shown in Figure 5-6 merely by specifying the LEVEL trigger event (TRIG LEVEL command).

The following program specifies level triggering to occur when the input signal reaches +5 V (50% of the 10 V range) on a negative slope (AC-coupled). Assuming the input signal has a peak value of 10 V and the measurement range is 10 V, the result is shown in Figure 5-6.

```
10OUTPUT 722;"PRESET DIG" !DCV DIGITIZING, 10 V RANGE
20OUTPUT 722;"TRIG LEVEL" !SELECT LEVEL TRIGGER EVENT
30OUTPUT 722;"SLOPE NEG"!TRIGGER ON NEGATIVE SLOPE OF SIGNAL
40OUTPUT 722;"LEVEL 50, AC" !LEVEL TRIGGER AT 50% OF 10 V RANGE,
45!AC-COUPLED
50END
```

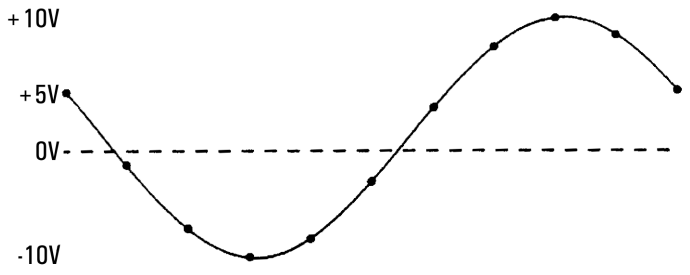

Figure 5-6 Level triggering, 50%, neg. slope, AC-coupled

The following program specifies level triggering to occur when the input signal reaches –5 V (–50% of the 10 V range) on a positive slope (AC-coupled). Assuming the input signal has a peak value of ±10 V and the measurement range is 10 V, the result is shown in Figure 5-7.

```
10OUTPUT 722;"PRESET DIG" !DCV DIGITIZING, 10 V RANGE
20OUTPUT 722;"TRIG LEVEL" !SELECT LEVEL TRIGGER EVENT
30OUTPUT 722;"SLOPE POS"!TRIGGER ON POSITIVE SLOPE OF SIGNAL
40OUTPUT 722;"LEVEL -50,AC"!LEVEL TRIGGER AT -50% OF 10 V RANGE,
45!(-5 V) AC-COUPLED
50END
```

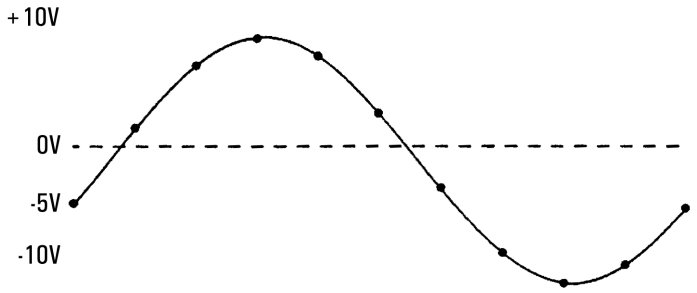

Figure 5-7 Level triggering, -50%, pos. slope, AC-coupled

In the following program the input signal is DC-coupled to the level detection circuitry and consists of a 5 V peak AC signal riding on a –5 V DC level. In this case, a negative percentage of the range (–25%) is used to level trigger at –2.5 V. positive slope. Figure 5-8 shows the result.

```
10OUTPUT 722;"PRESET DIG" !DCV DIGITIZING, 10 V RANGE
20OUTPUT 722;"TRIG LEVEL" !LEVEL TRIGGER EVENT
30OUTPUT 722;"SLOPE POS" !TRIGGER ON POSITIVE SLOPE OF SIGNAL
40OUTPUT 722;"LEVEL - 25, DC" !LEVEL TRIGGER AT -25% OF 10 V RANGE
45!DC coupled
50 END
```

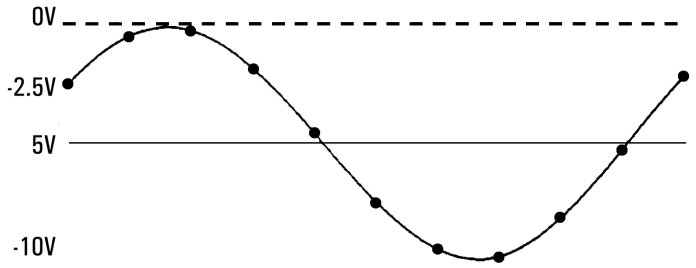

Figure 5-8 Level triggering, -25%, pos. slope, DC-coupled

Level filtering

When enabled, the level filter function connects a single-pole low-pass filter circuit to the input of the level-detection circuitry. The low-pass filter has a 3 dB point of 75 kHz and prevents high frequency components on the input signal from causing false triggers. To enable level filtering, send:

```
OUTPUT 722; "LFILTER ON"
```

NOTE The level filter function can also reduce the multimeter's sensitivity to high frequency noise for frequency and period measurements or when making synchronous (SETACV SYNC) ACV or ACDCV measurements.

DCV Digitizing

Digitizing can be done simply by specifying DC voltage measurements with a short integration time and a short interval between samples ("short" relative to the frequency of the signal being digitized). This is considered digitizing although the multimeter's track-and-hold circuit is not used. The advantages of DCV digitizing over direct-sampling (discussed later) are a lower noise level, higher resolution (up to 28 bits), and a maximum sampling rate of 100,000 samples per second (versus 50,000 for direct-sampling). The disadvantages of DCV digitizing are a greater amount of trigger jitter (see the "Appendix A: Specifications" on page 415), the inability to AC-couple the input signal, and a lower bandwidth input path of 150 kHz (vs. 12 MHz for direct- or sub-sampling). Since the track-and-hold circuit is not used for DCV digitizing, each sample is much wider (a minimum of 500 nanoseconds versus 2 nanoseconds for direct- or sub-sampling).

The PRESET DIG command configures the multimeter for DC voltage measurements with a sampling rate of 50,000 samples per second. PRESET DIG selects a 3 µs integration time and level triggering when the input signal crosses zero volts on its positive slope. The primary commands executed by PRESET DIG are:

```
TARM HOLD -- Suspends triggering
TRIG LEVEL -- LEVEL trigger event
LEVEL 0,AC -- Level trigger at 0% of range (0 V), AC-coupled
TIMER 20E-6 -- 20 µs interval between samples
NRDGS 256,TIMER -- 256 samples per trigger, TIMER sample event
DCV 10 -- DC voltage measurements, 10 V range
DELAY 0 -- No delay
APER 3E-6 -- 3 µs integration time
MFORMAT SINT -- Single integer memory format
OFORMAT SINT -- Single integer output format
AZERO OFF -- Disables the autozero function
DISP OFF -- Disables the display
```

After executing PRESET DIG, you can increase the sampling rate by decreasing the TIMER interval and by reducing the integration time using the APER command. The minimum integration time for DCV is 500 nanoseconds.

DCV remarks

– For DCV digitizing, you should use the SINT memory/output format when the integration time is ≤1.4 µs. Use the DINT memory/output format when the integration time is >1.4 µs. (These formats are discussed in detail in Chapter 4.)

NOTE

To achieve the fastest possible transfer of samples to reading memory and/or the controller, you can use the SINT output/memory format for integration times up to 10.8 µs. However when the integration time is >1.4 µs, the A/D converter is producing more bits of resolution than can be accommodated by the SINT format (the least significant bit(s) are discarded). Whenever using the SINT output/memory format with integration times >10.8 µs, the multimeter must convert the data coming from the A/D converter and cannot maintain the high-speed mode. You should use the DINT memory/output format (which is compatible with the high-speed mode) when the integration time is >10.8 µs.

– Whenever making measurements using the TIMER sample event or the SWEEP command, autorange is disabled. You can use the range selected by PRESET DIG (10 V range) or specify the range as the first parameter of the DCV or RANGE command (*max_input* parameter). The *max_input* parameters and the ranges they select are:

***max._input* parameter**	**Selects range**	**Full scale**
0 to .12	100 mV	120 mV
>.12 to 1.2	1 V	1.2 V
>1.2 to 12	10 V	12 V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

– The multimeter's triggering hierarchy (trigger arm event, trigger event, and sample event) applies to DCV digitizing. Refer to Chapter 4 for more information on the triggering hierarchy. For DCV digitizing, you can use either the TIMER sample event and the NRDGS *n*,TIMER command: or the SWEEP command. The NRDGS and SWEEP commands are interchangeable, the

multimeter uses whichever command was specified last. (When using the SWEEP command, the sample event is automatically set to TIMER.)

– Aperture time is the time when the multimeter is actually sampling the input signal. For direct- and sub-sampling using the track-and-hold, the aperture time is fixed at 2 ns and cannot be changed. For DCV digitizing, the aperture time is equal to the A/D converter's integration time and can be varied from 500 ns to 1 s. The multimeter effectively averages the input signal during its aperture time. An amplitude error is introduced when the signal is changing during the aperture time. Table 5-2 shows the input signal frequencies where 3 dB of amplitude error occurs for selected aperture times and the bits of resolution produced for these aperture times.

Table 5-2 Amplitude error and resolution vs. aperture

Aperture time	Bits of resolution	Frequency For 3 dB error
2 ns	16	100 MHz
500 ns	15	400 kHz
1 µs	16	206 kHz
3 µs	17	69 kHz
6 µs	18	35 kHz
100 µs	21	2 kHz

DCV example

The following program takes 256 DC voltage samples at a rate of 100,000 samples per second and places them in reading memory using SINT format. The samples are then transferred to the controller using the SINT output format. The controller converts the samples from SINT format and stores the samples. By deleting line 100, samples will be transferred directly to the controller instead of using reading memory. However, the controller and GPIB must be able to transfer samples at a rate of at least 200k-bytes/second or the multimeter will generate the TRIGGER TOO FAST error. Refer to High-speed transfer across GPIB in Chapter 4 for more information.

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20Num_samples=256!SPECIFY NUMBER OF SAMPLES
30INTEGER Int_samp(1:256) BUFFER!CREATE INTEGER BUFFER
40ALLOCATE REAL Samp(1:Num_samples)!CREATE REAL ARRAY FOR SAMPLES
50ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
60ASSIGN @Int_samp TO BUFFER Int_samp(*)!ASSIGN I/O PATH NAME TO BUFFER
70OUTPUT @Dvm;"PRESET DIG"!TARM HOLD, DCV, 10 V RANGE, 256 SAMPLES
71!PER TRIGGER, TIMER SAMPLE EVENT, TIMER INTERVAL = 20 µs, TRIG
75!LEVEL (0%, AC-COUPLED), 3 µs INTEGRATION TIME, SINT FORMATS
80OUTPUT @Dvm;"TIMER 10E-6"!10 µs INTERVAL BETWEEN SAMPLES
90OUTPUT @Dvm;"APER 1.4E-6"!MAXIMUM APERTURE FOR 100 kHZ SAMP. RATE
100OUTPUT @Dvm;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
110OUTPUT @Dvm; "TARM SYN"!SYNCHRONOUS TRIGGER ARM EVENT
120TRANSFER @Dvm TO @Int_samp;WAIT!SYN EVENT,TRANSFER READINGS INTO
121!READING MEMORY AND THEN INTO AN INTEGER ARRAY IN THE COMPUTER;
122!SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS SINT, NO DATA
123!CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
130OUTPUT @Dvm; "ISCALE?"!QUERY SCALE FACTOR FOR SINT FORMAT
140ENTER @Dvm;S!ENTER SCALE FACTOR
150FOR I=1 TO Num_samples
160  Samp(I)=Int_samp(I)!CONVERT EACH INTEGER READING TO REAL
165  !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
170  R=ABS(Samp(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
180  IF R>=32767 THEN PRINT "OVLD"!IF OVLD, PRINT OVERLOAD MESSAGE
190  Samp(I)=Samp(I)*S!MULTIPLY READING TIMES SCALE FACTOR
200  Samp(I)=DROUND(Samp(I),4)!ROUND TO 4 DIGITS
210NEXT I
220END
```

Direct-Sampling

Direct-sampling is similar to DCV digitizing in that samples are taken in real-time with each successive sample spaced a specified time interval from the preceding sample. The difference between the two is that direct sampling uses the multimeter's track-and-hold circuit and has a wider bandwidth input path (12 MHz bandwidth). In addition, direct sampling has less trigger jitter but greater measurement noise than DCV digitizing (see the "Appendix A: Specifications" on page 415).

The track-and-hold circuit takes a very fast sample of the input signal and then holds the value while the A/D converter integrates it. By using the track and hold circuit, the width of each sample is reduced from a minimum of 500 nanoseconds for DCV to 2 nanoseconds for direct-sampling. This makes direct sampling ideal for applications such as capturing the peak amplitude of a narrow pulse. The disadvantage of direct-sampling is a slower maximum sampling rate of 50,000 samples per second versus 100,000 for DC voltage.

You specify direct sampling using the DSAC or DSDC command. The DSAC command selects AC-coupling, which measures only the AC component of the input signal. The DSDC command selects DC-coupling, which measures the combined AC and DC components of the input signal.

Figure 5-9 shows 20 samples made using direct sampling on a sine wave input (the numbers indicate the order in which the samples were taken). With direct sampling, the minimum possible interval between samples is 20 µs.

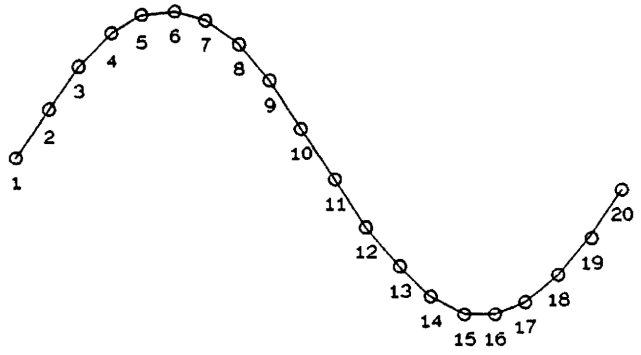

Figure 5-9 Direct sampling

Direct sampling remarks

– You cannot use autorange for direct-sampled measurements; you must specify the range as the first parameter of the DSAC or DSDC command (*max._input* parameter). The *max._input* parameters and the ranges they select are:

		Full scale	
***max._input* parameter**	**Selects range**	**SINT format**	**DINT format**
0 to .012	10 mV	12 mV	50 mv
>.012 to .120	100 mV	120 mV	500 mV
>.120 to 1.2	1 V	1.2 V	5.0 V
>1.2 to 12	10 V	12 V	50 V
>12 to 120	100 V	120 V	500 V
>120 to 1E3	1000 V	1050 V	1050 V

Notice that when using the DINT memory/output format, the full scale values for direct-sampling are 500% (5 times) the ranges of 10 mV, 100 mV, 1 V, 10 V, and 100 V. This is particularly important to consider when specifying the percentage for level triggering. When specifying the level triggering voltage, use a percentage of the range. For example, assume the input signal has a peak value of 20 V and you are using the 10 V range. If you want to level trigger at 15 V specify a level triggering percentage of 150% (LEVEL 150 command). (The slew rate of the multimeter's amplifiers may be exceeded when measuring a signal with a frequency >2 MHz and an amplitude >120% of range; signals ≤120% of range with frequencies up to 12 MHz do not cause slew rate errors.)

– The multimeter's triggering hierarchy (trigger arm event, trigger event, and sample event) applies to direct-sampling. This means that these events must occur in the proper order before direct sampling begins. Refer to Chapter 4 for more information on the triggering hierarchy. For direct sampling, you can use either the TIMER sample event and the NRDGS *n*,TIMER command; or the SWEEP command (SWEEP is the simpler to program). The NRDGS and SWEEP commands are interchangeable; the multimeter uses whichever command was specified last. (When using the SWEEP command, the sample event is automatically set to TIMER.)

– When direct-sampling an input signal with a frequency content ≥1 MHz, the first sample may be in error because of interpolator settling time. To ensure the first sample is accurate, insert a 500 ns delay before the first sample (DELAY 500E-9 command).

Direct sampling example

The following program is an example of DC-couple direct-sampled digitizing. The SWEEP command specifies an interval of 30 µs and 200 samples. Level triggering is set for 250% of the 10 V range (250% of 10 V = 25 V). The samples are sent to reading memory in DINT format. The samples are then sent to the controller, converted, and printed. By deleting line 110, samples will be transferred directly to the controller instead of using reading memory. However, the controller and GPIB must be able to transfer samples at a rate of at least 134k-bytes/second or the multimeter will generate the TRIGGER TOO FAST error. Refer to High-speed transfer across GPIB in Chapter 4 for more information.

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20INTEGER Num_samples,I,J,K!CREATE INTEGER VARIABLES
30Num_samples = 200!200 SAMPLES
35ASSIGN @Dvm TO 722!DESIGNATE MULTIMETER ADDRESS
40ASSIGN @Buffer TO BUFFER [4*Num_samples]!SETUP CONTROLLER BUFFER FOR
45!SAMPLES, (4-BYTES/SAMPLE * 200 SAMPLES = 800 BYTES)
50ALLOCATE REAL Samp(1:Num_samples)!CREATE REAL ARRAY FOR SAMPLES
60OUTPUT @Dvm;"PRESET FAST"!DINT FORMATS, TARM SYN, TRIG AUTO
70OUTPUT @Dvm; "SWEEP 30E - 6,200"!30 µs INTERVAL, 200 SAMPLES
80OUTPUT @Dvm; "DSDC 10"!DIRECT-SAMPLING, 10 V RANGE
90OUTPUT @Dvm;"LEVEL 250, DC"!LEVEL TRIGGER AT 250% OF RANGE (25 V)
100OUTPUT @Dvm;TRIG LEVEL"!LEVEL TRIGGER EVENT
110OUTPUT @Dvm; "MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
120TRANSFER @Dvm TO @Buffer;WAIT!TRANSFER SAMPLES TO CONTROLLER
130OUTPUT @Dvm; "ISCALE?"!QUERY SCALE FACTOR FOR DINT FORMAT
140ENTER @Dvm;S!ENTER SCALE FACTOR
150FOR I=1 TO Num_samples
```

```
160  ENTER @Buffer USING "#,W,W";J,K!ENTER ONE 16-BIT 2’S COMPLEMENT
161  !WORD INTO EACH VARIABLE J AND K (# = STATEMENT TERMINATION NOT
165  !REQUIRED; W = ENTER DATA AS 16-BIT 2’S COMPLEMENT INTEGER)
170  Samp(I)=(J*65536.+K+65536.*(K<0))!CONVERT TO REAL NUMBER
180  R=ABS(Samp(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
190  IF R>2147483647 THEN PRINT "OVLD"!IF OVERLOAD OCCURRED, PRINT
MESSAGE
200  Samp(I)=Samp(I)*S!APPLY SCALE FACTOR
210  Samp(I)=DROUND(Samp(I),8)!ROUND CONVERTED READING
220  PRINT Samp(I)!PRINT READINGS
230NEXT I
240END
```

Sub-Sampling

In sub-sampling (also known as sequential-sampling), the multimeter takes one or more samples on each period of the input signal. With each successive period, the beginning sample point is delayed further-and more samples are taken. After a number of periods have occurred and the specified number of samples have been taken, the samples can be reconstructed to form a composite waveform with a period equal to that of the input signal.

The advantage of sub-sampling is that samples can be effectively spaced at a minimum interval of 10 ns versus 10 µs for DCV digitizing and 20 µs for direct-sampling. This means that sub-sampling can be used to digitize signals with frequency components up to 12 MHz (the upper bandwidth of the signal path for sub-sampling). Sub-sampled measurements use the track-and-hold circuit, which has a 2 nanosecond aperture. Sub-sampling (and direct-sampling) have less trigger jitter than DCV digitizing (see the "Appendix A: Specifications" on page 415). The disadvantages of sub-sampling are that the input signal must be periodic (repetitive) and sub-sampling is not a real-time measurement.

You specify sub-sampling using the SSAC or SSDC command. The SSAC command selects AC-coupled sub-sampling which digitizes only the AC component of the input signal. The SSDC command selects DC-coupled sub-sampling, which digitizes the combined AC and DC components of the signal.

Sub-sampling fundamentals

In sub-sampling, the samples in the composite waveform can be spaced very closely together. This means that the interval between samples in the composite waveform (*effective_interval*) can be much smaller (and the effective sampling rate much greater) than in the DCV or direct-sampling methods. For example, assume you need to digitize a repetitive 10 kHz input signal with a 5 µs *effective_interval* between samples. This is a sampling rate of 1/5E-6 or 200,000 samples per second, (This application would be impossible using DCV or direct-sampling since their maximum sampling rates are 100,000 and 50,0000 samples per second, respectively.) Figure 5-10 illustrates how this can be done using sub-sampling. The *effective_interval* is specified as 5 µs and specified number of samples is 20. The *effective_interval* and the total number of samples are specified by the SWEEP command. After specifying the *effective_interval* and the number of samples, the multimeter calculates how many bursts (a burst is a group of samples) it needs to make and how many samples will be in each burst.

For this example, on the first period of the input signal, the multimeter takes a burst of 5 samples. On the second period, the multimeter delays the trigger point by 5 µs and takes another burst of 5 samples. On each of the remaining two periods, the multimeter delays the trigger point by another 5 µs and takes a burst of 5 samples. As shown in Figure 5-11, when all the samples are arranged in the proper sequence, the result is one period of the input signal consisting of 20 samples spaced at 5 µs intervals. In this example then, the *effective sampling rate* is 200,000 samples per second.

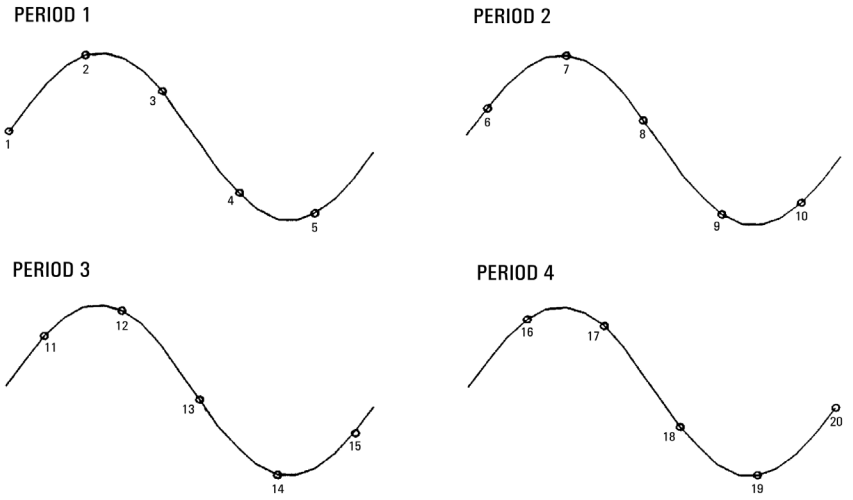

Figure 5-10 Sub-sampling example

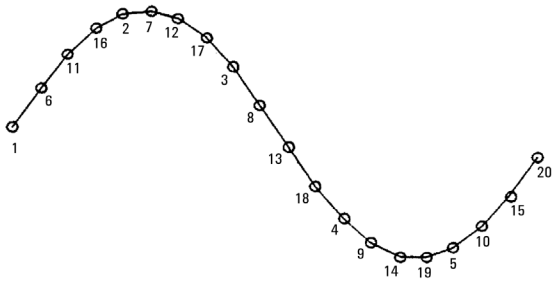

Figure 5-11 Composite waveform

The sync source event

In the preceding sub-sampling example, it was assumed that the multimeter could somehow synchronize itself to the periods of the input waveform. This is the function of the sync source event. You can use either the EXT event or the LEVEL event as the sync source event. The EXT sync source event (specified by the SSRC EXT command) occurs on the negative-edge transition on the multimeter's Ext Trig connector. This requires an external pulse that is synchronous with the input signal. Figure 5-12 shows a typical input signal and the required synchronizing signal. Notice in Figure 5-12 that the synchronizing signal does not necessarily have to occur once for every period of the input signal. It does, however, have to be synchronized in time with the input signal.

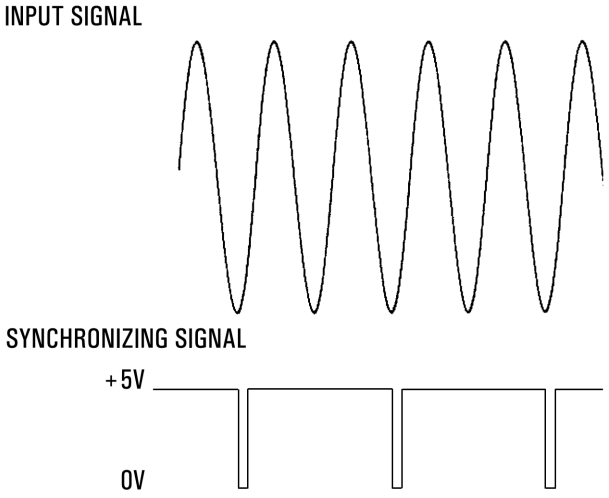

Figure 5-12 Typical synchronizing signal for EXT sync source

The LEVEL sync source event (which is the power-on/default sync source event) occurs when the input signal reaches a specified voltage level on the specified slope (level triggering). Figure 5-10 shows the operation of the LEVEL sync source event (for this example, the LEVEL is specified as 0%, positive slope, AC-coupling). The first sync source event occurs when the input signal crosses 0 V with a positive slope. The multimeter then takes a burst of samples (5 samples in this case). Following the next occurrence of the sync source event (period 2 of the

input signal) the multimeter delays the trigger point and takes 5 more samples. This process repeats until the specified number of samples are completed.

In the following example, the SSDC command is used to digitize a 1 MHz signal with a peak value of 5 V riding on a 5 V DC level. The SWEEP command instructs the multimeter to take 4000 samples with a 10-nanosecond *effective_interval*. Lines 60 through 80 program the voltage level and the slope for the LEVEL sync source event. This will initiate sampling when the first period of the input signal reaches 7.5 VDC (75% of the 10 V range). Line 90 satisfies the trigger arm event, which essentially enables the sync source event.

```
10OUTPUT 722;"PRESET FAST"!TARM SYN, TRIG AUTO, DINT FORMATS
20OUTPUT 722;"MEM FIFO"!ENABLE READING MEMORY, FIFO MODE
30OUTPUT 722;"MFORMAT SINT"!SINT READING MEMORY FORMAT
40OUTPUT 722."SSDC 10"!SUB-SAMPLING, 10 V RANGE, LEVEL SYNC SOURCE
45 !EVENT (DEFAULT EVENT)
50OUTPUT 722;"SWEEP 10E-9,4000"!4000 SAMPLES, 10 ns EFFECTIVE INTERVAL
60OUTPUT 722;"LEVEL 75 DC"!LEVEL TRIGGER AT 75% OF RANGE, DC-COUPLED
70OUTPUT 722;"SLOPE POS"!LEVEL TRIGGER ON POSITIVE SLOPE
80OUTPUT 722;"SSRC LEVEL"!LEVEL SYNC SOURCE EVENT
90OUTPUT 722; "TARM SGL"!ENABLE SAMPLING
100END
```

Sub-sampling remarks

- For sub-sampling, the trigger event and sample event requirements are ignored (these events are discussed in Chapter 4). The only triggering events that apply to sub-sampling are the trigger arm event (TARM command) and the sync source event (SSRC command).
- You cannot use the NRDGS command for sub-sampling. You must use the SWEEP command to specify the number of samples and the *effective_interval*. The minimum *effective_interval* for sub-sampling is 10 nanoseconds. The maximum rate at which samples arc taken is 50k samples per second (20 µs between samples).

– You cannot use autorange for sub-sampled measurements; you must specify the range as the first parameter of the SSAC or SSDC command (*max._input* parameter). The *max._input* parameters and the ranges they select are:

max._ input parameter	Selects range	Full scale
0 to .012	10 mV	12 mV
>.012 to .120	100 mV	120 mV
>.120 to 1.2	1 V	1.2 V
>1.2 to 12	10 V	12 V
>12 to 120	100 V	120 V
>120 to lE3	1000 V	1050 V

As with direct sampling, you can specify a level triggering voltage up to 500% of the range. The required SINT format, however, cannot handle samples greater then 120% of range.

– If reading memory is disabled when you execute the SSAC or SSDC command, the multimeter automatically sets the output format to SINT (the memory format is not changed). Later, when you change to another measurement function, the output format returns to that previously specified. You must use the SINT output format when sub-sampling and outputting samples directly to the GPIB. You can however, use any output format if the samples are first placed in reading memory (see next remark). To do this, you should enable reading memory before executing the SSAC or SSDC command (executing SSAC or SSDC does not change the output format to SINT when reading memory is enabled).

– When sub-sampling with reading memory is enabled, reading memory must be in FIFO mode, must be empty (executing MEM FIFO clears reading memory), and the memory format must be SINT prior to the occurrence of the trigger arm event. If not, the multimeter generates the SETTINGS CONFLICT error when the trigger arm event occurs and no samples are taken.

– When sub-sampling an input signal with a frequency content ≥1 MHz, the first sample may be in error because of interpolator settling time. To ensure the first sample is accurate, insert a 500 ns delay using the DELAY 500E-9 command.

(When sub-sampling, the delay is inserted between the sync source event and the first sample in each burst; the default delay for sub-sampling is 0 seconds.)

Sending samples to memory

When samples are sent directly to reading memory (MEM FIFO command), the multimeter automatically re-orders the samples producing a composite waveform. For example, in the following program, the sub-sampled data is sent to reading memory using the required SINT memory format. The multimeter places the samples in memory in the corrected order. The samples are then transferred to the controller using the DREAL output format (when placing sub-sampled data in reading memory first, you are not restricted to using the SINT output format).

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20REAL Samp(1:200) BUFFER!CREATE BUFFER ARRAY
30ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
40ASSIGN @Samp TO BUFFER Samp(*) !ASSIGN BUFFER
50OUTPUT @Dvm;"PRESET FAST"!TARM SYN, TRIG AUTO, DINT FORMATS
60OUTPUT @Dvm;"MEM FIFO"!FIRST-IN-FIRST-OUT READING MEMORY
70OUTPUT @Dvm;"MFORMAT SINT"!SINT MEMORY FORMAT
80OUTPUT @Dvm;"OFORMAT DREAL"!DOUBLE REAL OUTPUT FORMAT
90OUTPUT @Dvm;"SSDC 10"!SUB-SAMPLING, 10 V RANGE, DC-COUPLED
100OUTPUT @Dvm;"SWEEP 5E-6,200"!5 µs EFF. INTERVAL, 200 SAMPLES
110TRANSFER @Dvm TO @Samp;WAIT!TRANSFER SAMPLES TO CONTROLLER BUFFER
120FOR I=1 TO 200
130  IF ABS(Samp(I))=1E+38 THEN!DETECT OVERLOAD
140    PRINT "Overload Occurred"!PRINT OVERLOAD MESSAGE
150  ELSE!IF NO OVERLOAD OCCURRED:
160    Samp(I)=DROUND(Samp(I),5)!ROUND TO 5 DIGITS
170    PRINT Samp(I)!PRINT EACH SAMPLE
180  END IF
190NEXT I
200END
```

Sending samples to the controller

When samples are sent directly to the controller, an algorithm must be used to re-order the samples and produce the composite waveform. The SSPARM? command returns three parameters for the algorithm. The first parameter returned is the number of bursts measured that contained *N* samples. The second parameter returned is the number of bursts measured that contained *N-1* samples. The third parameter returned is the value of *N*. For example, assume you are sub-sampling a 10 kHz signal and specify 22 samples with an *effective_interval* of 5 µs. In this example, the multimeter takes 2 bursts containing 6 samples each and 2 bursts containing 5 samples each. Each burst is delayed 5 µs from the previous burst. The values returned by SSPARM? are then 2, 2, and 6.

When sub-sampling, the maximum sample rate is 50k samples per second regardless of the specified *effective_interval*. (If you specify an *effective_interval* of ≥20 µs, the multimeter is no longer sub-sampling but direct-sampling.) When sending samples directly to the controller (using the required SINT format which is 2-bytes per sample) the GPIB/controller must be able to handle the data at a maximum rate of 100k-bytes per second. If not, the multimeter generates the TRIGGER TOO FAST error.

In the program on the following page, the SSAC command is used to digitize a 10 kHz signal with a peak value of 5 V. The SWEEP command instructs the multimeter to take 1000 samples (Num_samples variable) with a 2 µs *effective_interval* (Eff_int variable). The measurement uses the default level triggering for the sync source event (trigger from input signal, 0%. AC-coupling, positive slope). Line 110 generates a SYN event and transfers the samples directly to the computer. Lines 230 through 400 sort the sub-sampled data to produce the composite waveform. The composite waveform is stored in the Wave_form array.

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20INTEGER Num_samples,Inc,I,J,K,L!DECLARE VARIABLES
30Num_samples=1000!DESIGNATE NUMBER OF SAMPLES
40Eff_int=2.0E-6!DESIGNATE EFFECTIVE INTERVAL
50INTEGER Int_samp(1:1000) BUFFER!CREATE INTEGER BUFFER
60ALLOCATE REAL Wave_form(1:Num_samples)  !CREATE ARRAY FOR SORTED DATA
70ALLOCATE REAL Samp(1:Num_samples)!CREATE ARRAY FOR SAMPLES
80ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
```

```
90ASSIGN @Int_samp TO BUFFER Int_samp(*)  !ASSIGN BUFFER I/O PATH NAME
100OUTPUT @Dvm;"PRESET FAST;LEVEL;SLOPE;SSDC 10;SWEEP
";Eff_int,Num_samples
101!FAST OPERATION, TARM SYN, DEFAULT LEVEL & SLOPE, SUB-SAMPLING (SINT
105!OUTPUT FORMAT), 10 V RANGE, 2 µs EFFECTIVE INTERVAL, 1000 SAMPLES
110TRANSFER @Dvm TO @Int_samp;WAIT!SYN EVENT, TRANSFER READINGS INTO
111!INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
115! SINT, NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
120OUTPUT @Dvm; "I SCALE?"!QUERY SCALE FACTOR FOR SINT FORMAT
130ENTER @Dvm;S!ENTER SCALE FACTOR
140OUTPUT @Dvm; "SSPARM?"!QUERY SUB-SAMPLING PARAMETERS
150ENTER @Dvm;Nl,N2,N3!ENTER SUB-SAMPLING PARAMETERS
160FOR I=1 TO Num_samples
170  Samp(I)=Int_samp(I)!CONVERT EACH INTEGER READING TO REAL
175  !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
180  R=ABS(Samp(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
190  IF R>=32767 THEN PRINT "OVLD"! IF OVLD, PRINT OVERLOAD MESSAGE
200  Samp(I)=Samp(I)*S!MULTIPLY READING TIMES SCALE FACTOR
210  Samp(I)=DROUND(Samp(I),4)!ROUND TO 4 DIGITS
220NEXT I
225 !-------------------SORT SAMPLES----------------------
230Inc=Nl+N2!TOTAL NUMBER OF BURSTS
240K=1
250FOR I=1 TO N1
260  L=I
270  FOR J=1 TO N3
280    Wave_form(L)=Samp(K)
290    K=K+1
300    L=L+Inc
310  NEXT J
```

```
320NEXT I
330FOR I=Nl+1 TO Nl+N2
340  L=I
350  FOR J=1 TO N3-1
360    Wave_form(L)=Samp(K)
370    K=K+1
380    L=L+Inc
390  NEXT J
400NEXT I
410END
```

Viewing Sampled Data

The program on the following page plots digitized data to the controller's CRT (this particular program uses sub-sampling and the subroutine *Plot_it* does the actual plotting). This program is helpful when developing digitizing programs (especially when sub-sampling) since it allows you to see the data being captured. Since this program simply draws vectors between the samples (linear interpolation), it works well when the sampling rate is greater than 10 times the frequency of the signal being measured. If the sampling rate is less than 10 times the frequency of the input signal, this program will plot an incorrect representation of the input signal. Figure 5-13 shows a typical plot produced by this program.

NOTE

The 3458A Option 005 Waveform Analysis Library is a software package designed to capture and process digitized data. It contains routines that initialize the system, capture data, compare data, compute parameters on the data, perform Fourier transforms on the data, and plot/output the data. Contact your Keysight Sales Office for more information.

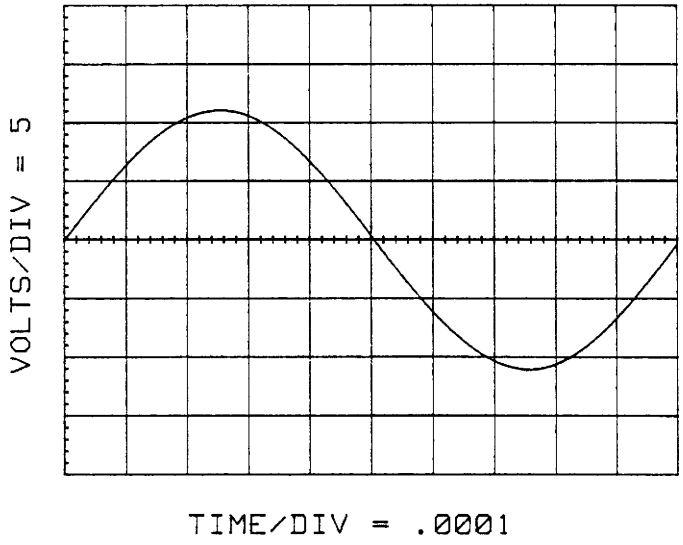

Figure 5-13 Typical plotted waveform

```
10OPTION BASE 1!COMPUTER ARRAY NUMBERING STARTS AT 1
20INTEGER Num_samples,Inc,I,J,K,L!DECLARE VARIABLES
30INTEGER Int_samp(1:1000) BUFFER!CREATE INTEGER BUFFER
40ALLOCATE REAL Wave_form(1:Num_samples)!CREATE ARRAY FOR SORTED DATA
50ALLOCATE REAL Samp(1:Num_samples)!CREATE ARRAY FOR SAMPLES
60Num_samples=1000!DESIGNATE NUMBER OF SAMPLES
70Eff_int=2.0E-6!DESIGNATE EFFECTIVE INTERVAL
80ASSIGN @Dvm TO 722!ASSIGN MULTIMETER ADDRESS
90ASSIGN @Int_samp TO BUFFER Int_samp(*)!ASSIGN I/O PATH NAME TO BUFFER
100OUTPUT @Dvm;"PRESET FAST;SSDC 10;SWEEP ";Eff_int, Num_samples
101!FAST OPERATION, TARM SYN, SUB-SAMPLING (SINT OUTPUT FORMAT), 10 V
RANGE
102!2 µs EFFECTIVE INTERVAL, 1000 SAMPLES
110TRANSFER @Dvm TO @Int_samp;WAIT!SYN EVENT, TRANSFER READINGS
120OUTPUT @Dvm;"ISCALE?"!QUERY SCALE FACTOR FOR SINT FORMAT
130ENTER @Dvm;S!ENTER SCALE FACTOR
140OUTPUT @Dvm;"SSPARM?"!QUERY SUB-SAMPLING PARAMETERS
150ENTER @Dvm;N1,N2,N3!ENTER SUB-SAMPLING PARAMETERS
160FOR I=1 TO Num_samples
170  Samp(I)=Int_samp(I)!CONVERT EACH INTEGER READING TO REAL
175!FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT LINE)
180  R=ABS(Samp(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD
190  IF R>=32767 THEN PRINT "OVLD"!IF OVLD, PRINT OVERLOAD MESSAGE
200  Samp(I)=Samp(I)*S!MULTIPLY READING TIMES SCALE FACTOR
210  Samp(I)=DROUND(Samp(I),4)!ROUND TO 4 DIGITS
220NEXT I
230Inc=N1+N2!Inc = TOTAL NUMBER OF BURSTS
240K=1!SORT SAMPLES
250FOR I=1 TO N1!    "
260  L=I!    "
```

```
270  FOR J=1 TO N3!    "
280    Wave_form(L)=Samp(K)!    "
290    K=K+1!    "
300    L=L+Inc!    "
310  NEXT J!    "
320NEXT I!    "
330FOR I=Nl+1 TO Nl+N2!    "
340  L=I!    "
350  FOR J=1 TO N3-1!    "
360    Wave_form(L)=Samp(K)!    "
370    K=K+1!    "
380    L=L+Inc!    "
390  NEXT J!    "
400NEXT I!    "
410DISP!CLEAR CONTROLLER CRT
420Time_div=1.0E-5 !TIME PER DIVISION FOR PLOT
430Volts_div=5!VOLTS PER DIVISION FOR PLOT
440Plot_it(Time_div,Volts_div,Wave_form(*),Eff_int)
450END
460SUB Plot_it(Time_div,Volts_div,Wave_form(*),Time_base)
470DIM X_axis$[80],Y_axis$[80]
480GINIT
490GRAPHICS ON
500RAD
510MOVE 35,10
520LDIR 0
530X_axis$="TIME/DIV = "&VAL$(Time_div)
540LABEL X_axis$
550MOVE 15,35
560LDIR PI/2
```

```
570Y_axis$="VOLTS/DIV = "&VAL$(Volts_div)
580LABEL Y_axis$
590VIEWPORT 20,110,20,90
600WINDOW 0,10*Time_div,-4*Volts_div,4*Volts_div
610AXES Time_div/5,Volts_div/5,0,0,1,1,1
620GRID Time_div,Volts_div
630Wave x=0
640MOVE Wave_x,Wave_form(BASE(Wav_form,1))
650FOR Wave_y=BASE(Wave_form,1)+1 TO SIZE(Wave_form,1)-1+BASE
(Wave_form,1)
660  Wave_x=Wave_x+Time_base
670  DRAW Wave_x,Wave_form(Wave_y)
680NEXT Wave_y
690IF Wave_x>10*Time_div THEN DISP "More samples taken than displayed"
700SUBEND
```

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6 Command Reference

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Commands by Functional Group 236
Commands vs. Measurement Functions 238

Introduction

The first part of this chapter discusses the multimeter's language. This includes core commands, command termination, parameters, query commands, lists of commands by functional group, and a table relating commands to measurement functions. The remainder of the chapter consists of detailed descriptions of each command (listed in alphabetical order, by command).

Before using this chapter, you should read about the multimeter functions you need to use in the preceding tutorial chapters (Chapter 2, Chapter 3, Chapter 4, and Chapter 5). The tutorial chapters describe each multimeter function and identify which commands you need to use. You can then use this chapter to learn more about the individual commands.

The commands in this chapter are described using the following format:

Command header

Command description

Syntax statement

shows the command format and its parameters. parameters shown in brackets ([]) are optional (have default values). parameters shown without brackets have no default values and must be specified.

Parameter description

describes the parameter and shows the choices or ranges available.

Power-on value

shows the parameter used when power is applied.

Default value

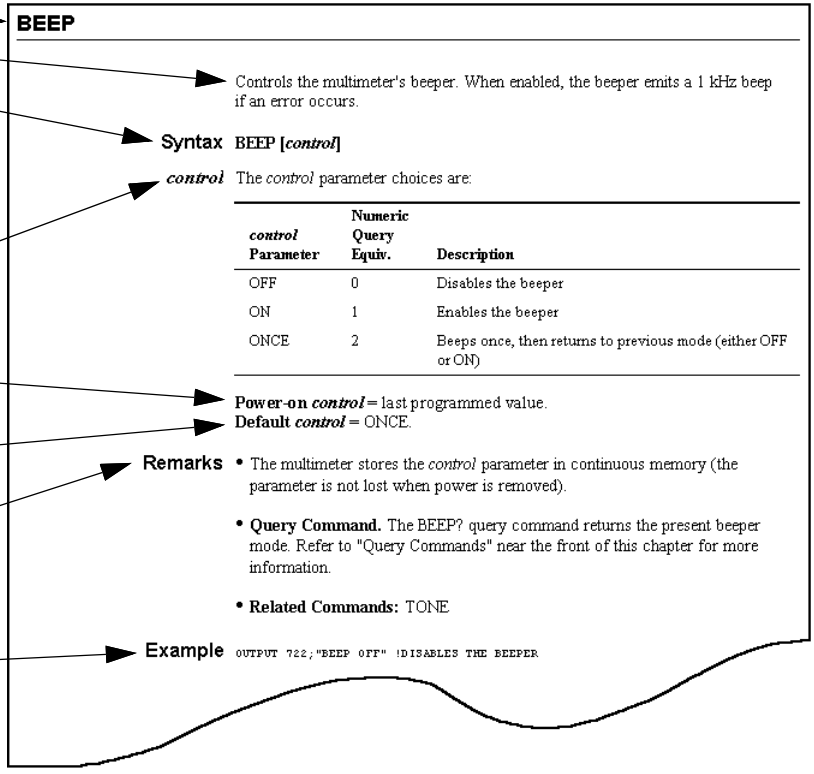
shows the parameter used if you execute the command but do not specify a parameter.

Remarks

contains special information about the command.

Examples

show typical BASIC language programs or statements (multimeter at address 722). Program syntax is applicable to HP Series 200/300 Computers.



BEEP

Controls the multimeter's beeper. When enabled, the beeper emits a 1 kHz beep if an error occurs.

Syntax **BEEP [*control*]**

control The *control* parameter choices are:

control Parameter	Numeric Query Equiv.	Description
OFF	0	Disables the beeper
ON	1	Enables the beeper
ONCE	2	Beeps once, then returns to previous mode (either OFF or ON)

Power-on *control* = last programmed value.
Default *control* = ONCE.

Remarks

- The multimeter stores the *control* parameter in continuous memory (the parameter is not lost when power is removed).
- **Query Command.** The BEEP? query command returns the present beeper mode. Refer to "Query Commands" near the front of this chapter for more information.
- **Related Commands:** TONE

Example

```
OUTPUT 722;"BEEP OFF" !DISABLES THE BEEPER
```

Language conventions

The multimeter communicates with a system controller over the GPIB bus.[1] Each instrument connected to GPIB has a unique address. The examples used in this manual are intended for Hewlett-Packard Series 200 or 300 Computers using BASIC language. They assume an GPIB interface select code of 7 and a device address of 22 (factory address setting) resulting in a combined GPIB address of 722. We recommend you retain this address to simplify programming.

Command termination

The carriage return (*cr*), line feed (*lf*), semicolon (*;*), or EOI sent concurrent with the last character indicate the end of message (command terminator) to the multimeter. When you send a command from the system controller in the standard format (e.g., OUTPUT 722;"TEST"), the controller typically adds a *cr lf* to the end of the command. With its input buffer off (off is the power-on input buffer mode), the multimeter processes the *cr* immediately, but does not process the *lf* until the command completes execution. This means that, because of the *lf*, the bus is held and you cannot regain use of the controller until the multimeter is done executing the command (or the GPIB CLEAR command is executed which aborts execution of the command). You can prevent. the bus from being held by suppressing the *cr lf* when sending commands or by enabling the input buffer (INBUF ON command). The following program line shows how to use the # and K image specifiers to suppress *cr lf* when sending a multimeter command.

```
OUTPUT 722 USING "#,K";"TEST;"
```

NOTE The # and K image specifiers apply to HP Series 200/300 computers. Refer to your computer's operating manual for information on how your computer suppresses *cr lf*. The semicolon following the TEST command indicates the end of the command to the multimeter and must be present when you suppress *cr lf*.

[1] GPIB (General Purpose Interface Bus) is Keysight Technologies implementation of IEEE Standard 488-1978 and ANSI MC1.1.

Multiple commands

Multiple commands, separated by semicolons, may be sent in one command string. For example, the following command string contains three multimeter commands.

```
OUTPUT 722; "TRIG HOLD;DCV 3;NPLC 10"
```

Parameters

Numbers specified as command parameters can be either integer, floating-point, or exponential in format. parameters in floating-point format are rounded to the nearest integer if the command requires an integer. For example, “SUB 2.49” is rounded *down* to “SUB 2” and “SUB 2.5” is rounded *up* to “SUB 3”.

Defaulting parameters

You can default a parameter by omitting it or replacing it with -1 (minus 1). For example, to specify 10 for the first parameter and default the second parameter send:

```
OUTPUT 722;"ACV 10"
```

or

```
OUTPUT 722;"ACV 10,-1"
```

From remote only, you can use two commas to indicate a default value. For example, to specify 10 for the first parameter and default the second parameter, send:

```
OUTPUT 722;"ACV 10,,"
```

To default the first parameter (which selects autorange in this example) and specify .01 for the second parameter, send:

```
OUTPUT 722; "ACV,,.01"
```

Query commands

A query command ends with a question mark and returns one or more responses to a particular question. For example, the ID? query command returns the response *Keysight 3458A*.

Standard query commands

The following standard query commands are documented individually in this chapter:

AUXERR?LINE?
CALNUM?MCOUNT?
ERR?OPT?
ERRSTR?REV?
ID?SSPARM?
ISCALE?STB?
TEMP?

Additional query commands

In addition to the standard query commands, you can create others by appending a question mark to any command that can be used to configure or program the multimeter. (Query commands of this type are not documented individually in this chapter. Instead, they are combined with the parent command. That is, the AZERO command page contains information on both AZERO and AZERO?.) As an example, the AZERO command enables or disables the autozero function. The possible autozero modes are OFF, ON, or ONCE. You can determine the present autozero mode by appending a question mark to the AZERO command as shown in the following program.

```
10 OUTPUT 722;"AZERO?"
20 ENTER 722;A$
30 PRINT A$
40 END
```

In the power-on state, the multimeter returns numeric responses to query commands. For example, the above program might return 1 which is the numeric query equivalent of the ON parameter. Numeric query equivalents are listed under each applicable command in this chapter.

For commands that have parameter choices (such as the AZERO command), the query version of the command returns the presently specified choice (or its numeric query equivalent). Many commands use actual values specified in

seconds, volts, ohms, etc, instead of parameter choices. For example, the APER command specifies integration time in seconds. The range of values for this command is 500 ns to 1 s. When you send the APER? query command, the multimeter responds with the actual value of integration time presently specified.

The QFORMAT (query format) command can be used to specify whether query responses will be numeric (as shown above), alpha, or alphanumeric. For example, the following program changes the query format to ALPHA. This causes the multimeter to return an alpha command header and an alpha response (whenever possible) as shown in the following program.

```
10 OUTPUT 722;"QFORMAT ALPHA"
20 OUTPUT 722;"AZERO?"
30 ENTER 722;A$
40 PRINT A$
50 END
```

Typical response: AZERO ON

In the ALPHA query format, commands that use actual values return an alpha command header and a numeric response. For example, a typical response to the APER? query command is:

```
APER 166.667E-03
```

Many query commands can return both alpha and numeric responses. For example, the NRDGS? query command returns two responses. The first response is numeric and indicates the number of readings per trigger event. The second response is alpha (assuming QFORMAT = ALPHA) and indicates the specified sample event. The following program executes the NRDGS? query command and prints the responses.

```
10 OUTPUT 722;"NRDGS?"
20 ENTER 722;A$,B$
30 PRINT A$,B$
40 END
```

Responses to query commands are always output over the GPIB in the ASCII output format regardless of the specified output format. Following the query response, the output format returns to that previously specified (SINT, DINT, SREAL, DREAL, or ASCII).

Commands by Functional Group

The following is a list of all commands recognized by the multimeter categorized by function (measurement functions, digitizing. A/D converter, etc.).

Measurement functions

ACDCI
ACDCV
ACI
ACV
DCI
DCV
DSAC
DSDC
FREQ
FUNC
OHM
OHMF
PER
SSAC
SSDC

Measurement related

ACBAND
ARANGE
AZERO
DELAY
FIXEDZ
FSOURCE
LFILTER
OCOMP
PRESET (DIG, FAST, or NORM)
RANGE or R
RATIO
SETACV
SSPARM?
TERM

Digitizing

DSAC
DSDC
LEVEL
LFILTER
SLOPE
NRDGS
PRESET (DIG and FAST)
SSAC
SSDC
SSPARM?
SSRC
SWEEP
TIMER

Triggering

EXTOUT
LEVEL
LFILTER
NRDGS
SLOPE
SSRC
SWEEP
TARM
TBUFF
TIMER
TRIG or T

Reading memory

MCOUNT?
MEM
MFORMAT
MSIZE
RMEM

Program memory

CALL
COMPRESS
CONT
DELSUB
PAUSE
SCRATCH
SUB
SUBEND

State memory

PURGE
RSTATE
SCRATCH
SSTATE

A/D converter

APER
LFREQ
LINE?
NPLC
RES

Status

CSB
RQS
SRQ
STB?

Input/Output

END
INBUF
ISCALE?
OFORMAT
QFORMAT

Errors

AUXERR?
EMASK
ERR?
ERRSTR?

Math

MATH
MMATH
RMATH
SMATH

Keyboard

DEFKEY
LOCK
MENU

Bus

ADDRESS
ID?
SRQ

System

BEEP
DEFEAT
EXTOUT
OPT?
PRESET (DIG, FAST, or NORM)
QFORMAT
RESET
TONE

Display

DISP
NDIG

Calibration/Test

ACAL
CAL
CAL?
CALNUM?
CALSTR
REV?
SCAL
SECURE
TEMP?
TEST

GPIB commands

ABORT IO
CLEAR
LOCAL
LOCAL LOCKOUT
REMOTE
SPOLL
TRIGGER

Commands vs. Measurement Functions

Table 6-1 shows the multimeter commands that apply only to certain measurement functions. A bullet (●) indicates the command applies with no restrictions. A number (1 - 5) indicates the command applies with qualifications (see numbered footnotes below the table). A blank indicates the command is not applicable to the measurement function. The remaining multimeter commands not shown in Table 6-1 apply to all measurement functions with no restrictions.

Table 6-1 Commands vs. measurement functions

	DCV	DCI	OHM OHMF	ACV ACDCV (ANA)	ACV ACDCV (SYNC)	ACV ACDCV (RNDM)	ACI ACDCI	FREQ PER	DSAC DSDC	SSAC SSDC
ACBAND				●	●	●	●	●		
APER	●	●	●	●			●			
ARANGE[1]	●	●	●	●	●	●	●	●		
AZERO	●	●	●							
FIXEDZ	●		●							
FSOURCE								●		
ISCALE?	●	●	●	●	●	●	●	1	●	●
LEVEL	●				2			3	●	●
LFILTER	●				●			●	●	●
LFREQ	●	●	●	●			●			
(M) MATH[1]	●	●	●	●	●	●	●	●	●	4
MFORMAT	●	●	●	●	●	●	●	1	●	5
NPLC	●	●	●	●			●			
OCOMP			●							
OFORMAT	●	●	●	●	●	●	●	1	●	5
RATIO	●			●	●	●				

Table 6-1 Commands vs. measurement functions

	DCV	DCI	OHM OHMF	ACV ACDCV (ANA)	ACV ACDCV (SYNC)	ACV ACDCV (RNDM)	ACI ACDCI	FREQ PER	DSAC DSDC	SSAC SSDC
SETACV				●	●	●				
SLOPE	●				**2**			**3**	●	●
SSPARM?										●
SSRC					●					●
SWEEP	●	●	●	●			●		●	●
TIMER	●	●	●	●			●		●	

1 You should not use the SINT or DINT output/memory format for FREQ or PER measurements; when a realtime or post-process math operation is enabled (except STAT or PFAIL); or when autorange is enabled.

2 Level triggering is the default sync source event for synchronous ACV or ACDCV; however, the level trigger voltage and the slope are determined automatically and cannot be specified.

3 You cannot use the LEVEL trigger or sample event for FREQ or PER measurements. You can, however, specify the voltage level and slope that the level detection circuits use to measure frequency or period.

4 You cannot use MATH for sub-sampling; you can use MMATH for sub-sampling.

5 For sub-sampling, when using reading memory, the memory format must be SINT. When not using reading memory, the output format must be SINT.

ACAL

Autocal. Instructs the multimeter to perform one or all of its self calibrations.

Syntax

ACAL [*type*][,*security_code*]

type

The *type* parameter choices are:

type parameter	Numeric query equiv.	Description
ALL	0	Performs the DCV, OHMS, and AC autocals
DCV	1	DC voltage gain and offset (see first Remark)
AC	2	ACV flatness, gain, and offset (see second Remark)
OHMS	4	OHMS gain and offset (see third Remark)

Power-on *type* = none.
Default *type* = ALL.

security_code

When autocal is secured, you must enter the correct security code to perform an autocal. When autocal is not secured, no security code is required. Refer to the SECURE command for more information on the security code and how to secure or unsecure autocal.

Remarks

- Since the DCV autocal applies to all measurement functions, you should perform it before performing the AC or OHMS autocal. When ACAL ALL is specified, the DCV autocal is performed prior to the other autocals.
- The multimeter should be in a thermally stable environment with its power turned on for at least 2 hours before performing any autocal. For maximum accuracy, you should perform ACAL ALL once every 24 hours or when the multimeter's temperature changes by ±1°C from when it was last externally calibrated or from the last autocal.

- The AC autocal performs specific enhancements for ACV or ACDCV (all measurement methods), ACI or ACDCI, DSAC, DSDC, SSAC, SSDC, FREQ, and PER measurements.
- The OHMS autocal performs specific enhancements for 2- or 4-wire ohms, DCI, and ACI measurements.
- Always disconnect any AC input signals before you perform an autocal. If you leave an input signal connected to the multimeter, it may adversely affect the autocal.
- The autocal constants are stored in continuous memory (they remain intact when power is removed). You do not necessarily need to perform autocal simply because power has been cycled.
- The approximate time required to perform each autocal routine is:

```
ALL: 16 minutes
DCV: 2 minutes 45 seconds
AC: 2 minutes 45 seconds
OHMS: 11 minutes
```

- After performing autocal, let the instrument sit for the recommended time shown below before taking a reading, to allow the relays to thermally stabilize:

Types of ACAL	Settling time
ACAL ALL	30 minutes
ACAL DCV	15 minutes
ACAL OHM	30 minutes
ACAL ACV	15 minutes

- **Related commands**: CAL, SCAL, SECURE

Example

```
OUTPUT 722;"ACAL ALL,3458A" !RUNS ALL AUTOCALS USING
                            !FACTORY SECURITY CODE
```

ACBAND

AC bandwidth. Specifies the frequency content (bandwidth) of the input signal for all AC or AC+DC measurements. Specifying the bandwidth allows the multimeter to configure for the fastest possible measurements.

Syntax

ACBAND [*low_frequency*][,*high_frequency*]

low_frequency

Specifies the lowest expected frequency component of the input signal.

Power-on *low_frequency* = 20 Hz

Default *low_frequency* = 20 Hz

high_frequency

Specifies the highest expected frequency component of the input signal.

Power-on *high_frequency* = 20 MHz

Default *high_frequency* = 2 MHz

Remarks

- Refer to the "Appendix A: Specifications" on page 415 for accuracy and reading rate specifications based on the bandwidth of the input signal.
- For synchronous ACV or ACDCV (SETACV SYNC command), the bandwidth parameters are used by the multimeter to calculate time-out values and sampling parameters. When using level triggering (default mode), if the input signal is removed during a reading and does not return within the time limits, the measurement method changes to random so that the reading can be completed. (After the reading, the measurement method returns to SYNC.) For synchronous ACV or ACDCV, it is very important that the specified bandwidth corresponds to the frequency content of the signal being measured.
- For frequency or period measurements with autorange enabled, the bandwidth parameters are used to determine the amount of time needed for autoranging. For these measurements, it is very important that the specified bandwidth (especially *low_frequency*) corresponds to the frequency content of the signal being measured.

- If you are unsure of the frequency content of the input signal, default the ACBAND parameters.
- **Query command**: The ACBAND? query command returns two numbers separated by a comma. The first number is the currently specified *low_frequency*, the second number is the *high_frequency*. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: ACDCI, ACDCV, ACI, ACV, FREQ, FUNC, PER. SETACV

Example

```
OUTPUT 722;"ACBAND 500,1000" !SPECIFIES THAT THE INPUT SIGNAL
                             !IS BETWEEN 500 - 1000 Hz
```

ACDCI, ACDCV, ACI, ACV

Refer to the FUNC command.

ADDRESS

Sets the multimeter's GPIB address (from the front panel only). The address is stored in continuous memory and is not lost when power is removed.

Syntax

ADDRESS *value*

value

The *value* parameter is an integer from 0 to 31.

Power-on *value* = previously stored address (factory setting = 22).
Default *value* = none; parameter required.

Remarks

- When you specify address 31, it doesn't actually change the multimeter's address but sets the multimeter to the Talk Only mode. In this mode, the multimeter outputs readings directly to an GPIB printer without a controller on the bus (you must use the ASCII output format). The multimeter's **TALK** annunciator illuminates when in Talk Only mode. You cannot specify address 31 with a controller on the bus. To remove the multimeter from Talk Only mode, press the **Reset** key or specify an address other than 31.
- The controller's address is typically 21. Do not use the controller's address for any other device on the GPIB bus.
- When the multimeter detects a CMOS RAM failure (auxiliary error bit 12). It sets the address to 22.
- **ADDRESS? query**: From the multimeter's front panel, you can read the present address using the **Address** key (shifted **Local** key).
- **Related commands**: ID?

APER

Aperture. Specifies the A/D converter integration time in seconds.

Syntax

APER [*aperture*]

aperture

Specifies the A/D converter's integration time and overrides any previously specified integration time or resolution. The valid range for *aperture* is 0 - 1 s in increments of 100 ns. (Specifying a value <500 ns selects minimum aperture which is 500 ns.)

Power-on *aperture* = is determined by the power-on value for NPLC which specifies an integration time of 166.667 ms for a 60 Hz power line frequency, or 200 ms for a power line frequency of 50 Hz or 400 Hz.
Default *aperture* = 500 ns.

Remarks

- Since the APER and NPLC commands both set the integration time, executing either will cancel the integration time previously established by the other. The RES command or the *%_resolution* parameter of a function or RANGE command can also be used to indirectly select an integration time. An interaction occurs between APER (or NPLC) when you specify resolution as follows:

  If you send the APER (or NPLC) command *before* specifying resolution, the multimeter satisfies the command that specifies greater resolution (more integration time).

  If you send the APER (or NPLC) command *after* specifying resolution, the multimeter uses the integration time specified by the APER (or NPLC) command, and any previously specified resolution is ignored.

- **Query command**: The APER? query command returns the currently specified integration time (in seconds) used by the A/D converter. The integration time may have been specified by the APER, NPLC, or RES command or by the *%_resolution* parameter of a function command or the RANGE command. Refer to Query commands near the front of this chapter for more information.

- **Related commands**: FUNC, NPLC, RANGE, RES

Example

```
OUTPUT 722; "APER 10E-6" !SETS APERTURE TO 10 MICROSECONDS
```

ARANGE

Autorange. Enables or disables the autorange function.

Syntax

ARANGE [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Disables autorange algorithm
ON	1	Enables autorange algorithm
ONCE	2	Causes the multimeter to autorange once, then disables autoranging

Power-on *control* = ON.
Default *control* = ON.

Remarks

- With autorange enabled, the multimeter samples the input signal before each reading and selects the appropriate range.
- Refer to the FUNC or RANGE command for a listing of the ranges for each measurement function.
- Autorange does not operate for direct- or sub-sampled measurements (DSAC, DSDC, SSAC, or SSDC command) or when using the TIMER sample event or the SWEEP command.
- **Query command**: The ARANGE? query command returns a response indicating the present autorange mode. Refer to Query commands near the front of this chapter for more information.

– **Related commands**: FUNC, RANGE

Example

```
OUTPUT 722;"ARANGE OFF" !DISABLES AUTORANGE
```

AUXERR?

Auxiliary error. When a hardware error is detected. the multimeter sets a bit in the auxiliary error register. The AUXERR? command returns a number representing the decimal-weighted sum of all set bits.The register is then cleared.

Syntax

AUXERR?

Auxiliary error conditions

The auxiliary error conditions and their weighted values are:

Weighted value	Bit number	Description
1	0	Slave processor not responding
2	1	DTACK failure
4	2	Slave processor self-test failure
8	3	Isolator test failure
16	4	A/D converter convergence failure
32	5	Calibration value out of range
64	6	GPIB chip failure
128	7	UART failure
256	8	Timer failure
512	9	Internal overload
1024	10	ROM checksum failure, low-order byte
2048	11	ROM checksum failure, high-order byte
4096	12	Nonvolatile RAM failure

Weighted value	Bit number	Description
8192	13	Option RAM failure
16384	14	Cal RAM write or protection failure

Remarks

- The auxiliary error register indicates hardware related errors. If one or more bits are set, the multimeter needs calibration or repair.
- The AUXERR? command returns a 0 if no error bits are set.
- If any bit in the auxiliary error register is set, the multimeter sets bit 0 (hardware error) in the error register. Reading the auxiliary error register does not clear bit 0 in the error register. You must read the error register (ERR? command) to clear it.
- Bits in the auxiliary error register cannot be masked to prevent them from setting bit 0 in the error register.
- **Related commands**: EMASK, ERR?, ERRSTR?, TEST

Example

```
10 OUTPUT 722;"AUXERR?" !READS THE AUXILIARY ERROR REGISTER
20 ENTER 722;A!ENTERS WEIGHTED SUM INTO VARIABLE A
30 PRINT A!PRINTS THE WEIGHTED SUM
40 END
```

As an example, assume the AUXERR? command returns the weighted sum 3072. This means that the errors with weighted values of 1024 (ROM checksum, low-order byte) and 2048 (ROM checksum, high-order byte) have occurred.

AZERO

Autozero. Enables or disables the autozero function. The autozero function applies only to DC voltage, DC current, and resistance measurements.

Syntax

AZERO [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Zero measurement is updated once, then only after a function, range, aperture, NPLC, or resolution change.
ON	1	Zero measurement is updated after every measurement.
ONCE	2	Zero measurement is updated once, then only after a function, range, aperture, NPLC, or resolution change.

Power-on *control* = ON
Default *control* = ON

Remarks

- When autozero is ON, the multimeter makes a zero measurement (measurement with the input disabled) following every reading and algebraically subtracts the zero measurement from the reading. This approximately doubles the time required per reading.
- Notice that the *control* parameters OFF and ONCE have the same effect. When autozero is OFF or ONCE, the multimeter makes one zero measurement and algebraically subtracts this from subsequent readings. After you execute AZERO OFF or AZERO ONCE, the multimeter takes the autozero measurement when the first trigger arm event occurs for all events except TARM EXT which causes an autozero measurement when the TARM EXT command is executed. The autozero measurement will be updated whenever the measurement function, range, or integration time is changed (this update will be made when the trigger arm event occurs or TARM EXT is executed).

- The display annunciator AZERO OFF illuminates when autozero is disabled.
- Autozero cannot be disabled for DC current measurements.
- For 2-wire ohms measurements with offset compensation enabled, the zero measurement and offset measurement are done simultaneously.
- Autozero should be on for 4-wire ohms measurements. If you must disable autozero, be sure to make all measurement connections before disabling autozero and ensure that the lead resistance will not change. If you disable autozero before making the 4-wire connections, or if you have a varying lead resistance with autozero disabled (such as when scanning), you will get inaccurate 4-wire ohms measurements.
- **Query command**: The AZERO? query command returns the present autozero mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: DCI, DCV, FUNC, OHM, OHMF

Example

```
OUTPUT 722; "AZERO OFF" !DISABLES AUTOZERO
```

BEEP

Controls the multimeter's beeper. When enabled, the beeper emits a 1 kHz beep if an error occurs.

Syntax

BEEP [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Disables the beeper
ON	1	Enables the beeper
ONCE	2	Beeps once, then returns to previous mode (either OFF or ON)

Power-on *control* = last programmed value.
Default *control* = ONCE.

Remarks

- The multimeter stores the *control* parameter in continuous memory (the parameter is not lost when power is removed).
- **Query command**: The BEEP? query command returns the present beeper mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: TONE

Example

```
OUTPUT 722;"BEEP OFF" !DISABLES THE BEEPER
```

CAL

This is a calibration command. Refer to the *3458A Calibration Manual* for details.

CALL

Call subprogram. Executes a previously stored subprogram.

Syntax

CALL [*name*]

name

Subprogram name. A subprogram name may contain up to 10 characters. The name can be alpha, alphanumeric, or an integer in the range of 0 to 127. Refer to the SUB command for details.

Power-on *name* = none.

Default *name* = 0.

Remarks

- Subprograms are created with the SUB command.

- The multimeter sets bit 0 in the status register after executing a stored subprogram.
- From the front panel, you can view all stored subprogram names by accessing the CALL command and pressing the up or down arrow key. Once you have found the correct subprogram, press the **Enter** key to execute the subprogram.
- **Related commands**: COMPRESS, CONT, DELSUB, PAUSE, SCRATCH, SUB, SUBEND

Examples

```
OUTPUT 722;"CALL DCCUR2" !EXECUTES SUBPROGRAM NAMED "DCCUR2"
```

CALNUM?

Calibration number query. Returns an integer indicating the number of times the multimeter has been calibrated.

Syntax

CALNUM?

Remarks

- The calibration number is incremented by 1 whenever the multimeter is calibrated. If autocal is secured, the calibration number is also incremented by 1 whenever an autocal is performed; if unsecured, autocal does not affect the calibration number.
- The calibration number is stored in cal-protected memory and is not lost when power is removed.
- The multimeter was calibrated before it left the factory. When you receive the multimeter, read the calibration number to determine its initial value.
- **Related commands**: CAL, CALSTR, SCAL

Example

```
10 OUTPUT 722;"CALNUM?" !READS CALIBRATION NUMBER
20 ENTER 722;A!ENTERS RESPONSE INTO COMPUTER
30 PRINT A!PRINTS RESPONSE
40 END
```

CALSTR

Calibration string (remote only). Stores a string in the multimeter's nonvolatile calibration RAM. Typical uses for this string include the multimeter's internal temperature at the time of calibration (TEMP? command), date of calibration, technician's name, and the scheduled date for the next calibration.

Syntax

CALSTR *string*[,*security_code*]

string

This is the alpha/numeric message that will be appended to the calibration RAM. The *string* parameter must be enclosed in single or double quotes. The maximum string length is 75 characters (the quotes enclosing the string are not counted as characters).

security_code

When the calibration RAM is secured (SECURE command) you must include the *security_code* in order to write a message to the calibration RAM. (You can always read the string using the CALSTR? command regardless of the security mode). Refer to the SECURE command for information on securing and unsecuring the calibration RAM.

Remarks

- **Query command**: The CALSTR? query command returns the character string from the multimeter's calibration RAM. This is shown in the second example below.
- **Related commands**: CAL, CALNUM?, SCAL, SECURE

Examples

CALSTR

```
OUTPUT 722;"CALSTR 'CALIBRATED 04/02/1987'"
```

CALSTR?

```
10 DIM A$[80] !DIMENSION STRING VARIABLE
20 OUTPUT 722; "CALSTR?" !READ THE STRING
30 ENTER 722;A$ !ENTER STRING
```

```
40 PRINT A$ !PRINT STRING
50 END
```

COMPRESS

Compress subprogram. Removes the ASCII text of a specified subprogram previously stored in memory. This saves memory space but removes the subprogram from continuous memory (the subprogram will be destroyed when power is removed).

Syntax

COMPRESS *name*

name

Subprogram name. A subprogram name may contain up to 10 characters. The name can be alpha. alphanumeric, or an integer in the range of 0 to 127. Refer to the SUB command for details.

Power-on *name* = none.
Default *name* = none; parameter required.

Remarks

- To avoid memory fragmentation, compress each subprogram before downloading other subprograms.
- You cannot store the COMPRESS command as part of a subprogram.
- **Related commands**: CALL, CONT, DELSUB, PAUSE, SCRATCH, SUB, SUBEND

Example

The following program statement compresses subprogram TEST12 (previously downloaded).

```
OUTPUT 722;"COMPRESS TEST12"
```

CONT

Continue. Resumes execution of a subprogram that has been suspended by a PAUSE command.

Syntax

CONT

Remarks

- The GPIB Group Execute Trigger function may also be used to resume execution of a suspended subprogram.
- Only one subprogram will be preserved in a suspended state. If a subprogram is paused and another is run which also becomes paused, the first will be terminated and the second will remain suspended.
- **Related commands**: PAUSE, SUB, SUBEND

Example

```
OUTPUT 722;"CONT” !CONTINUE SUBPROGRAM EXECUTION
```

CSB

Clear status byte. Clears (sets to 0) all bits in the status register.

Syntax

CSB

Remarks

- If a condition that set a bit in the status register still exists, that bit will be set again immediately after the CSB command is executed.
- When you clear bit 6 (service requested), the multimeter sets the GPIB SRQ line false.
- **Related commands**: RQS, SPOLL (GPIB command), STB?

Example

```
OUTPUT 722;"CSB" !CLEARS THE STATUS REGISTER
```

DCI, DCV

Refer to the FUNC command.

DEFEAT

Enables or disables the multimeter's input protection algorithm (see CAUTION below) and some syntax and error checking algorithms. With these algorithms disabled, the multimeter can change to a new measurement configuration faster than it can with them enabled.

Syntax

DEFEAT [*mode*]

mode

The *mode* parameter choices are:

mode parameter	Numeric query equiv.	Description
OFF	0	Enables protection, syntax, and error algorithms
ON	1	Disables protection, syntax, and error algorithms

Power-on *mode* = OFF
Default *mode* = OFF.

Remarks

CAUTION DEFEAT ON must only be used when you are certain that overload voltages on the Input terminals will not exceed ±100 V peak on the 10 V range or below. (On the 100 V and 1000 V ranges, the multimeter can withstand voltages up to ±1200 V peak regardless of whether DEFEAT is ON or OFF.) DEFEAT ON disables (defeats) the input switch sequencing that protects the multimeter's input circuitry from overload voltages. If input protection is disabled and an overload situation is detected on the 10 V range or below, the multimeter will enable input protection and internally tally the overload for instrument warranty considerations.

- Since DEFEAT ON disables certain syntax checking and error reporting algorithms, it should be used only after all system programming is complete and operational.
- **Query command**: The DEFEAT? query command returns the present DEFEAT mode. Refer to Query commands near the front of this chapter for more information.

Example

```
OUTPUT 722;"DEFEAT ON" !DISABLES PROTECTION, SYNTAX, & ERROR ALGORITHMS
```

DEFKEY

Define key. Allows you to assign one or more commands to a particular user-defined function key on the front panel (these keys are labeled **f0** - **f9**). After assigning one or more commands to a key, pressing that key displays the command(s) on the multimeter's display. Pressing the **Enter** key will then execute the command(s) in the order listed. The DEFKEY DEFAULT command erases the strings assigned to all user-defined keys.

Syntax

DEFKEY *number,string*

or

DEFKEY DEFAULT

number

The *number* parameter is an integer in the range 0 - 9 (or F0 - F9) that designates the particular function key.

Power-on *number* = none.
Default *number* = 0.

string

The *string* parameter is the command or list of commands to be assigned to the function key. (Link multiple commands with a semicolon.) The *string* parameter must be enclosed in single or double quotes. The maximum string length is 40 characters (the quotes enclosing the string are not counted as characters).

Power-on *string* = none.

Default *string* = none (clears any previous *string*).

DEFAULT

Erases the strings assigned to all user-defined keys.

Remarks

- Key definitions stored from the front panel can be edited from the front panel. Definitions stored from remote cannot be edited.
- You cannot embed quotes in the DEFKEY *string*. This means you cannot use the DISP command with a message in quotation marks as a *string* parameter. You can, however, use the DISP command and an unquoted message (refer to the DISP command for limitations on unquoted messages).
- **Query command**: The DEFKEY? query command returns the *string* parameter currently assigned to a particular function key (see example below). The string returned by the DEFKEY? query command is enclosed by double quotation marks, regardless of whether single or double marks where used when it was specified.
- **Related commands**: LOCK, MENU

Examples

DEFKEY

```
OUTPUT 722;"DEFKEY 1,'DCI 1;AZERO 0FF;NPLC 0'" !ASSIGNS COMMANDS TO F1
```

Clearing All DEFKEYs

```
OUTPUT 722;"DEFKEY DEFAULT" !CLEARS ALL DEFKEYS
```

DEFKEY?

```
10 OUTPUT 722;"DEFKEY? 1" !RETURNS DEFINITION FOR KEY 1
20 ENTER 722;A$ !ENTERS DEFINITION INTO A$ VARIABLE
30 PRINT A$!PRINTS DEFINITION
40 END
```

A typical response returned by the above program is: "*DCI 1;AZERO OFF;NPLC 0.*" If nothing is assigned to DEFKEY 1, the above program returns: "*DEFKEY F1.*"

DELAY

The DELAY command allows you to specify a time interval that is inserted between the trigger event and the first sample event.

Syntax

DELAY [*time*]

time

Specifies the delay time in seconds. Delay time can range from 1E-7 (100 ns) to 6000 seconds in 10 ns increments for direct- or sub-sampling (DSAC, DSDC, SSAC, or SSDC) or 100 ns increments for all other measurement functions. Specifying 0 for the delay sets the delay to its minimum possible value.

Power-on *time* = automatic (determined by function, range, resolution and ACBAND setting).

Default *time* = automatic (determined by function, range, resolution and ACBAND setting).

Remarks

- The default delay changes automatically (unless you have specified an alternate value) whenever you change the measurement function (DCV, ACV, etc.), the range, the resolution, or the AC bandwidth setting (ACBAND command).
- **Query command**: The DELAY? query returns the present delay time in seconds. Refer to Query commands near the front of this chapter for more information.

– **Related commands**: NRDGS, SWEEP, TIMER, TRIG

Examples

```
OUTPUT 722;"DELAY 5" !INSERTS A 5 SECOND DELAY
OUTPUT 722;"DELAY -1" !RETURNS TO AUTOMATIC (DEFAULT) DELAY
```

DELSUB

Delete subprogram. Removes a single subprogram from memory.

Syntax

DELSUB *name*

name

Subprogram name. A subprogram name may contain up to 10 characters. The name can be alpha, alphanumeric, or an integer in the range of 0 to 127. Refer to the SUB command for details.

Power-on *name* = none.
Default *name* = none; parameter required.

Remarks

– When a subprogram is deleted, the memory used to store it is freed and may be used to store a new subprogram (see the SUB command).

– To delete all subprograms at once, use the SCRATCH command.

– **Related commands**: COMPRESS, SCRATCH, SUB

Example

```
OUTPUT 722;"DELSUB TEST12" !DELETES SUBPROGRAM TEST12
```

DIAGNOST

This is a service-related command. Refer to the *3458A Service Manual* for details

DISP

Display. Enables or disables the multimeter's display, and may also be used to send a message to the display or to clear the display.

Syntax

DISP [*control*] [,*message*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Displays message if included (if no message, dashes are displayed); inactivates all annunciators except ERR; readings are no longer displayed and the display is not updated except to service front panel keystrokes and query commands.
ON	1	Normal (power-on mode) display operation
MSG	2	Displays message, annunciators activated
CLR	3	Clears the display

Power-on *control* = ON.
Default *control* = ON.

message

The *message* parameter is the message to be displayed. The message may contain spaces, numerals, lower or upper case letters, and any of the following characters:

```
! # $ % & ' ( ) ^ \ / @ ; : [ ] , . + - = * < > ? _
```

Remarks

- You must enclose a message in quotation marks only if it contains a space, comma, or semicolon. Either single or double marks (' or ") may be used: the beginning and ending marks must match.
- A message may contain up to 75 characters (quotes enclosing the message are not counted as characters).
- **Query command**: The DISP? query command returns the currently specified *control* parameter. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: NDIG

Examples

The following command causes the multimeter to display the message TIME-OUT and to stop automatically updating the display.

```
OUTPUT 722;"DISP OFF,TIME-OUT" !MESSAGE = TIME-OUT
```

In the following command, the message must be enclosed in quotation marks because it contains a space.

```
OUTPUT 722;"DISP MSG,'TIME OUT'" !MESSAGE = TIME OUT
```

DSAC, DSDC

Direct-sampling. Configures the multimeter for direct-sampled measurements (digitizing). The DSAC function measures only the AC component of the input waveform. The DSDC function measures the combined AC and DC components. Otherwise, the two functions are identical. The DSAC and DSDC functions use the track/hold circuit (2 nanosecond aperture) and a wide bandwidth input path (12 MHz bandwidth).

Syntax

DSAC [*max._input*] [,*%-resolution*]

DSDC [*max._input*] [,*%-resolution*]

max._input

Selects the measurement range. (You cannot use autorange for direct-sampled measurements). To select a range, you specify *max._input* as the input signal's expected peak amplitude. The multimeter then selects the correct range. The following table shows the *max._input* parameters and the ranges they select.

***max._put* parameter**	**Full scale**		
	Selects range	**SINT format**	**DINT format**
0 to .012	10 mV	12 mV	50 mV
>.012 to .120	100 mV	120 mV	500 mV
>.120 to 1.2	1 V	1.2 V	5.0 V
>1.2 to 12	10 V	12 V	50 V
>12 to 120	100 V	120 V	500 V
>120 to 1E3	1000 V	1050 V	1050 V

Power-on *max._input* = not applicable
Default *max._input* = 10 V

%_resolution

Is ignored by the multimeter when used with the DSAC or DSDC command. This parameter is allowed in the command syntax to be consistent with the other function commands (FUNC, ACT, DCV, etc.).

Remarks

- You cannot use autorange for direct-sampled measurements: you must specify the range as the first parameter of the DSAC or DSDC command (*max._input* parameter).
- Notice that when using the DINT memory/output format the full scale values for direct-sampling are 500% (5 times) the ranges of 10 mV, 100 mV, 1 V, 10 V, and 100 V. This is particularly important to consider when specifying the percentage for level triggering. When specifying the level triggering voltage, use a percentage of the range. For example, assume the input signal has a peak value of 20 V and you are using the 10 V range. If you want to level trigger at 15 V, specify a level triggering percentage of 150% (LEVEL 150

command). (The slew rate of the multimeter's amplifiers may be exceeded when measuring a signal with a frequency >2 MHz and an amplitude >120% of range; signals <120% of range with frequencies up to 12 MHz do not cause slew rate errors.)

- The multimeter's triggering hierarchy (trigger arm event, trigger event, and sample event) applies to direct-sampling. This means that these events must occur in the proper order before direct-sampling begins. Refer to Chapter 4 for more information on the triggering hierarchy. For direct-sampling, you can use either the TIMER sample event and the NRDGS n,TIMER command, or the SWEEP command (SWEEP is the simpler to program). The NRDGS and SWEEP commands are interchangeable, the multimeter uses whichever command was specified last. (When using the SWEEP command, the sample event is automatically set to TIMER.)
- For direct-sampling, you should use the SINT memory/output format when the peak value of the input signal is <120% of the specified range. Use the DINT memory/output format when the input signal is ≥120% of the range. (SINT and DINT are the formats used internally by the A/D converter; by using the correct memory/output format, no format conversions are necessary.)
- **Related commands**: DSDC, FUNC, LEVEL, LFILTER, SLOPE, NRDGS, PRESET FAST, PRESET DIG, SSAC, SSDC, SSPARM?, SWEEP, TARM, TIMER, TRIG

Example

The following program is an example of DC-coupled, direct-sampled digitizing. The SWEEP command specifies an interval of 30 µs and 200 samples. Level triggering is set for 250% of the 10 V range (250% of 10 V = 25 V). The samples are sent to reading memory in DINT format. The samples are then sent to the controller, converted, and printed. By deleting line 110, samples will be transferred directly to the controller instead of using reading memory. However, the controller and GPIB must be able to transfer samples at a rate of at least 134k-bytes/second or the multimeter will generate the TRIGGER TOO FAST error. Refer to High-speed transfer across GPIB in Chapter 4 for more information.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_samples,I,J,K !CREATE INTEGER VARIABLES
30 Num_samples = 200 !200 SAMPLES
30 ASSIGN @Dvm TO 722 !DESIGNATE MULTIMETER ADDRESS
40 ASSIGN @Buffer TO BUFFER [4*Num_samplesl !ASSIGN BUFFER I/O PATH NAME
45 !SAMPLES, (4-BYTES/SAMPLE * 200 SAMPLES = 800 BYTES)
50 ALLOCATE REAL Samp(1:Num_samples) !CREATE REAL ARRAY FOR SAMPLES
```

```
60 OUTPUT @Dvm;"PRESET FAST" !DINT FORMATS, TARM SYN, TRIG AUTO
70 OUTPUT @Dvm;"SWEEP 30E-6,200" !30 µs INTERVAL, 200 SAMPLES
80 OUTPUT @Dvm;"DSDC 10" !DIRECT-SAMPLING, 10 V RANGE
90 OUTPUT @Dvm;"LEVEL 250, DC" !LEVEL TRIGGER AT 250% OF RANGE (25 V)
100 OUTPUT @Dvm;"TRIG LEVEL" !LEVEL TRIGGER EVENT
110 OUTPUT @Dvm;"MEM FIFO" !ENABLE READING MEMORY, FIFO MODE
120 TRANSFER @Dvm TO @Buffer;WAIT !TRANSFER SAMPLES TO CONTROLLER
130 OUTPUT @Dvm;"ISCALE?" !QUERY SCALE FACTOR FOR DINT FORMAT
140 ENTER @Dvm;S !ENTER SCALE FACTOR
150 FOR I=1 TO Num_samples
160 ENTER @Buffer USING "#,W,W";J,K !ENTER ONE 16-BIT 2'S COMPLEMENT
161 !WORD INTO EACH VARIABLE J AND K (# = STATEMENT TERMINATION NOT
165 !REQUIRED; W= ENTER DATA AS 16-BIT 2'S COMPLEMENT INTEGER)
170 Samp(I)=(J*65536.+K+65536.*(K<0)) !CONVERT TO REAL NUMBER
180 R=ABS(Samp(I)) !USE ABSOLUTE VALUE TO CHECK FOR OVLD
190 IF R>2147483647 THEN PRINT "OVLD" !IF OVERLOAD OCCURRED, PRINT
MESSAGE
200 Samp(I)=Samp(I)*S !APPLY SCALE FACTOR
210 Samp(I)=DROUND(Samp(1),8) !ROUND CONVERTED READING
220 PRINT Samp(I) !PRINT READINGS
230 NEXT I
240 END
```

EMASK

Error mask. Enables certain error condition(s) to set the error bit (bit 5) in the status register.

Syntax

EMASK [*value*]

value

You enable an error condition by specifying its decimal weight as the *value* parameter. To enable more than one error condition, specify the sum of the weights. The error conditions and their weights are:

Weighted value	Bit number	Error conditions
1	0	Hardware error (see AUXERR? for more information)
2	1	Calibration error
4	2	Trigger too fast error
8	3	Syntax error
16	4	Command not allowed from remote (ADDRESS command)
32	5	Undefined parameter received
64	6	Parameter out of range
128	7	Memory error
256	8	Destructive overload detected
512	9	Out of calibration
1024	10	Calibration required
2048	11	Settings conflict (memory improperly configured for sub-sampling)
4096	12	Math error (divide by 0, integer overflow, etc.)
8192	13	Subprogram error (calling a deleted sub, CONT with no PAUSE, SUBEND or PAUSE only allowed in sub, SCRATCH, DELSUB, CONT, not allowed in sub)
16384	14	System error

Power-on *value* = 32767 (all enabled).
Default *value* = 32767 (all enabled).

Remarks

- When an error occurs, it sets the corresponding bit in the *error register* regardless of whether or not it has been enabled by the EMASK command. Disabling an error bit prevents it from setting the error bit in the *status register* only, and thereby generating a service request.
- **Query command**: The EMASK? query command returns the weighted sum of all enabled error conditions (see example below).
- **Related commands**: AUXERR?, ERR?, ERRSTR?, RQS, STB?

Examples

```
OUTPUT 722;"EMASK 4" !ENABLES THE TRIGGER TOO FAST ERROR
OUTPUT 722;"EMASK 248" !ENABLES ERRORS 8, 16, 32, 64, AND 128
OUTPUT 722;"EMASK 0" !DISABLES ALL ERRORS
10 OUTPUT 722; "EMASK?" !RETURNS EMASK VALUE
20 ENTER 722;A !ENTER RESPONSE
30 PRINT A !PRINT VALUE
40 END
```

END

The END command enables or disables the GPIB End Or Identify (EOI) function.

Syntax

END [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	EOI line never set true
ON	1	For multiple readings (SWEEP or NRDGS >1) the EOI line is set true with the last byte of the last reading sent. For single readings, EOI line set true with the last byte of each reading.
ALWAYS	2	EOI line set true when the last byte of each reading sent.

Power-on *control* = OFF.
Default *control* = ALWAYS.

Remarks

– Each reading output to the GPIB in ASCII format is normally followed by *cr,lf* (carriage return, line feed). The *cr lf* indicates the end of transmission to most

controllers. Readings output in any other format do not have the *cr lf* end of line sequence. When using the ASCII output format and multiple readings are recalled from reading memory using the RMEM command, the multimeter places a comma between readings. In this case, the *cr,lf* occurs only once, following the last reading in the group being recalled. Commas are not used when readings are output directly to the bus (reading memory disabled), when readings are recalled using “implied read”, or when using any other output format.

- Check your computer manual for information on how your computer responds to the EOI line.
- If END ALWAYS is specified for the high-speed mode, the EOI mode automatically becomes ON while the readings are being taken. Following completion of the readings, the EOI mode returns to ALWAYS. Refer to Increasing the Reading Rate in Chapter 4 for more information on the high-speed mode.
- **Query command**: The END? query command returns the present EOI mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: OFORMAT

Example

```
OUTPUT 722;"END ALWAYS" !ENABLES GPIB EOI
```

ERR?

Error query. When an error occurs, it sets a bit in the error register and illuminates the display's ERR annunciator. The ERR? command returns a number representing all set bits, clears the register, and shuts off the annunciator. The returned number is the weighted sum of all set bits.

Syntax

ERR?

Error Conditions

The error conditions and their weighted values are:

Weighted value	Bit number	Error conditions
1	0	Hardware error (see AUXERR? for more information)
2	1	Calibration error
4	2	Trigger too fast error
8	3	Syntax error
16	4	Command not allowed from remote (ADDRESS command)
32	5	Undefined parameter received
64	6	Parameter out of range
128	7	Memory error
256	8	Destructive overload detected
512	9	Out of calibration
1024	10	Calibration required
2048	11	Settings conflict (memory improperly configured for sub-sampling)
4096	12	Math error (divide by 0, integer overflow, etc.)
8192	13	Subprogram error (calling a deleted sub, CONT with no PAUSE, SUBEND, or PAUSE only allowed in sub, SCRATCH, DELSUB, CONT, not allowed in sub)
16384	14	System error

Remarks

- The ERR? command returns a 0 if no error bits are set.
- If bit 0 is set (weight = 1), refer to the auxiliary error register (AUXERR? command) for more information.
- Executing the ERR? command clears the status register's error bit (bit 5).
- **Related commands**: AUXERR?, EMASK, ERRSTR?

Example

```
10 OUTPUT 722;"ERR?" !READS & CLEARS ERROR REGISTER
20 ENTER 722;A !ENTERS WEIGHTED SUM INTO VARIABLE A
```

```
30 PRINT A!PRINTS RESPONSE
40 END
```

ERRSTR?

Error string query. The ERRSTR? command reads the least significant set bit in either the error register or the auxiliary error register and then clears the bit. The ERRSTR? command returns two responses separated by a comma. The first response is an error number (100 Series = error register; 200 Series = auxiliary error register) and the second response is a message (string) explaining the error.

Syntax

ERRSTR?

Remarks

- The maximum string length returned by ERRSTR? is 255 characters.
- The ERRSTR? command reads and clears only the least significant set bit in a register. If more than one bit is set in a register, you must execute ERRSTR? repetitively to read and clear each set bit. After all set bits have been read and cleared (or if there were no set bits in either register), the ERRSTR? command returns *0,"NO ERROR*". When the auxiliary and error registers are cleared, the error bit in the status register (bit 5) will also be cleared.
- When bit 0 in the error register is set, it means that one or more bits in the auxiliary error register are set. In this case, the ERRSTR? command reads and clears each set bit in the auxiliary error register first. When all auxiliary errors have been read, bit 0 in the error register is cleared and the ERRSTR? command can then be used to read any remaining errors in the error register.
- **Related commands**: AUXERR?, EMASK, ERR?, QFORMAT

Example

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM A$[200] !DIMENSION STRING VARIABLE
30 OUTPUT 722;"ERRSTR?"!READS ERROR MESSAGE
40 ENTER 722; A,A$ !ENTERS NUMERIC INTO A, STRING INTO A$
50 PRINT A,A$ !PRINTS RESPONSES
```

```
60 IF A>0 THEN GOTO 30 !LOOPS FOR EACH ERROR
70 END
```

EXTOUT

External output. Specifies the event that will generate a signal on the rear panel Ext Out connector (EXTOUT signal). This command also specifies the polarity of the EXTOUT signal.

Syntax

EXTOUT [*event*][,*polarity*]

event

The *event* choices are:

event parameter	Numeric query equiv.	Description
OFF	0	None; EXTOUT is disabled
ICOMP	1	Input complete (1 µs pulse after A/D converter has integrated each reading or, for direct- or sub-sampling, after the track and hold has acquired the input signal)
ONCE	2	Outputs a 1 µs pulse upon execution of the EXTOUT ONCE command; the event then becomes OFF
APER	3	Aperture waveform (a level indicating when the A/D converter is making a measurement)
BCOMP	4	Burst complete (1 µs pulse following a group of readings)
SRQ	5	Status event occurred (1 µs pulse whenever a status register event occurs that has been enabled to assert the GPIB SRQ). (See second Remark below.)
RCOMP	6	Reading complete (1 µs pulse after each reading)

Power-on *event* = ICOMP.
Default *event* = ICOMP.

polarity

Specifies the polarity of the EXTOUT signal. The choices are:

polarity parameter	Numeric query equiv.	Description
NEG	0	Generates a low-going TTL signal
POS	1	Generates a high-going TTL signal

Power-on *polarity* = NEG.
Default *polarity* = NEG.

Remarks

- All events except APER generate a 1 µs pulse on the EXTOUT connector. If APER is selected, the A/D's aperture waveform is output directly. The leading edge of the EXTOUT signal is the response to the event. Refer to The EXTOUT Signal in Chapter 4 for a detailed description of the above events.
- When a status event sets the SRQ bit in the status register, that bit remains set until cleared (CSB command, for example). When specified, the EXTOUT SRQ pulse occurs whenever any status event occurs that has been enabled to assert SRQ (RQS command). The EXTOUT SRQ pulse does not necessarily occur whenever the SRQ bit is set; it occurs whenever an enabled status event occurs.
- **Query command**: The EXTOUT? query command returns two responses separated by a comma. The first response indicates the currently specified EXTOUT event. The second response indicates the *polarity*. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: NRDGS, SRQ, STB?, SWEEP, TBUFF

Example

```
OUTPUT 722;"EXTOUT APER" !SETS EXTOUT EVENT TO APERTURE WAVEFORM
```

FIXEDZ

The FIXEDZ command enables or disables the fixed input resistance function for DC voltage measurements. When enabled, the multimeter maintains its input resistance at 10 megohms for all ranges. This prevents a change in input resistance (caused by a range change) from affecting the DC voltage measurements.

Syntax

FIXEDZ [*control*]

control

The *control* parameter choices are:

control parameters	Numeric query equiv.	Description	Input resistances	
			DCV .1 V, 1 V, 10 V, and 1000 V ranges	DCV 100 V ranges
OFF	0	FIXEDZ disabled	>10 GΩ	10 MΩ
ON	1	FIXEDZ enabled	10 MΩ	10 MΩ

Power-on *control* = OFF.
Default *control* = ON.

Remarks

- FIXEDZ remains enabled when you change from DC voltage measurements to 2-wire or 4-wire ohms measurements. Resistance measurements made with FIXEDZ enabled will be in error because the multimeter's input resistance represents a 10 MΩ resistance in parallel with the input terminals.
- FIXEDZ is temporarily disabled when you change from DC voltage measurements to AC voltage, AC+DC voltage, any type of current, frequency, or period measurements. For example, if FIXEDZ is enabled and you change from DC voltage measurements to AC voltage measurements, FIXEDZ becomes disabled. When you return to DC voltage measurements, however, FIXEDZ is once again enabled.

- **Query command**: The FIXEDZ? query command returns the present fixed input resistance mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: DCV, FUNC, OHM, OHMF,

Example

```
OUTPUT 722; "FIXEDZ ON" !ENABLES FIXED IMPEDANCE
```

FREQ

Frequency. Instructs the multimeter to measure the frequency of the input signal. You must specify whether the input signal is AC voltage, AC+DC voltage, AC current, or AC+DC current using the FSOURCE command.

Syntax

FREQ [*max._input*][,*%_resolution*]

max._input

Selects a fixed range or the autorange mode. The ranges correspond to the type of input signal specified in the FSOURCE command. That is, if ACV is the specified input signal, the *max._input* parameter specifies an AC voltage measurement range. To select a fixed range, you specify *max._input* as the absolute value (no negative numbers) of the expected peak value of the input signal. The multimeter then selects the proper range. Refer to the FUNC or RANGE command for tables showing the ranges available for each type of input signal.

To select the autorange mode, specify AUTO for *max._input* or default the parameter. In the autorange mode, the multimeter samples the input signal before each frequency reading and selects the proper range.

Power-on *max._input* = not applicable.
Default *max._input* = AUTO.

%_resolution

The *%_resolution* parameter specifies the digits of resolution and the gate time as shown below (*%_resolution* also affects the reading rate, refer to the "Appendix A: Specifications" on page 415 for more information).

%_resolution parameter	Selects gate time	Digits of resolution
.00001	1 s	7
.0001	100 ms	7
.001	10 ms	6
.01	1 ms	5
.1	100 µs	4

Power-on *% _resolution* = not applicable.
Default *%_resolution* = .00001

Remarks

- The reading rate is the longer of 1 period of the input signal, the gate time, or the default reading timeout of 1.2 seconds.
- Frequency (and period) measurements are made using the level detection circuitry to determine when the input signal crosses a particular voltage on its positive or negative slope. (This is why you cannot use the LEVEL trigger or sample event or the LINE trigger event when making frequency or period measurements.) The power-on or default level triggering values select zero volts, positive slope. You can control the level triggering voltage and coupling using the LEVEL command. You can specify either the positive or negative slope using the SLOPE command.
- The leftmost digit which is a half digit for most measurement functions, is a full digit (0 - 9) for frequency measurements.
- Readings made with autorange enabled take longer because the input signal is sampled (to determine the proper range) between frequency readings.
- For frequency (and period) measurements, an overload indication means the voltage or current amplitude is too great for the specified measurement range. It does not mean the applied frequency (or period) is too great to be measured.
- **Related commands**: ACBAND, FSOURCE, FUNC, LFILTER, PER, RES

Example

```
10 OUTPUT 722;"FSOURCE ACI" !SELECTS AC CURRENT AS INPUT SOURCE
20 OUTPUT 722;"FREQ .01,.001" !SELECTS FREQUENCY MEASUREMENTS, 10 mA
25 !RANGE, 10 ms GATE TIME, 5 DIGITS RES.
30 END
```

FSOURCE

Frequency source. Specifies the type of signal to be used as the input signal for frequency or period measurements.

Syntax

FSOURCE [*source*]

source

The *source* parameter choices are:

source parameter	Numeric query equiv.	Description (measurement capabilities)
ACV	2	AC voltage (FREQ 1 Hz - 10 MHz; PER 100 ns - 1 s)
ACDCV	3	AC+DC voltage (FREQ 1 Hz - 10 MHz; PER 100 ns - 1 s)
ACI	7	AC current (FREQ 1 Hz - 100 kHz; PER 10 µs - 1 s)
ACDCI	8	AC+DC current (FREQ 1 Hz - 100 kHz; PER 10 µs - 1 s)

Power-on *source* = ACV.
Default *source* = ACV.

Remarks

- **Query command**: The FSOURCE? query command returns the present frequency source. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: FREQ, FUNC, PER

Example

```
10 OUTPUT 722;"FSOURCE ACDCI" !SELECTS ACDCI AS THE INPUT SOURCE
20 OUTPUT 722;"FREQ .1,.9=01" !SELECTS FREQUENCY, 100 mA RANGE, 1 ms
25 !GATE TIME, 4 DIGITS OF RESOLUTION
30 END
```

FUNC

Function. Selects the type of measurement (AC voltage, DC current. etc.). It also allows you to specify the measurement range and resolution. (The FUNC header is optional and may be omitted.)

Syntax

FUNC [*function*][,*max._input*][,*%_resolution]*

or

[FUNC] *function*[,*max._input*][,*%_resolution*]

function

The *function* parameter designates the type of measurement. The parameter choices are:

function parameter	Numeric query equiv.	Description
DCV	1	Selects DC voltage measurements
ACV	2	Selects AC voltage measurements (the mode is set by the SETACV command)
ACDCV	3	Selects AC+DC voltage measurements (the mode is set by the SETACV command)
OHM	4	Selects 2-wire ohms measurements
OHMF	5	Selects 4-wire ohms measurements
DCI	6	Selects DC current measurements
ACI	7	Selects AC current measurements

function parameter	Numeric query equiv.	Description
ACDCI	8	Selects AC+DC current measurements
FREQ[a]	9	Selects frequency measurements
PER[a]	10	Selects period measurements
DSAC[a]	11	Direct sampling, AC coupled
DSDC[a]	12	Direct sampling, DC coupled
SSAC[a]	13	Sub-sampling, AC coupled
SSDC[a]	14	Sub-sampling, DC coupled

[a] These functions require additional explanation and are documented individually in this chapter. Refer to the corresponding DSAC, DSDC, FREQ, PER, or SSAC, SSDC command for details.

Power-on *function* = DCV.
Default *function* = DCV.

max._input

Selects a fixed range or the autorange mode. To select a fixed range, you specify *max._input* as the absolute value (no negative numbers) of the input signal's maximum expected amplitude (or the maximum resistance for ohms measurements). The multimeter then selects the correct range.

To select autorange, specify AUTO for *max._input* or default the parameter. In the autorange mode, the multimeter samples the input signal before each reading and selects the appropriate range.

– The following tables show the *max._input* parameters and the ranges they select for each measurement function.

For DCV:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .12	100 mV	120 mV
>.12 to 1.2	1 V	1.2 V
>1.2 to 12	10 V	12 V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

For ACV or ACDCV:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .012	10 mV	12 mV
>.012 to .12	100 mV	120 mV
>.12 to 1.2	1 V	1.2 V
>1.2 to 12	10 V	12 V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

For OHM or OHMF:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to 12	10 Ω	12 Ω
>12 to 120	100 Ω	120 kΩ
>120 to 1.2E3	1 kΩ	1.2 kΩ
>1.2E3 to 1.2E4	10 kΩ	12 kΩ
>1.2E4 1.2E5	100 kΩ	120 kΩ
>1.2E5 to 1.2E6	1 MΩ	1.20 MΩ
>1.2E6 to 1.2E7	10 MΩ	12 MΩ
>1.2E7 1.2E8	100 MΩ	120 MΩ
>1.2E8 1.2E9	1 GΩ	1.2 GΩ

For DCI:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .12E-6	.1 µA	.12 µA
>.12E-6 to 1.2E-6	1 µA	1.2 µA
>1.2E-6 to 12E-6	10 µA	12 µA
>12E-6 to 120E-6	100 µA	120 µA
>120E-6 to 1.2E-3	1 mA	1.2 mA
>1.2E-3 to 12E-3	10 mA	12 mA
>12E-3 to 120E-3	100 mA	120 mA
>120E-3 to 1.2	1 A	1.05 A

For ACI or ACDCI:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .120E-6	100 µA	120 µA
>120E-6 to 1.2E-3	1 mA	1.2 mA
>1.2E-3 to 12E-3	10 mA	12 mA
>12E-3 to 120E-3	100 mA	120 mA
>120E-3 to 1.2	1 A	1.05 A

For SSAC or SSDC:

max._input parameter	Selects range	Full scale
0 to .012	10 mV	12 mV
>.012 to .120	100 mV	120 mV
>.120 to 1.2	1 V	1.2 V
>1.2 to 12	10 V	12 V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

For DSAC or DSDC:

max._input parameter	Full scale		
	Selects range	SINT format	DINT format
0 to .012	10 mV	12 mV	50 mV
>.012 to .120	100 mV	120 mV	500 mV
>.120 to 1.2	1 V	1.2 V	5.0 V
>1.2 to 12	10 V	12 V	50 V
>12 to 120	100 V	120 V	500 V
>120 to 1E3	1000 V	1050 V	1050 V

Power-on *max._input* = AUTO.
Default *max._input* = AUTO.

%_resolution

For most measurement functions, you specify the *%_resolution* as a percentage of the *max._input* parameter. (Refer to the FREQ and PER commands for tables showing how *%_resolution* affects frequency and period measurements; *%_resolution* is ignored when the *function* parameter is DSAC, DSDC, SSAC, or SSDC.)

For all functions except FREQ, PER, DSAC, DSDC, SSAC, and SSDC, the multimeter multiplies *%_resolution* times *max._input* to determine the measurement's resolution. For example, suppose you are measuring DC voltage, your maximum expected input is 10 V, and you want 1 mV of resolution. To determine *%_resolution*, use the equation:

%_resolution = (actual resolution/maximum input) × 100

For this example, the equation evaluates to:

%_resolution = (.001/10) × 100 = .0001 × 100 = .01

NOTE **When using autorange, the multimeter multiplies the *%_resolution* parameter times the full scale reading of the selected range. The result is the minimum resolution. The multimeter always gives you at least the minimum resolution and, in many cases, gives you additional digits of resolution.**

Power-on *%_resolution* = none. At power-on, the resolution is determined by the NPLC command which produces 8½ digits. (The power-on value for NDIG masks 1 display digit causing the multimeter to display only 7½ digits. You can use the NDIG 8 command to display all 8½ digits; refer to the NDIG command for details.)

Default % resolution:

For frequency or period measurements, the default *%_resolution* is .00001 which selects a gate time of 1 s and 7 digits of resolution.

For sampled ACV or ACDCV, the default *%_resolution* is 0.01% for SETACV SYNC, or 0.4% for SETACV RNDM.

For all other measurement functions, the default resolution is determined by the present integration time.

Remarks

- **Query command**: The FUNC? query command returns two responses separated by a comma. The first response is the present measurement function. The second response is the present measurement range (this is the actual range, not necessarily the value specified for *max._input*). The FUNC? query command does not indicate the autorange mode. Use the ARANGE? query to determine the autorange mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: ACDCI, ACDCV, ACI, ACV, APER, DCI, DCV, DSAC, DSDC, FREQ, OHM, OHMF, PER, RATIO, NPLC, RES, SETACV, SSAC, SSDC

Examples

In the following program, line 10 allows *%_resolution* in line 20 to control the resolution. The resolution specified by line 20 is 6 V × .0000167 = 100 µV.

```
10 OUTPUT 722;"NPLC 0" !SETS PLCS TO MINIMUM
20 OUTPUT 722;"FUNC DCV,6,.00167" !SELECTS DC VOLTS, 6 V MAX,
30 END !100 µV RESOLUTION
```

In the following program, line 10 sets the number of PLCs to 1000. This corresponds to maximum resolution (7.5 digits) and prevents *%_resolution* in line 20 from affecting the measurement. The requested resolution from line 20 is 10 µΩ. However. because of line 10, the actual resolution is 100 µΩ.

```
10 OUTPUT 722;"NPLC 1000" !SETS PLCS TO MAXIMUM
20 OUTPUT 722;"FUNC OHM,1E3,.001" !SELECTS 2-WIRE OHMS,
30 END !1 kΩ MAX, 10 mΩ RESOLUTION
```

ID?

Identity query. The multimeter responds to the ID? command by sending the string “Keysight 3458A”. This feature allows the GPIB controller to locate the multimeter by its address.

Syntax

ID?

Remarks

- **Related commands**: ADDRESS, QFORMAT

Example

```
10 OUTPUT 722;"ID?” !RETURNS RESPONSE
20 ENTER 722;A$ !ENTERS RESPONSE INTO THE COMPUTER'S A$ VARIABLE
30 PRINT A$ !PRINTS RESPONSE
40 END
```

INBUF

Input buffer. Enables or disables the multimeter's input buffer. When enabled, the input buffer temporarily stores the commands it receives over the GPIB bus. This releases the bus immediately after a command is received, allowing the controller to perform other tasks while the multimeter executes the stored command.

Syntax

INBUF [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Disables the input buffer; commands are accepted only when the multimeter is not busy
ON	1	Enables the input buffer; commands are stored, releasing the bus immediately

Power-on *control* = OFF.
Default *control* = ON.

Remarks

- Turning the input buffer OFF causes a minor degradation in speed performance, but is useful for synchronizing bus activity. With the input buffer OFF, the multimeter accepts only one command at a time and does not release the bus until it has finished executing that command. This ensures that subsequent commands sent to other bus devices cannot be executed until the multimeter has finished executing its command(s).
- Turning the input buffer ON causes the multimeter to buffer (store) incoming messages and release the GPIB bus as soon as message transmission is complete. This allows the controller to communicate with other bus devices while the multimeter executes its command(s). However, synchronization with other bus devices may be lost if they execute their instructions before the

multimeter finishes its instructions. In this case, the ready bit in the status register may be monitored (using a serial poll) to determine when the multimeter is finished.

- A series of commands longer than 255 characters fills the input buffer and causes the multimeter to halt bus activity while it executes the first commands received. The remainder of the message is input when room becomes available in the buffer.
- **Query command**: The INBUF? query command returns the present input buffer mode. Refer to Query commands near the front of this chapter for more information.

Example

The following program enables the input buffer prior to running all of the autocalibration routines. This prevents the bus from being held during the autocal which takes over 16 minutes to complete.

```
10 OUTPUT 722;"INBUF ON" !ENABLE INPUT BUFFER
20 OUTPUT 722;"ACAL ALL" !AUTOCAL (TAKES >11 MINUTES)
30 END
```

ISCALE?

Integer scale query. Returns the scale factor for readings output in the SINT or DINT formats.

Syntax

ISCALE?

Remarks

- The scale factor is always 1 for the ASCII, SREAL, and DREAL output formats.
- Readings output in the SINT or DINT formats (see the OFORMAT command) are first compressed by the multimeter so they may be expressed as integers. Multiplying the readings by the value returned by ISCALE? will restore them to their actual values. The scale factor is determined by the configuration of the multimeter when ISCALE? is executed. This includes the measurement function, range, and integration time. Therefore, the multimeter's configuration must be the same when the scale factor is retrieved as it was

when the readings were taken. You can retrieve the scale factor after the multimeter is configured but before readings are triggered or immediately after the readings made.

- You should not use the SINT or DINT output or memory format for frequency or period measurements when a real-time or post-process math function is enabled (except STAT or PFAIL) or when autorange is enabled.
- **Related commands**: OFORMAT, SSAC, SSDC

Examples

SINT example

The following program outputs 10 readings in SINT format, retrieves the scale factor, and multiplies the scale factor times each reading.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Int_rdgs (1:10) BUFFER !CREATE INTEGER BUFFER ARRAY
30 REAL Rdgs(1:10) !CREATE REAL ARRAY
40 Num_readings=10! NUMBER OF READINGS = 10
50 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
60 ASSIGN @Int_rdgs TO BUFFER Int_rdgs(*) !ASSIGN BUFFER I/O PATH NAME
70 OUTPUT @Dvm;"PRESET NORM;OFORMAT SINT;NPLC 0;NRDGS ";Num_readings
75 !TARM AUTO, TRIG SYN, SINT OUTPUT FORMAT, MIN. INTEGRATION TIME
80 TRANSFER @Dvm TO @Int_rdgs;WAIT !SYN EVENT, TRANSFER READINGS INTO
81 !INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
85 !SINT,NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
90 OUTPUT @Dvm;"ISCALE?" !QUERY SCALE FACTOR FOR SINT FORMAT
100 ENTER @Dvm;S !ENTER SCALE FACTOR
110 FOR I=1 TO Num_readings
120 Rdgs(I)=Int_rdgs(I) !CONVERT EACH INTEGER READING TO REAL
125 !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
130 R=ABS(Rdgs(I)) !USE ABSOLUTE VALUE TO CHECK FOR OVLD
140 IF R>=32767 THEN PRINT "OVLD" !IF OVLD, PRINT OVERLOAD MESSAGE
150 Rdgs(I)=Rdgs(I)*S !MULTIPLY READING TIMES SCALE FACTOR
160 Rdgs(I)=DROUND(Rdgs(I),4) !ROUND TO 4 DIGITS
170 NEXT I
180 END
```

DINT example

The following program is similar to the preceding program except that it takes 50 readings and transfers them to the computer using the DINT format.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1

20 INTEGER Num_readings,I,J,K !DECLARE VARIABLES

30 Num_readings=50 !NUMBER OF READINGS = 50

40 ALLOCATE REAL Rdgs(1:Num_readings) !CREATE ARRAY FOR READINGS

50 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS

60 ASSIGN @Buffer TO BUFFER[4*Num_readingsl !ASSIGN BUFFER I/O PATH NAME

70 OUTPUT @Dvm;"PRESET NORM;RANGE 10;OFORMAT DINT;NRDGS ";Num_readings

75 !TARM AUTO, TRIG SYN, DCV 10 V RANGE, DINT OUTPUT FORMAT, NRDGS
50,AUTO

80 TRANSFER @Dvm TO @Buffer;WAIT !SYN EVENT,TRANSFER READINGS

90 OUTPUT @Dvm; "ISCALE?" !QUERY SCALE FOR DINT

100 ENTER @Dvm;S !ENTER SCALE FACTOR

110 FOR I=1 TO Num_readings

120 ENTER @Buffer USING "#,W,W";J,K !ENTER ONE 16-BIT 2'S COMPLEMENT

121 !WORD INTO EACH VARIABLE J AND K (# = STATEMENT TERMINATION NOT

125 !REQUIRED; W= ENTER DATA AS 16-BIT 2'S COMPLEMENT INTEGER)

130 Rdgs(I)=(J*65536.+K+65536.*(K<0)) !CONVERT TO REAL NUMBER

140 R=ABS(Rdgs(I))!USE ABSOLUTE VALUE TO CHECK FOR OVLD

150 IF R>2147483647 THEN PRINT "OVLD" !IF OVERLOAD OCCURRED, PRINT
MESSAGE

160 Rdgs(I)=Rdgs(I)*S !APPLY SCALE FACTOR

170 Rdgs(I)=DROUND(Rdgs(I),8) !ROUND CONVERTED READING

180 PRINT Rdgs(I) !PRINT READINGS

190 NEXT I

200 END
```

LEVEL

The LEVEL command specifies the level triggering voltage (as a percentage of the present range) and the coupling (AC or DC) for level triggering. A level trigger event occurs when the input signal reaches the specified voltage on its positive-going or negative-going slope as specified by the SLOPE command.

Syntax

LEVEL [*percentage*][,*coupling*]

percentage

Specifies the percentage of the present range for level triggering. The valid range for this parameter is -500% to +500% in 5% steps for direct- or sub-sampling or -120% to 120% in 1% steps for DC voltage (refer to Chapter 5 for details).

Power-on *percentage* = 0% (0 V).
Default *percentage* = 0% (0 V).

The full scale values for direct-sampling are 500% (5 times) the ranges of 10 mV 100 mV, 1 V, 10 V, and 100 V. When specifying the level triggering percentage, remember to use a percentage of the range. For example, assume the input signal has a peak value of 20 V and you are using the 10 V range. If you want to level trigger at 15 V, you would specify a level triggering percentage of 150% (LEVEL 150 command).

coupling

The coupling parameter selects the coupling of the signal to the level-detection circuitry only. This does not affect the coupling of the signal being measured.

coupling parameter	Numeric query equiv.	Description
DC	1	Selects DC-coupled input to level-detection circuitry
AC	2	Selects AC-coupled input to level-detection circuitry

Power-on *coupling* = AC.
Default *coupling* = AC.

Remarks

- Level triggering can be used for DC voltage, direct-sampling, and sub-sampling. (The LEVEL command also affects the zero crossing threshold and the input signal coupling for frequency and period measurements.) For DC voltage and direct-sampling, level triggering can be used as the trigger event (TRIG LEVEL command) or the sample event (NRDGS n, LEVEL command). For sub-sampling, level triggering can be used for the sync source event only (SSRC LEVEL command).
- Because of hysteresis, the actual level triggering point is the specified *percentage* ±4% of the measurement range.
- Autozero should be disabled when using level triggering (AZERO OFF command) for DC voltage measurements. (Autozero doesn't apply to direct- or sub-sampling.)
- **Query command**: The LEVEL? query command returns two responses separated by a comma. The first response is the currently specified *percentage*. The second response is the present coupling mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: DCV, DSAC, DSDC, LFILTER, NRDGS, SETACV, SYNC, SLOPE, SSAC, SSDC, SSRC, TRIG

Example

```
10 OUTPUT 722;"TARM HOLD" !SUSPENDS TRIGGERING

20 OUTPUT 722;"PRESET DIG" !FAST DCV MEASUREMENTS, 10 V RANGE

30 OUTPUT 722;"TRIG LEVEL" !SELECT LEVEL TRIGGER EVENT

40 OUTPUT 722;"SLOPE POS" !TRIGGER ON POSITIVE SLOPE OF SIGNAL

50 OUTPUT 722;"LEVEL 50,AC" !TRIGGER AT 50% OF 10 V RANGE (5 V)
AC-COUPLED

60 END
```

LFILTER

Level filter. Enables or disables the level filter function. When enabled, the level filter function connects a single pole low-pass filter circuit to the input of the level-detection circuitry. The low-pass filter has a 3-dB point of 75 kHz and prevents high frequency components from causing false triggers.

Syntax

LFILTER [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Disables the level filter; no filtering is done
ON	1	Enables the level filter

Power-on *control* = OFF.
Default *control* = ON.

Remarks

- Level filtering can be used when level triggering for DC voltage, direct- and sub-sampling. The level filter can also be used to reduce sensitivity to noise for frequency and period measurements or when making AC or AC+DC voltage measurements using the synchronous method (SETACV SYNC command).
- **Query command**: The LFILTER? query command returns the present level filter mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: DCV, DSAC, DSDC, FREQ, LEVEL, NRDGS, PER, SETACV, SYNC, SLOPE, SSAC, SSDC, SSRC, TRIG

Example

```
OUTPUT 722;"LFILTER ON" !ENABLES THE LEVEL FILTER
```

LFREQ

The LFREQ command allows you to specify the A/D converter's reference frequency or measure the line frequency and set the reference frequency to the measured value.

Syntax

LFREQ [*frequency*]

or

LFREQ LINE

frequency

Allows you to specify the reference frequency. The valid range for the *frequency* parameter is 45 - 65 Hz, or 360 - 440 Hz. When you specify a frequency in the range of 360 - 440 Hz, the multimeter divides that value by 8. For example, if you specify LFREQ 400, the multimeter sets the reference frequency to 400/8 = 50 Hz.

Power-on reference frequency = rounded value of 50 or 60 Hz (see first Remark below).

Default reference frequency = the exact measured line frequency (or measured value/8 for 400 Hz line frequency).

LINE

Measures the exact value of the line frequency and sets the reference frequency to that value (or measured value/8 if the measured value is between 360 and 440 Hz).

Remarks

- When power is applied, the multimeter measures the line frequency, rounds it to 50 or 60 Hz, and sets the A/D Converter's reference frequency to the rounded value. (For a 400 Hz power line frequency, the multimeter uses 50 Hz as a reference frequency which is a subharmonic of 400 Hz.)
- The step size for the period of the reference frequency is 100 ns. For example, the period of a 60 Hz reference frequency is 1/60 Hz = .0166666... Since the step size is 100 ns, the multimeter uses the value of .0166667 s. The step size is most noticeable when using the LFREQ? query command. For example, if

you have specified 60 Hz as the reference frequency, the LFREQ? returns 59.99988 (1/.0166667).

- The multimeter multiplies the period of the reference frequency times the specified number of power line cycles (NPLC command) to determine the actual integration time. The multimeter's normal mode noise rejection (NMR) specifications for DC and resistance measurements are related to the accuracy of the A/D converter's reference frequency.
- **Query command**: The LFREQ? query command returns the present value of the line frequency reference used by the multimeter's A/D converter. Since the step size is 100 ns, if the period of the value specified is not evenly divisible by 1/100 ns, the value returned by LFREQ? will be slightly different than the value specified. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: LINE?, NPLC

Example

```
OUTPUT 722; "LFREQ LINE" !MEASURES LINE FREQUENCY, SETS REFERENCE
!FREQUENCY TO MEASURED VALUE (OR MEASURED
!VALUE/8 FOR 400 HZ LINE FREQUENCY)
```

LINE?

Line frequency query. Measures and returns the frequency of the AC power line.

Syntax

LINE?

Remarks

- Refer to the LFREQ command on the previous page for an example showing how to measure the line frequency and automatically set the A/D converter's reference frequency to the measured value.
- **Related commands**: LFREQ

Example

```
10 OUTPUT 722; "LINE?" !MEASURES THE LINE FREQUENCY
20 ENTER 722;A !ENTERS RESPONSE INTO COMPUTER'S A VARIABLE
30 PRINT A !PRINTS RESPONSE
40 END
```

LOCK

Lockout. Enables or disables the multimeter's keyboard

Syntax

LOCK [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Enables the keyboard (normal operation)
ON	1	Disables the keyboard (pressing keys has no affect)

Power-on *control* = OFF.
Default *control* = ON.

Remarks

- The LOCK command is accessible from the front panel's alphabetic command directory. However, executing the LOCK command from the front panel has no effect.
- After disabling the keyboard, you can only enable it from the controller or by cycling power. The LOCK command disables the multimeter's **Local** key.
- **Query command**: The LOCK? query command returns the present LOCK mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: LOCAL LOCKOUT (GPIB command)

Example

```
OUTPUT 722;"LOCK ON" !DISABLES THE KEYBOARD
```

MATH

The MATH command enables or disables real-time math operations.

Syntax

MATH [*operation_a*][,*operation_b*]

operation

The operation parameter choices are:

operation parameter	Numeric equiv.	Description
OFF	0	Disables all enabled real-time math operations
CONT	1	Enables the previous math operation. To resume two math operations, send MATH CONT,CONT
CTHRM	3	Result = temperature (Celsius) of a 5 kΩ thermistor (40653B). Function must be OHM or OHMF (10 kΩ range or higher).
DB	4	Result = 20 x Log_{10}(reading/REF register). The REF register is initialized to 1, yielding dBV.
DBM	5	Result =10 x $\log_{10}$(reading^2/RES register/1 mW). Function must be ACV, DCV, or ACDCV.
FILTER	6	Result = output of exponentially weighted digital low-pass filter. Response is set by DEGREE register.
FTHRM	8	Result = temperature (Fahrenheit) of a 5 kΩ thermistor (40653B). Function must be OHM or OHMF (10 kΩ range or higher).
NULL	9	Result = reading-OFFSET register. The OFFSET register is set to first reading–after that you can change it.
PERC	10	Result = ((reading - PERC register) / PERC register x 100.
PFAIL	11	Reading vs. MAX and MIN registers.

operation parameter	Numeric equiv.	Description
RMS	12	Result = squares reading, applies FILTER operation, takes square root.
SCALE	13	Result = (reading-OFFSET register) / SCALE register.
STAT	14	Performs statistical calculations on the present set of readings and stores results in these registers: SDEV = standard deviation MEAN = average of readings NSAMP = number of readings UPPER = largest reading LOWER = smallest reading
CTHRM2K	16	Result = temperature (Celsius) of a 2 kΩ thermistor (40653A). Function must be OHM or OHMF.
CTHRM10K	17	Result = temperature (Celsius) of a 10 kΩ thermistor (40653C). Function must be OHM or OHMF.
FTHRM2K	18	Result = temperature (Fahrenheit) of a 2 kΩ thermistor (40653A). Function must be OHM or OHMF.
FTHRM10K	19	Result = temperature (Fahrenheit) of a 10 kΩ thermistor (40653C). Function must be OHM or OHMF.
CRTD85	20	Result = temperature (Celsius) of 100 Ω RTD with alpha of 0.00385 (40654A or 406548). Function must be OHM or OHMF.
CRTD92	21	Result = temperature (Celsius) of 100 Ω RTD with alpha of 0.003916. Function must be OHM or OHMF.
FRTD85	22	Result = temperature (Fahrenheit) of 100 Ω RTD with alpha of 0.00385 (40654A or 406548). Function must be OHM or OHMF.
FRTD92	23	Result = temperature (Fahrenheit) of 100 Ω RTD with alpha of 0.003916. Function must be OHM or OHMF.

Power-on *operation_a,operation_b* = OFF,OFF.
Default *operation_a,operation_b* = OFF,OFF.

Power-on *register* values = all registers are set to 0 with the following exceptions:

DEGREE = 20	REF = 1
SCALE = 1	RES = 50
PERC = 1	

Remarks

- The FILTER, RMS, STAT, or PFAIL math operations are performed on all subsequent readings. However, whenever the multimeter's configuration is changed, the previous math results are erased and the operation starts over on the new readings. All other math operations stay enabled until you set MATH OFF, execute the MATH command specifying other math operation(s), or enable post-process math operation(s) (except MMATH PFAIL or MMATH STAT as described under the MMATH command).
- When two real-time math operations are enabled, *operation_a* is performed on the reading first. Next, *operation_b* is performed on the result of the first operation.
- When a real-time math operation is enabled, the display's half digit becomes a full digit. For example, if you are making 4.5 digit AC voltage measurements and then enable the SCALE math operation, the display is capable of showing 5 full digits.
- Math registers may be written to with the SMATH command. Math registers may be read with the RMATH command.
- **Query command**: The MATH? query command returns two responses, separated by a comma, which indicate the enabled real-time math function(s). Refer to Query commands near the front of this chapter for more information.
- **Related commands**: MMATH, RMATH, SMATH

Example

The following program performs the real-time NULL math operation on 20 readings. After executing the NULL command, the first reading is triggered by line 50. The value in the OFFSET register is then changed to 3.05. The 20 readings are triggered by line 90 and 3.05 is subtracted from each reading.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
```

```
20 DIM Rdgs(20) !DIMENSION ARRAY FOR 20 READINGS
30 OUTPUT 722;"PRESET NORM" !PRESET, NRDGS 1,AUTO, DCV 10
40 OUTPUT 722;"MATH NULL" !ENABLE REAL-TIME NULL MATH OPERATION
50 OUTPUT 722;"TRIG SGL" !TRIGGER 1 READING, STORED IN OFFSET
60 OUTPUT 722;"SMATH OFFSET,3.05" !WRITE 3.05 TO OFFSET REGISTER
70 OUTPUT 722;"NRDGS 20" !20 READINGS PER TRIGGER
80 OUTPUT 722;"TRIG SYN" !SYN TRIGGER EVENT
90 ENTER 722;Rdgs(*) !SYN EVENT, ENTER NULL CORRECTED READINGS
100 PRINT Rdgs(*) !PRINT NULL CORRECTED READINGS
110 END
```

MCOUNT?

Memory count query. Returns the total number of stored readings.

Syntax

MCOUNT?

Remarks

- **Related commands**: MEM, MFORMAT, MSIZE, RMEM

Example

```
10 OUTPUT 722; "MCOUNT?" !RETURNS TOTAL NUMBER OF STORED READINGS
20 ENTER 722;A !ENTERS RESPONSE INTO A VARIABLE
30 PRINT A !PRINTS RESPONSE
40 END
```

MEM

Memory. Enables or disables reading memory and designates the storage mode.

Syntax

MEM [*mode*]

mode

The *mode* parameter choices are:

mode parameter	Numeric query equiv.	Description
OFF	0	Stops storing readings (stored readings stay intact)
LIFO	1	Clears reading memory and stores new readings LIFO (last-in-first-out)
FIFO	2	Clears reading memory and stores new readings FIFO (first-in-first-out)
CONT	3	Keeps memory intact and selects previous mode (if there was no previous mode, FIFO is selected)

Power-on *mode* = OFF.
Default *mode* = ON.

Remarks

- In the high-speed mode, when reading memory is enabled in the FIFO mode and becomes full, the trigger arm event becomes HOLD which stops readings and removes the multimeter from the high-speed mode. After removing some or all of the readings from memory, you can resume measurements by changing the trigger arm event (TARM command). When not in the high-speed mode, when you fill memory in the FIFO mode, the stored readings remain intact and new readings are not stored. In the LIFO mode, when reading memory becomes full, the oldest readings are replaced with the newest readings regardless of whether in the high-speed mode or not.
- When the controller requests data from the multimeter and its output buffer is empty in the LIFO or FIFO mode, a reading is removed from memory and sent to the controller. This is the “implied read” method of recalling readings. In the LIFO mode, the most recent reading is returned. In the FIFO mode, the oldest reading is returned. The reading storage mode (LIFO or FIFO) is important only when you are using the “implied read” method of recalling readings. The reading storage mode has no effect on readings recalled using the RMEM command.

- Use the MFORMAT command to specify the memory format (SINT, DINT, ASCII, SREAL, or DREAL).
- Executing the RMEM command sets reading memory to OFF. You must execute MEM CONT, MEM FIFO, or MEM LIFO to re-enable reading memory after executing RMEM.
- **Query command**: The MEM? query command returns the present memory mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: MCOUNT?, MFORMAT, MSIZE, RMEM

Example

```
OUTPUT 722;"MEM FIFO" !ENABLES READING MEMORY, FIFO MODE
```

MENU

The MENU command selects the SHORT or FULL list of commands in the front panel's alphabetic command menu.

Syntax

MENU [*mode*]

mode

The *mode* parameter choices are:

mode parameter	Numeric query equiv.	Description
SHORT	0	Selects the short command menu
FULL	1	Selects the full command menu

Power-on *mode* = mode selected when power was removed.
Default *mode* = FULL

Remarks

- To access the alphabetic command menu, press any of the shifted MENU keys labeled C, E, L, N, R, S, and T. You can then locate a particular command using the up and down arrow keys.
- The *mode* parameter is stored in continuous memory (not lost when power is removed).
- The FULL menu contains all commands except query commands that can be made by accessing a command and appending a question mark (e.g., BEEP, BEEP?). The SHORT menu eliminates the GPIB bus-related commands and any commands that have dedicated front panel keys (e.g., RSTATE command, **Recall State** key).
- **Query command**: The MENU? query command returns a response indicating the present menu mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: DEFKEY, LOCK

Example

```
OUTPUT 722;"MENU SHORT" !SELECTS SHORT MENU
```

MFORMAT

Memory format. Clears reading memory and designates the storage format for new readings.

Syntax

MFORMAT [*format*]

format

The *format* parameter choices are:

format parameter	Numeric query equiv.	Description
ASCII	1	ASCII-16 bytes per reading[a]
SINT	2	Single Integer-16 bits 2's complement (2 bytes per reading)

format parameter	Numeric query equiv.	Description
DINT	3	Double Integer-32 bits 2's complement (4 bytes per reading)
SREAL	4	Single Real-(IEEE-754) 32 bits (4 bytes per reading)
DREAL	5	Double Real-(IEEE-754) 64 bits (8 bytes per reading)

[a] The ASCII format is actually 15 bytes for the reading plus 1 byte for a null character which is used to separate stored ASCII readings only.

Power-on *format* = SREAL.
Default *format* = SREAL.

Remarks

- The multimeter indicates an overload by storing the value ±1E+38 in memory instead of the reading. When overload values are recalled to the display, the value ±1E+38 is displayed. When overload values are transferred from reading memory to the GPIB output buffer, they are converted to the overload number for the specified output format. (See the OFORMAT command for details.)
- When using the SINT or DINT memory format, the multimeter stores each reading assuming a certain scale factor. This scale factor is based on the present measurement function, range, A/D setting, and enabled math operations. When you recall a reading, the multimeter calculates the scale factor based on the present measurement function, range, A/D setting, and enabled math operations. It then multiplies the scale factor by the stored reading and sends the result (recalled reading) to the display or the output buffer. Therefore, always ensure that the multimeter's configuration is the same when storing and recalling data in the SINT or DINT format.
- You should not use the SINT or DINT output or memory format for frequency or period measurements when a real-time or post-process math function is enabled (except STAT or PFAIL) or when autorange is enabled.
- The memory format does not affect the output format specified by the OFORMAT command.
- You enable reading memory using the MEM command. You access stored readings using the RMEM command or by using the “implied read.” The “implied read” is discussed under Using Reading Memory in Chapter 4.

- When using reading memory for sub-sampled measurements (SSAC or SSDC command), the memory format must be set to SINT, the memory mode must be FIFO (MEM FIFO command), and reading memory must be empty (done by executing the MEM FIFO command) before samples are taken. If these requirements are not met when the trigger arm event occurs, an error is generated.
- **Query command**: The MFORMAT? query command returns the present memory format. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: MCOUNT?, MEM, MSIZE, RMEM

Example

```
10 OUTPUT 722;"NPLC 10" !10 PLCS OF INTEGRATION TIME
20 OUTPUT 722;"DCV 7" !DC VOLTAGE, 10 V RANGE
30 OUTPUT 722;"MATH OFF" !SHUTS OFF MATH FUNCTIONS
40 OUTPUT 722;"MEM FIFO" !ENABLES READING MEMORY (FIFO MODE)
50 OUTPUT 722;"MFORMAT DINT" !SELECTS DINT MEMORY FORMAT
60 END
```

When recalling the stored data, make sure that the multimeter is configured as it was when you stored the data.

MMATH

Memory math. Enables or disables post-process math operations.

Syntax

MMATH [*operation_a*] [,*operation_b*]

operation

The operation parameter choices are:

operation parameter	Numeric Equiv.	Description
OFF	0	Disables all post-process math operations
CONT	1	Enables the previous math operation. To resume two math operations, send MMATH CONT,CONT
CTHRM	3	Result = temperature (Celsius) of a 5 kΩ thermistor (40653B). Function must be OHM or OHMF (10 kΩ range or higher).
DB	4	Result = 20 x $\log_{10}$ (reading/REF register). The REF register is initialized to 1, yielding dBV.
DBM	5	Result = 10 x $\log_{10}$ (reading^2/RES register/1 mW). Function must be ACV, DCV, or ACDCV.
FILTER	6	Result = output of exponentially weighted digital low-pass filter. Response is set by DEGREE register.
FTHRM	8	Result = temperature (Fahrenheit) of a 5 kΩ thermistor (40653B). Function must be OHM or OHMF (10 kΩ) range or higher).
NULL	9	Result = reading-OFFSET register. The OFFSET register is set to first reading–after that you can change it.
PERC	10	Result = ((reading - PERC register) / PERC register) x 100.
PFAIL	11	Reading vs. MAX and MIN registers.
RMS	12	Result = squares reading, applies FILTER operation, takes square root.
SCALE	13	Result = (reading-OFFSET register) / SCALE register.
STAT	14	Performs statistical calculations on the present set of readings and stores results in these registers: SDEV = standard deviation MEAN = average of readings NSAMP = number of readings UPPER = largest reading LOWER = smallest reading
CTHRM2K	16	Result = temperature (Celsius) of a 2 kΩ thermistor (40653A). Function must be OHM or OHMF.
CTHRM10K	17	Result = temperature (Celsius) of a 10 kΩ thermistor (40653C). Function must be OHM or OHMF.

operation parameter	Numeric Equiv.	Description
FTHRM2K	18	Result = temperature (Fahrenheit) of a 2 kΩ thermistor (40653A). Function must be OHM or OHMF.
FTHRM10K	19	Result = temperature (Fahrenheit) of a 10 kΩ thermistor (40653C). Function must be OHM or OHMF.
CRTD85	20	Result = temperature (Celsius) of 100 Ω RTD with alpha of 0.00385 (40654A or 40654B). Function must be OHM or OHMF.
CRTD92	21	Result = temperature (Celsius) of 100 Ω RTD with alpha of 0.003916. Function must be OHM or OHMF.
FRTD85	22	Result = temperature (Fahrenheit) of 100 Ω RTD with alpha of 0.00385 (40654A or 40654B). Function must be OHM or OHMF.
FRTD92	23	Result = temperature (Fahrenheit) of 100 Ω RTD with alpha of 0.003916. Function must be OHM or OHMF.

Power-on *operation_a,operation_b* = OFF,OFF.
Default *operation_a,operation_b* = OFF,OFF.

Power-on *register* values = a11 registers are set to 0 with the following exceptions:

DEGREE = 20	REF = 1
SCALE = 1	RES = 50
PERC = 1	

Remarks

– Any enabled post-process math operations except STAT and PFAIL are performed on each reading as it is removed or copied from reading memory to the display or the GPIB output buffer. (The readings in memory are not altered by any post-process math operation.) The STAT or PFAIL post-process math operations are performed using the readings in memory immediately after executing the MMATH command. (The STAT and PFAIL operations are not updated for any additional readings placed in memory after executing the MMATH command.)

- For the STAT operation, results are stored in the SDEV, MEAN, NSAMP,UPPER, and LOWER math registers (refer to the RMATH command for information on these registers).
- For the PFAIL operation, whenever an out of limit reading is detected, bit number 1 in the status register is set (this sets the GPIB SRQ fine if enabled by the RQS command) and the display shows the FAILED LOW or FAILED HIGH message.
- An enabled post-process math operation remains enabled until you set MMATH OFF, enable a real-time math operation (MATH command), or execute the MMATH command specifying another math operation (except as described in the following remark).
- When MMATH is executed from the front panel, the result goes to the display only. When MMATH is executed from remote, the result goes to the output buffer only.
- When two post-process math operations are enabled, *operation_a* is performed on the reading first. Next, *operation_b* is performed on the result of the first operation.
- When a post-process math operation is enabled, the display's half digit becomes a full digit. For example, if you are making 4.5 digit AC voltage measurements and then enable the SCALE operation, the display is capable of showing 5 full digits.
- Math registers may be written to with the SMATH command. Math registers may be read with the RMATH command.
- **Query command**: The MMATH? query command returns two responses (separated by a comma) which indicate the currently enabled post-process math functions.
- When you use the RMEM command to recall readings, it turns off reading memory. This means any new readings will not be placed in reading memory and cannot have an enabled memory math operation performed on them. When you use the “implied read” method to recall readings, reading memory is not turned-off.
- **Related commands**: MATH, MEM, RMATH, RMEM, SMATH

Example

The following program performs the post-process NULL operation on 20 readings. After executing the MMATH NULL command, 21 readings are taken and stored in reading memory in FIFO mode. Line 80 recalls the first reading taken which is stored in the OFFSET register. The value in the OFFSET register is then changed to 3.05. The remaining 20 readings in memory are recalled and the NULL operation is performed on each.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(20) !DIMENSION ARRAY FOR 20 READINGS
30 OUTPUT 722; "PRESET NORM" !PRESET, NRDGS 1,AUTO, DCV 10
40 OUTPUT 722;"MEM FIFO" !ENABLE READING MEMORY, FIFO MODE
50 OUTPUT 722;"MMATH NULL" !ENABLE POST-PROCESS NULL OPERATION
60 OUTPUT 722;"NRDGS 21" !21 READINGS PER TRIGGER
70 OUTPUT 722;"TRIG SGL" !TRIGGER READINGS
80 ENTER 722;A !RECALL FIRST READING USING IMPLIED READ
90 OUTPUT 722; "SMATH OFFSET, 3.05" !WRITE 3.05 TO OFFSET REGISTER
100 ENTER 722;Rdgs(*) !RECALL READINGS USING IMPLIED READ,
105 !PERFORM NULL OPERATION ON EACH
110 PRINT Rdgs(*) !PRINT NULL MODIFIED READINGS
120 END
```

MSIZE

Memory size. On a previous multimeter, the MSIZE command was used to clear all memory and allocate memory space for readings, subprograms, and state storage. The 3458A accepts the MSIZE command to maintain language compatibility, but performs no action since the 3458A's memory allocations are predefined and cannot be changed. The MSIZE? query command, however, is useful to determine the total reading memory and the largest unused block of subprogram/state memory.

Syntax

MSIZE [*reading_memory*][,*subprogam_memory*]

Remarks

- As subprogram/state memory is used, it eventually becomes fragmented into many small blocks. The MSIZE? command returns the total number of bytes of reading memory and the number of bytes of the largest unused block of subprogram/state memory. The SCRATCH command clears all subprograms and states from memory returning these memory areas to one contiguous block. Also, when power is cycled, the multimeter combines fragmented blocks of memory wherever possible.
- **Query command**: The MSIZE? query command returns two responses separated by a comma. The first response is the total number of bytes of reading memory. The second response is the largest block (in bytes) of unused subprogram/state memory.
- **Related commands**: MCOUNT?, MEM, MFORMAT, RMEM, DELSUB, SCRATCH, SUB, SUBEND, SSTATE

Example

```
10 OUTPUT 722; "MSIZE?" !QUERY MEMORY SIZES
20 ENTER 722;A,B !ENTER RESPONSES
30 PRINT A,B !PRINT RESPONSES
40 END
```

NDIG

Number of digits. Designates the number of digits to be displayed by the multimeter.

Syntax

NDIG [*value*]

value

The *value* parameter can be an integer from 3 to 8 (there is an implied ½ digit; that is, when you specify NDIG 3, the multimeter displays 3½ digits.)

Power-on *value* = 7 (7½ digits).
Default *value* = 7 (7½ digits).

Remarks

- The NDIG command sets the maximum number of digits displayed. It does not affect the A/D converter's resolution or readings sent to memory or the GPIB bus. The multimeter cannot display more digits than are resolved by the A/D converter.
- **Query command**: The NDIG? query command returns the currently specified number of digits. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: DISP

Example

```
10 OUTPUT 722; "RESET" !RETURN TO POWER-ON STATE
20 OUTPUT 722;"NDIG 8" !DISPLAY 8 1/2 DIGITS
30 END
```

NPLC

Number of power line cycles. Specifies the A/D converter's integration time in terms of power line cycles. Integration time is the time during which the A/D converter measures the input signal.

Syntax

NPLC [*power_line_cycles*]

power_line_cycles

The primary use of the NPLC command is to establish normal mode noise rejection (NMR) at the A/D converter's reference frequency (LFREQ command). Any value ≥1 for the *power_line_cycles* parameter provides at least 60 dB of NMR at the power line frequency. Any value <1 provides no NMR; it only sets the integration time for the A/D converter. The ranges and the incremental step sizes for the *power_line_cycles* parameter are:

```
0 - 1 PLC in .000006 PLC steps for 60 Hz reference frequency (LFREQ
command)
```

or

```
0 - 1 PLC in .000005 PLC steps for 50 Hz reference frequency
```

```
1 - 10 PLC in 1 PLC steps
10 - 1000 PLC in 10 PLC steps.
```

Power-on *power_line_cycles* = 10
Default *power_line_cycles* = 0 (selects minimum integration time of 500 ns)

The relationship of the integration time (expressed in PLCs), the A/D converter's reference frequency (LFREQ command), and the digits of resolution is:

Digits of resolution			Power line cycles (NPLC command)	
DCV	DCI, OHM(F)	ACI, ACDCI, ACV[a], ACDCV[a]	Reference frequency (LFREQ) = 60 Hz	Reference frequency (LFREQ) = 50 Hz
4.5	4.5	4.5	0 - .000030	0 - .000025
5.5	5.5	5.5	.000036 - .000360	.000030 - .000300
6.5	6.5	6.5	.000366 - .030000	.000305 - .025000
7.5	7.5[b]	6.5	.030006 - 1	.025005 - 1
8.5[b]	7.5[b]	6.5	2 - 1000	2 - 1000

[a] Analog measurement method only (SETACV ANA command)

[b] For all ranges except the 10 Ω OHM(F) range and the 100 mV DCV range. The 10 Ω OHM(F) range has a maximum of 6.5 digits and the 100 mV DCV range has a maximum of 7.5 range.

Remarks

- For the ACV and ACDCV (SETACV ANA method only), ACT, ACDCI, DCI, DCV, OHM, and OHMF measurement functions, resolution is determined by the A/D converter's integration time. The integration time has no effect on FREQ or PER. For sampled ACV or ACDCV (SETACV SYNC or SETACV RNDM), the integration time is selected automatically and the specified resolution is achieved by varying the number of samples taken. For direct- or sub-sampled digitizing, the integration time is fixed and cannot be changed.
- Since the NPLC and APER commands both set the integration time, executing either will cancel the integration time previously established by the other. The RES command or the *%_resolution* parameter of a function command or the RANGE command can also be used to indirectly select an integration time. An

interaction occurs between NPLC (or APER) when you specify resolution as follows:

- If you send the NPLC (or APER) command *before* specifying resolution, the multimeter satisfies the command that specifies greater resolution (more integration time).
- If you send the NPLC (or APER) command *after* specifying resolution, the multimeter uses the integration time specified by the NPLC (or APER) command, and any previously specified resolution is ignored.
- The more common approach is the first of the two shown above; i.e., the NPLC command is executed first to establish normal mode noise rejection (NMR), then *%_resolution* is specified with a function or RANGE command. This ensures you will have NMR and at least the required resolution.
- **Query command**: The NPLC? query command returns the integration time (in units of PLCs) used by the A/D converter. Since the integration time can be set by the APER, NPLC, or RES command, or the *%_resolution* parameter of a function command or the RANGE command, it is possible for the NPLC? command to return a different number of PLCs than was last specified by the NPLC command.
- **Related commands**: APER, FUNC, LFREQ, RES

Examples

In the following program, line 10 sets the number of PLCs to minimum and allows *%_resolution* in line 20 to control the resolution. The resolution specified by line 20 is 100 µV.

```
10 OUTPUT 722;"NPLC 0" !SETS PLCS TO MINIMUM
20 OUTPUT 722;"DCV 6,.00167" !DC VOLTS, 6 V MAX, 100 µV RESOLUTION
30 END
```

In the following program, line 10 sets the number of PLCs to 1000. This corresponds to maximum resolution and prevents *%_resolution* in line 20 from affecting the measurement. The requested resolution from line 20 is 10 mΩ. However, because of line 10, the actual resolution is 100 µΩ.

```
10 OUTPUT 722;"NPLC 1000" !SETS PLCS TO MAXIMUM
20 OUTPUT 722;"OHM 1E3,.001" !SELECTS 2-WIRE OHMS, 1 kΩ MAX INPUT
30 END
```

NRDGS

Number of readings. Designates the number of readings taken per trigger and the event (sample event) that initiates each reading.

Syntax

NRDGS [*count*][,*event*]

count

Designates the number of readings per trigger event. The valid range for this parameter is 1 to 16777215. (The *count* parameter also corresponds to the record parameter in the RMEM command. Refer to the RMEM command for details.)

Power-on *count* = 1.
Default *count* = 1.

event

Designates the event that initiates each reading (sample event). The *event* parameter choices are:

event parameter	Numeric query equiv.	Description
AUTO	1	Initiates reading whenever the multimeter is not busy
EXTSYN	2	Initiates reading on negative edge transition on the multimeter's external trigger input connector
SYN	5	Initiates reading when the multimeter's output buffer is empty, reading memory is off or empty, and the controller requests data.
TIMER[a]	6	Similar to AUTO with a time interval between successive readings (specify interval with the TIMER command)
LEVEL[b]	7	Initiates reading when the input signal reaches the voltage specified by the LEVEL command on the slope specified by the SLOPE command.
LINE[a]	8	Initiates reading on a zero crossing of the AC line voltage

[a] The TIMER or LINE event cannot be used for sampled AC or AC+DC voltage measurements (SETACV RNDM or SYNC) or for frequency or period measurements.

[b] The LEVEL sample event can be used only for DC voltage and direct-sampled measurements.

Power-on *event* = AUTO.
Default *event* = AUTO.

Remarks

- Since the TIMER event designates an interval between readings, it only applies when *count* is greater than one. The first reading occurs without the TIMER interval. However, you can insert a time interval before the first reading with the DELAY command. (The TIMER event suspends autoranging.)
- You can use the SWEEP command to replace the two commands: NRDGS *n*,TIMER and TIMER *n*. The SWEEP command specifies the number of readings and the interval between readings. These commands are interchangeable; the multimeter uses whichever command was executed last in the programming. Executing the SWEEP command automatically sets the sample event to TIMER. In the power-on, RESET, and PRESET states, the multimeter uses the NRDGS command.
- When SYN is used for more than one of the trigger arm, trigger, or sample events, a single occurrence of the SYN event satisfies all of the specified SYN event requirements. This is shown in the second “SYN event” example below.
- **Query command**: The NRDGS? query command returns two responses separated by a comma. The first response is the specified number of readings per trigger. The second response is the present sample event. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: DELAY, LEVEL, RMEM, SLOPE, TARM, TIMER, TRIG, SWEEP

Examples

SYN event

In the following program, line 70 requests data from the multimeter. This satisfies the SYN event and initiates a reading. The reading is then sent to the controller and printed. The process repeats until the three readings have been taken and printed.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM A(3) !DIMENSION ARRAY
30 OUTPUT 722;"DCV 8,.00125" !DC VOLTAGE, 10 V RANGE, 100 µV RESOLUTION
40 OUTPUT 722;"NRDGS 3, SYN" !3 READINGS/TRIGGER, SYN SAMPLE EVENT
```

```
50 OUTPUT 722;"TRIG AUTO" !AUTO TRIGGER MODE
60 ENTER 722;A(*) !ENTER READINGS
70 PRINT A(*) !PRINT READINGS
80 END
```

In the following example, SYN is specified for the trigger arm, trigger, and sample events. Five readings per trigger are specified. A single occurrence of the SYN event (line 60) satisfies the trigger arm, trigger, and the first sample event and initiates the first reading. Four more SYN events (one for each reading) are then required to initiate the remaining four readings.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(5) !DIMENSION ARRAY FOR READINGS
30 OUTPUT 722;"PRESET NORM" !SYN TRIGGER EVENT, DCV, NPLC 1, MEM OFF
40 OUTPUT 722;"TARM SYN" !SYN TRIGGER ARM EVENT
50 OUTPUT 722;"NRDGS 5, SYN" !5 READINGS/TRIGGER, SYN SAMPLE EVENT
60 ENTER 722;Rdgs(*) !SYN EVENT, ENTER READINGS
70 PRINT Rdgs(*) !PRINT READINGS
80 END
```

TIMER

The following program makes 4 readings in response to the synchronous trigger (line 60). The first reading is made immediately after the preprogrammed default delay; the remaining 3 have a 200 ms interval between them.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM Rdgs(4) !DIMENSION ARRAY FOR READINGS
30 OUTPUT 722;"PRESET NORM" !TARM AUTO,TRIG SYN,DCV AUTORANGE
40 OUTPUT 722;"TIMER 200E-3" !SETS TIMER INTERVAL TO 200 m SECONDS
50 OUTPUT 722;"NRDGS 4,TIMER" !SELECTS 4 READINGS/TRIGGER & TIMER
60 ENTER 722;Rdgs(*) !TRIGGER AND ENTER READINGS
70 PRINT Rdgs(*) !PRINT READINGS
80 END
```

OCOMP

The OCOMP command enables or disables the offset compensated ohms function.

Syntax

OCOMP [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Offset compensated ohms disabled.
ON	1	Offset compensated ohms enabled.

Power-on *control* = OFF.
Default *control* = ON.

Remarks

- With offset compensation enabled, the multimeter measures the external offset voltage (with the ohms current source shut off) before each resistance reading and subtracts the offset from the following reading. This prevents the offset voltage from affecting the resistance reading, but it doubles the time required per reading.
- You can use offset compensated ohms on both 2-wire and 4-wire resistance measurements. When you have offset compensation enabled and change from ohms to some other measurement function (DCV, ACV, etc.), offset compensation is temporarily disabled. When you return to 2-wire or 4-wire ohms, however, offset compensation is once again enabled.
- The multimeter can only perform offset compensation on the 10 Ω through 100 kΩ ranges. If OCOMP is enabled when using the 1 MΩ through 1 GΩ ranges, readings are made without offset compensation.

- **Query command**: The OCOMP? query command returns the present offset compensation mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: OHM, OHMF

Example

```
OUTPUT 722;"OCOMP ON" !ENABLES OFFSET COMPENSATION
```

OFORMAT

Output format. Designates the GPIB output format for readings sent directly to the controller or transferred from reading memory to the controller.

Syntax

OFORMAT [*format*]

format

The *format* parameter choices are:

format parameter	Numeric query equiv.	Descriptions
ASCII	1	ASCII-15 bytes per reading (see 1st and 2nd Remarks below)
SINT	2	Single Integer-16 bits 2's complement (2 bytes per reading)
DINT	3	Double Integer-32 bits 2's complement (4 bytes per reading)
SREAL	4	Single Real-(IEEE-754) 32 bits, (4 bytes per reading)
DREAL	5	Double Real-(IEEE-754) 64 bits, (8 bytes per reading)

Power-on *format* = ASCII.
Default *format* = ASCII.

Remarks

- The ASCII output format sends the *cr lf* (carriage return, line feed) to indicate the end of the transmission to most computers. The SINT, DINT, SREAL, and DREAL output formats, however, do not send *cr lf*. With any format, you can

use the END command to indicate the end of the transmission using the GPIB EOI function. Refer to the END command for more information.

- When using the ASCII format, 2 additional bytes are required for the carriage-return, line-feed (*cr,lf*) end of line sequence. The *cr,lf* is used only for the ASCII format and normally follows each reading output in ASCII format. However, when using the ASCII output format and multiple readings are recalled from reading memory using the RMEM command, the multimeter places a comma between readings (comma = 1 byte). In this case, the *cr,lf* occurs only once, following the last reading in the group being recalled. Commas are not used when readings are output directly to the bus (reading memory disabled), when readings are recalled using "implied read," or when using any other output format.
- The multimeter indicates an overload condition (input greater than the present range can measure) by outputting the largest number possible for the particular output format as follows.

  ```
  SINT format: +32767 or -32768 (unscaled)

  DINT format: +2.147483647E+9 or -2.147483648E+9 (unscaled)

  ASCII, SREAL, DREAL: +/-1.OE+38
  ```

- When reading memory is disabled, executing the SSAC or SSDC command (sub-sampling) automatically sets the output format to SINT regardless of the previously specified format. You must use the SINT output format when sub-sampling and not using reading memory.
- The output format applies only to readings transferred over the GPIB bus. Responses to query commands are always output in ASCII format regardless of the specified output format. Following the query response, the output format returns to the specified type. The output format does not affect the memory format specified by the MFORMAT command.
- When using the SINT or DINT output formats, the multimeter applies a scale factor to each reading. This scale factor is based on the present measurement function, range, A/D setting, and enabled math operations. Therefore, ensure that the multimeter's configuration is the same when retrieving the scale factor (ISCALE? command) as it was when the readings were made.
- You should not use the SINT or DINT output or memory format for frequency or period measurements when a real-time or post-process math function is enabled (except STAT or PFAIL) or when autorange is enabled.

- **Query command**: The OFORMAT? query command returns the present output format mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: END, ISCALE?, MFORMAT, QFORMAT

Examples

SINT format

The following program outputs 10 readings in SINT format, retrieves the scale factor, and multiplies the scale factor times each reading.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_readings !DECLARE VARIABLE
30 INTEGER Int_rdgs (1:10) BUFFER!CREATE INTEGER BUFFER ARRAY
40 REAL Rdgs(1:10) !CREATE REAL ARRAY
50 Num_readings=10 !NUMBER OF READINGS = 10
60 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
70 ASSIGN @Int_rdgs TO BUFFER Int_rdgs(*) !ASSIGN BUFFER I/O PATH NAME
80 OUTPUT @Dvm;"PRESET NORM;OFORMAT SINT;NPLC 0;NRDGS ";Num_readings
85 !TARM AUTO, TRIG SYN, SINT OUTPUT FORMAT, MIN. INTEGRATION TIME
90 TRANSFER @Dvm TO @Int_rdgs;WAIT !SYN EVENT, TRANSFER READINGS INTO
91 !INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
95 !SINT, NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
100 OUTPUT @Dvm;"ISCALE?" !QUERY SCALE FACTOR FOR SINT FORMAT
110 ENTER @Dvm;S !ENTER SCALE FACTOR
120 FOR I=1 TO Num_readings
130 Rdgs(I)=Int_rdgs(I) !CONVERT EACH INTEGER READING TO REAL
135 !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
140 R=ABS(Rdgs(I)) !USE ABSOLUTE VALUE TO CHECK FOR OVLD
150 IF R>=32767 THEN PRINT "OVLD" !IF OVLD, PRINT OVERLOAD MESSAGE
160 Rdgs(I)=Rdgs(I)*S !MULTIPLY READING TIMES SCALE FACTOR
170 Rdgs(I)=DROUND(Rdgs(I),4) !ROUND TO 4 DIGITS
```

```
180 NEXT I
190 END
```

DINT format

The following program is similar to the preceding program except that it takes 50 readings and transfers them to the computer using the DINT format.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_readings,I,J,K !DECLARE VARIABLES
30 Num_readings=50 !NUMBER OF READINGS = 50
40 ALLOCATE REAL Rdgs(1:Num_readings) !CREATE ARRAY FOR READINGS
50 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
60 ASSIGN dBuffer TO BUFFER[4*Num_readings] !ASSIGN BUFFER I/O PATH NAME
70 OUTPUT @Dvm;"PRESET NORM;RANGE 10;OFORMAT DINT;NRDGS";Num_readings
75 !TARM AUTO, TRIG SYN, DCV 10 V RANGE, DINT OUTPUT FORMAT, NRDGS
50,AUTO
80 TRANSFER @Dvm TO @Buffer;WAIT !SYN EVENT,TRANSFER READINGS
90 OUTPUT @Dvm; "ISCALE?" !QUERY SCALE FOR DINT
100 ENTER @Dvm; S !ENTER SCALE FACTOR
110 FOR I=1 TO Num_readings
120 ENTER @Buffer USING "#,W,W";J,K !ENTER ONE 16-BIT 2'S COMPLEMENT
121 !WORD INTO EACH VARIABLE J AND K (# = STATEMENT TERMINATION NOT
125 !REQUIRED; W= ENTER DATA AS 16-BIT 2'S COMPLEMENT INTEGER)
130 Rdgs(I)=(J*65536.+K+65536.*(K<0)) !CONVERT TO REAL NUMBER
140 R=ABS(Rdgs(I)) !USE ABSOLUTE VALUE TO CHECK FOR OVLD
150 IF R>2147483647 THEN PRINT "OVLD" !IF OVERLOAD OCCURRED, PRINT
MESSAGE
160 Rdgs(I)=Rdgs(I)*S !APPLY SCALE FACTOR
170 Rdgs(I)=DROUND(Rdgs(I),8) !ROUND CONVERTED READING
180 PRINT Rdgs(I) !PRINT READINGS
190 NEXT I
200 END
```

SREAL format

The following program shows how to convert 10 readings output in the SREAL format.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_readings !DECLARE VARIABLE
30 Num_readings=10 !NUMBER OF READINGS = 10
40 ALLOCATE REAL Rdgs(1:Num_readings) !CREATE ARRAY FOR READINGS
50 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
60 ASSIGN @Buffer TO BUFFER [4*Num_readings] !ASSIGN BUFFER I/O PATH
NAME
70 OUTPUT @Dvm;"PRESET NORM;OFORMAT SREAL;NRDGS";Num_readings
75 !TRIG SYN, SREAL OUTPUT FORMAT, 1 PLC, DCV AUTORANGE, 10 READINGS
80 TRANSFER @Dvm TO @Buffer;WAIT !SYN EVENT; TRANSFER READINGS
90 FOR I=1 TO Num_readings
100 ENTER @Buffer USING "#,B";A,B,C,D !ENTER ONE 8-BIT BYTE INTO
101 !EACH VARIABLE, (# =STATEMENT TERMINATION NOT REQUIRED, B = ENTER
ONE
105 !8-BIT BYTE AND INTERPRET AS AN INTEGER BETWEEN 0 AND 255)
110 S=1 !CONVERT READING FROM SREAL
120 IF A>127 THEN S=-1 !CONVERT READING FROM SREAL
130 IF A>127 THEN A=A-128 !CONVERT READING FROM SREAL
140 A=A*2- 127 !CONVERT READING FROM SREAL
150 IF B>127 THEN A=A+1 !CONVERT READING FROM SREAL
160 IF B<=127 THEN B=B+128 !CONVERT READING FROM SREAL
170 Rdgs(I)=S*(B*65536.+C*256.+D)*2^(A-23) !CONVERT READING FROM SREAL
180 Rdgs(I)=DROUND(Rdgs(I),7) !ROUND READING TO 7 DIGITS; YOU
181 !MUST DO THIS WITH SREAL TO ENSURE ANY OVLD VALUES ARE ROUNDED TO
185 !1.E+38 (WITHOUT ROUNDING, THE VALUE MAY BE SLIGHTLY LESS)
190 IF ABS(Rdgs(I)=1.E+38 THEN !IF OVERLOAD OCCURRED:
200 PRINT "Overload Occurred" !PRINT OVERLOAD MESSAGE
210 ELSE !IF NO OVERLOAD OCCURRED:
```

```
220 PRINT Rdgs(I) !PRINT READING
230 END IF
240 NEXT I
250 END
```

DREAL format

The following program uses the DREAL output format. Notice that no conversion is necessary using this format since DREAL is the same format that the controller uses as its internal data format (8-bytes/word).

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 REAL Rdgs(1:10) BUFFER !CREATE BUFFER ARRAY
30 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
40 ASSIGN @Rdgs TO BUFFER Rdgs(*) !ASSIGN BUFFER I/O PATH NAME
50 OUTPUT @Dvm;"PRESET NORM;NPLC 10;OFORMAT DREAL;NRDGS 10"
55 !TRIG SYN, 10 PLCs, DCV AUTORANGE, DREAL OUTPUT FORMAT, 10 RDGS/TRIG.
60 TRANSFER @Dvm TO @Rdgs;WAIT !SYN EVENT, TRANSFER READINGS
70 FOR I=1 TO 10
80 IF ABS(Rdgs(I))=1.E+38 THEN !IF OVERLOAD OCCURRED:
90 PRINT "OVERLOAD OCCURRED" !PRINT OVERLOAD MESSAGE
100 ELSE !IF NO OVERLOAD:
110 Rdgs(I)=DROUND(Rdgs(I),8) !ROUND READINGS
120 PRINT Rdgs(I) !PRINT READINGS
130 END IF
140 NEXT I
150 END
```

The preceding program used the TRANSFER statement to get readings from the multimeter. The following program uses the ENTER statement to transfer readings to the computer using the DREAL format. The ENTER statement is easier to use since no I/O path is necessary but is much slower than the TRANSFER statement. Also when using the ENTER statement, you must use the FORMAT OFF command to instruct the cont]roller to use its internal data structure instead of ASCII.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT
```

```
20 Num_readings=20 !NUMBER OF READINGS = 20
30 ALLOCATE REAL Rdgs(1:Num_readings) !CREATE ARRAY FOR READINGS
40 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
50 OUTPUT @Dvm;"PRESET NORM;OFORMAT DREAL;NPLC 10;NRDGS";Num_readings
55 !TRIG SYN, DCV AUTORANGE, DREAL OUTPUT FORMAT,10 PLC, 20 READINGS/
TRIG
60 ASSIGN @Dvm;FORMAT OFF !USE 8-BYTE/WORD DATA STRUCTURE
70 FOR I=1 TO Num_readings
80 ENTER @Dvm;Rdgs(I) !ENTER EACH READING
90 IF ABS(Rdgs(I))=1.E+38 THEN !IF OVERLOAD OCCURRED:
100 PRINT "OVERLOAD OCCURRED" !PRINT OVERLOAD MESSAGE
110 ELSE !IF NO OVERLOAD OCCURRED
120 Rdgs(I)=DROUND(Rdgs(I),8) !ROUND READINGS TO 8 DIGITS
130 PRINT Rdgs(I) !PRINT READINGS
140 END IF
150 NEXT I
160 END
```

OHM, OHMF

Refer to the FUNC command.

OPT?

Option query. Returns a response indicating the multimeter's installed options. The possible responses are:

```
0 = No installed options
1 = Extended Reading Memory Option
```

Syntax

OPT?

Remarks

– **Related commands**: QFORMAT

Example

```
10 OUTPUT 722;"OPT?" !QUERY INSTALLED OPTIONS
20 ENTER 722;A$ !ENTER RESPONSE
30 PRINT A$ !PRINT RESPONSE
40 END
```

PAUSE

Suspends subprogram execution. The subprogram can be resumed using the CONT command or by executing the GPIB Group Execute Trigger command.

Syntax

PAUSE

Remarks

– The PAUSE command is allowed only within a subprogram.

– Only one subprogram will be preserved in a suspended state. If a subprogram is paused and another is run which also becomes paused, the first will be terminated and the second will remain suspended.

– With the input buffer off (INBUF OFF command), the GPIB bus is normally held by the multimeter until a called subprogram is completely executed. If a PAUSE command is encountered in a subprogram, the GPIB bus is released immediately.

– Nested PAUSE commands are not allowed; that is, when a subprogram is called from another subprogram, the called subprogram cannot contain a PAUSE command.

– **Query command**: The PAUSE? query command returns a response indicating whether a subprogram is currently paused. The possible responses are YES (numeric query equiv. = 1) indicating a subprogram is paused, or NO (numeric query equiv. = 0).

– **Related commands**: CALL, COMPRESS, CONT, DELSUB, TRIGGER (GPIB command), SCRATCH, SUB, SUBEND

Example

```
10 OUTPUT 722;"SUB OHMAC1" !STORES SUBPROGRAM NAMED OHMAC1
20 OUTPUT 722;"PRESET NORM" !SUSPENDS TRIGGERING, PRESET
30 OUTPUT 722;"MEM FIFO" !ENABLES READING MEMORY, FIFO MODE
40 OUTPUT 722;"OHM" !SELECTS 2-WIRE OHMS MEASUREMENTS
50 OUTPUT 722;"NRDGS 5" !SELECTS 5 READINGS PER TRIGGER
60 OUTPUT 722;"TRIG SGL" !GENERATES A SINGLE TRIGGER
70 OUTPUT 722;"PAUSE" !SUSPENDS PROGRAM EXECUTION
80 OUTPUT 722;"ACV" !SELECTS AC VOLTAGE MEASUREMENTS
90 OUTPUT 722;"NRDGS 10" !SELECTS 10 READINGS PER TRIGGER
100 OUTPUT 722;"TRIG SGL" !GENERATES A SINGLE TRIGGER
110 OUTPUT 722;"SUBEND" !SIGNIFIES THE END OF THE SUBPROGRAM
120 END
```

When you call the above subprogram, the multimeter executes the subprogram line by line. Lines 20 through 60 cause the multimeter to make five 2-wire ohms readings and place them in reading memory. When line 70 is encountered, subprogram execution ceases. A subsequent CONT command or Group Execute Trigger resumes program execution. Lines 80 through 100 then cause the multimeter to make 10 AC voltage readings and place them in reading memory. When the subprogram is finished, a total of 15 readings are in memory. To call the above subprogram, send:

```
OUTPUT 722;"CALL OHMAC1"
```

After the five 2-wire ohms readings are complete, connect an AC voltage source to the multimeter. Subprogram execution is resumed by sending the CONT command or by executing (on the controller):

```
TRIGGER 7
```

PER

Period. Instructs the multimeter to measure the period of the input signal. You can specify whether the input signal is AC voltage (default), AC+DC voltage, AC current, or AC+DC current using the FSOURCE command.

Syntax

PER [*max._input*][,*%_resolution*]

max._input

The *max_input* parameter selects a fixed range or the autorange mode. The ranges correspond to the type of input signal specified in the FSOURCE command. That is, if ACV is the specified input signal, the *max._input* parameter specifies an AC voltage measurement range. To select a fixed range, you specify *max._input* as the absolute value (no negative numbers) of the expected peak value of the input signal. The multimeter then selects the proper range. Refer to the FUNC or RANGE command for tables showing the ranges available for each type of input signal.

To select the autorange mode, specify AUTO for *max._input* or default the parameter. In the autorange mode, the multimeter samples the input signal before each period reading and selects the proper range.

Power-on *max._input* = not applicable

Default *max._input* = AUTO

%_resolution

The *%_resolution* parameter specifies the digits of resolution and the gate time as shown below (*%_resolution* also affects the reading rate, refer to the "Appendix A: Specifications" on page 415 for more information).

%_resolution parameter	Selects gate time	Digits of resolution
.00001	1 s	7
.0001	100 ms	7
.001	10 ms	6
.01	1 ms	5
.1	100 µs	4

Power-on *%_resolution* = not applicable.
Default %_resolution = .00001.

Remarks

- The reading rate is the longer of 1 period of the input signal, the gate time, or the default reading time-out of 1.2 seconds.
- Period (and frequency) measurements are made using the level detection circuitry to determine when the input signal crosses a particular voltage on its positive or negative slope. (This is why you cannot use the LEVEL trigger or sample event or the LINE trigger event when making period or frequency measurements.) The power-on or default level triggering values select zero volts, positive slope. You can control the level triggering voltage and coupling using the LEVEL command. You can specify either the positive or negative slope using the SLOPE command.
- The leftmost digit, which is a half digit for most measurement functions, is a full digit (0 - 9) for period measurements.
- Readings made with autorange enabled take longer because the input signal is sampled (to determine the proper range) between readings.
- For period (and frequency) measurements, an overload indication means the voltage or current amplitude is too great for the specified measurement range. It does not mean the applied period (or frequency) is too great to be measured.
- **Related commands**: ACBAND, FREQ, FSOURCE, FUNC, RES

Example

```
10 OUTPUT 722;"FSOURCE ACI" !SELECTS AC CURRENT AS INPUT SOURCE
20 OUTPUT 722;"PER .01" !SELECTS PERIOD MEASUREMENTS, 10 mA RANGE
30 END
```

PRESET

Configures the multimeter to one of three predefined states.

Syntax

PRESET [*type*]

type

Specifies the NORM, FAST, or DIG preset state (the numeric query equivalents of these parameters are 1, 0, and 2, respectively).

Power-on *type* = not applicable.
Default *type* = NORM.

NORM

PRESET NORM is similar to RESET but optimizes the multimeter for remote operation. Executing PRESET NORM executes the following commands:

```
ACBAND 20,2E+6MEM OFF (last memory operation set to FIFO)
AZERO ONMFORMAT SREAL
BEEP ONMMATH OFF
DCV AUTONDIG 6
DELAY -1NPLC 1
DISP ONNRDGS 1,AUTO
FIXEDZ OFF OCOMP OFF
FSOURCE ACVOFORMAT ASCII
INBUF OFFTARM AUTO
LOCK OFFTIMER 1
MATH OFFTRIG SYN
All math registers set to 0 except:
DEGREE = 20
PERC = 1
REF = 1
RES = 50
SCALE = 1
```

FAST

PRESET FAST configures the multimeter for fast readings, fast transfer to memory, and fast transfer from memory to GPIB. (Refer to Increasing the Reading Rate in Chapter 4 for more information on fast measurements.) Executing PRESET FAST executes the commands shown under PRESET NORM with the following exceptions:

```
DCV 10
AZERO OFF
DISP OFF
MFORMAT DINT
OFORMAT DINT
TARM SYN
TRIG AUTO
```

DIG

PRESET DIG configures the multimeter for DCV digitizing (DCV digitizing is discussed in Chapter 5). Executing PRESET DIG executes the commands shown under PRESET NORM with the following exceptions:

```
DCV 10
AZERO OFF
DELAY 0
DISP OFF
TARM HOLD
TRIG LEVEL
LEVEL 0,AC
NRDGS 256,TIMER
TIMER 20E-6
APER 3E-6
MFORMAT SINT
OFORMAT SINT
```

Remarks

- **Related commands**: RESET

Examples

```
OUTPUT 722;"PRESET NORM" !CONFIGURES FOR REMOTE OPERATION
OUTPUT 722;"PRESET FAST" !CONFIGURES FOR FAST READINGS/TRANSFER
OUTPUT 722;"PRESET DIG" !CONFIGURES FOR FAST DCV DIGITIZING
```

PURGE

Purge state. Removes a single stored state from memory.

Syntax

PURGE *name*

name

State name. A state name may contain up to 10 characters. The name can be alpha, alphanumeric, or an integer in the range of 0 to 127. Refer to the SSTATE command for details.

Power-on *name* = none.
Default *name* = none; parameter required.

Remarks

- To delete all stored states, use the SCRATCH command.
- **Related commands**: DELSUB, SCRATCH

Example

```
OUTPUT 722; "PURGE A2"!PURGES STORED STATE A2
```

QFORMAT

Query format. Designates whether query responses contain numeric or alpha characters (whenever possible), and whether command headers are returned.

Syntax

QFORMAT [*type*]

format

The *type* parameter choices are:

type parameter	Numeric query equiv.	Description
NUM	0	Query responses sent to either GPIB or the display are numeric only (whenever possible) with no headers
NORM	1	Query responses sent to the GPIB are numeric only (whenever possible) with no headers; query responses sent to the display contain alpha headers and alpha responses (whenever possible)
ALPHA		Query responses sent to either GPIB or the display contain an alpha header and an alpha response (whenever possible)

Power-on *type* = NORM.
Default *type* = NORM.

- The *numeric query equivalents* for alpha parameters are shown under each applicable command in this chapter. Some query commands such as DEFKEY? will always return alpha characters regardless of the specified QFORMAT. Similarly, some query commands such as NDIG? will always return a numeric response.
- When you execute a query command from the multimeter's front panel, the result goes to the display only. When you execute a query command from the controller, the result goes to the multimeter's output buffer only. Query results are returned in ASCII format, after which the output format returns to the previously specified type (ASCII, SINT, etc.).

- **Query command**: The QFORMAT? query command returns the present query format. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: All query commands, OFORMAT

Examples

NORM

```
10 OUTPUT 722;"QFORMAT NORM"
20 OUTPUT 722;"ARANGE?"
30 ENTER 722;A
40 PRINT A
50 END
```

Typical response: `1`

NUM

```
10 OUTPUT 722;"QFORMAT NUM"
20 OUTPUT 722;"ARANGE?"
30 ENTER 722;A
40 PRINT A
50 END
```

Typical response: `1`

ALPHA

```
10 OUTPUT 722; "QFORMAT ALPHA"
20 OUTPUT 722; "ARANGE?"
30 ENTER 722;A$
40 PRINT A$
50 END
```

Typical response: ARANGE ON

R

R is an abbreviation for the RANGE command.

Syntax

R [*max._input*][,*%_resolution*]

Refer to the RANGE command for more information.

RANGE

The RANGE command allows you to select a measurement range or the autorange mode.

Syntax

RANGE [*max._input*][,*%_resolution*]

max._input

The *max._input* parameter selects a fixed range or the autorange mode. To select a fixed range, you specify the *max._input* as the absolute value (no negative numbers) of the maximum expected amplitude of the input signal. The multimeter then selects the correct range. To select the autorange mode, specify AUTO for *max._input* or default the parameter. In the autorange mode, the multimeter samples the input signal before each reading and selects the appropriate range.

– The following tables show the *max._input* parameters and the ranges they select for each measurement function.

For DCV:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .12	100 mV	120 mV
>.12 to 1.2	1 V	1.2V
>1.2 to 12	10 V	12 V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

For ACV or ACDCV:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .012	10 mV	12mV
>.012 to .12	100 mV	120 mV
>.12 to 1.2	1V	1.2V
>1.2 to 12	10 V	12V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

For OHM or OHMF:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to 12	10Ω	12Ω
>12 to 120	100Ω	120kΩ
>120 to 1.2E3	1kΩ	1.2kΩ
>1.2E3 to 1.2E4	10kΩ	12kΩ
>1.2E4 1.2E5	100kΩ	120kΩ
>1.2E5 to 1.2E6	1MΩ	1.20MΩ
>1.2E6 to 1.2E7	10MΩ	12MΩ
>1.2E7 1.2E8	100MΩ	120MΩ
>1.2E8 1.2E9	1GΩ	1.2GΩ

For DCI:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .12E-6	.1 µA	.12 µA
>.12E-6 to 1.2E-6	1 µA	1.2 µA
>1.2E-6 to 12E-6	10 µA	12 µA
>12E-6 to 120E-6	100 µA	120 µA
>120E-6 to 1.2E-3	1 mA	1.2 mA
>1.2E-3 to 12E-3	10 mA	12 mA
>12E-3 to 120E-3	100 mA	120 mA
>120E-3 to 1.2	1 A	1.05 A

For ACI or ACDCI:

max._input parameter	Selects range	Full scale
–1 or AUTO	Autorange	
0 to .120E-6	100 µA	120 µA
>120E-6 to 1.2E-3	1mA	1.2mA
>1.2E-3 to 12E-3	10 mA	12mA
>12E-3 to 120E-3	100 mA	120 mA
>120E-3 to 1.2	1A	1.05A

For SSAC or SSDC:

max._input parameter	Selects range	Full scale
0 to .012	10 mV	12mV
>.012 to .120	100 mV	120 mV
>.120 to 1.2	1V	1.2V
>1.2 to 12	10 V	12V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

For DSAC or DSDC:

max._input parameter	Full scale		
	Selects range	SINT format	DINT format
0 to .012	10 mV	12mV	50 mV
>.012 to .120	100 mV	120 mV	500 mV
>.120 to 1.2	1V	1.2V	5.0 V
>1.2 to 12	10 V	12V	50 V
>12 to 120	100 V	120 V	500 V
>120 to 1E3	1000 V	1050 V	1050 V

Power-on *max._input* = AUTO.
Default *max._input* = AUTO.

%_resolution

For all functions except the digitizing functions (DSAC. DSDC, SSAC, and SSDC), the *%_resolution* parameter specifies the measurement resolution. (The multimeter ignores *%_resolution* when included with a digitizing command.) For frequency and period measurements, you specify *%_resolution* as the number of digits to be resolved. For the remaining measurement functions (DCV, ACV, ACDCV, OHM, OHMF, DCI, and ACI), you specify the *%_resolution* as a percentage of the *max._input* parameter. The multimeter then multiplies *%_resolution* by the *max._input* to determine the measurement's resolution.

For example, suppose your maximum expected input is 10 V and you want 1 mV of resolution. To determine *%_resolution*, use the equation:

%_resolution = (actual resolution/maximum input) × 100

In this example, the equation evaluates to:

%_resolution = (.001/10) × 100 = .0001 × 100 = .01

NOTE **When using autorange, the multimeter multiplies the %_resolution parameter times the full scale reading of the selected range. The result is the minimum resolution. The multimeter always gives you at least the minimum resolution and, in many cases, gives you additional digits of resolution.**

Power-on *%_resolution* = none. At power-on, the resolution is determined by the NPLC command which produces 8 ½ digits. (The power-on value for NDIG masks 1 display digit causing the multimeter to display only 7 ½ digits. You can use the NDIG 8 command to display all 8 ½ digits; refer to the NDIG command for details.)

Default *%_resolution*:

For frequency or period measurements, the default *%_resolution* is .00001 which selects a gate time of 1 s and 7 digits of resolution.

For sampled ACV or ACDCV, the default *%_resolution* is 0.01% for SETACV SYNC, or 0.4% for SETACV RNDM.

For all other measurement functions, the default resolution time is determined by the present integration time.

Remarks

- **Query command**: The RANGE? query command returns the present measurement range. (RANGE? does not indicate the autorange mode; use the ARANGE? command to determine the autorange mode.) Refer to Query commands near the front of this chapter for more information.
- **Related commands**: ARANGE, FUNC, R

Examples

In the following program, line 10 allows *%_resolution* in line 30 to control the resolution. The resolution specified by line 30 is 10 m**Ω**.

```
10 OUTPUT 722;"NPLC 0" !SETS PLCS TO MINIMUM
20 OUTPUT 722;"OHM" !SELECTS 2-WIRE OHMS
30 OUTPUT 722;"RANGE 800,.00125" !SELECTS 800 Ω MAX, 10 mΩ
40 END!RESOLUTION
```

RATIO

The RATIO command instructs the multimeter to measure a DC reference voltage applied to the Ω Sense terminals and a signal voltage applied to the Input terminals. The multimeter then computes the ratio as:

$$\text{Ratio} = \frac{\text{Signal Voltage}}{\text{DC Reference Voltage}}$$

Syntax

RATIO [*control*]

control

control parameter	Numeric query equiv.	Description
OFF	0	Disables ratio measurements
ON	1	Enables ratio measurements using the present measurement function (DCV, ACV, or ACDCV)

Power-on *control* = OFF.
Default *control* = ON.

Remarks

- The Ω Sense LO and the Input LO terminals must have a common reference and cannot have a voltage difference >0.25 V.
- The signal voltage can be measured using the DCV, ACV, or ACDCV measurement function. (For ACV or ACDCV, any of the three measurement methods ANA, RNDM, or SYNC may be used.) The multimeter always uses DCV for the reference voltage measurement. The measurable reference

voltage range is ±12 VDC (autorange only). To specify ratio measurements, you first select the measurement function (and the measurement method for ACV or ACDCV) and then enable ratio measurements with the RATIO command (see example below).

- **Query command**: The RATIO? query command returns the present ratio mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: ACDCV, ACV, DCV, SETACV

Example

```
10 OUTPUT 722;"PRESET NORM" !SUSPEND READINGS,NRDGS=1
20 OUTPUT 722;"ACV" !SELECT AC VOLTAGE MEASUREMENTS
30 OUTPUT 722;"SETACV SYNC" !SYNCHRONOUS ACV MEASUREMENTS
40 OUTPUT 722;"RATIO ON" !ENABLE RATIO MEASUREMENTS
50 OUTPUT 722;"TRIG SGL" !TRIGGER MEASUREMENT
60 ENTER 722;A !ENTER RATIO
70 PRINT A !PRINT RATIO
80 END
```

RES

Resolution. Specifies reading resolution.

Syntax

RES [*%_resolution*]

%_resolution

For frequency and period measurements, the *%_resolution* parameter specifies the digits of resolution and the gate time as shown below. (*%_resolution* also affects the reading rate. Refer to the "Appendix A: Specifications" on page 415 for more information.) If you default the *%_resolution* parameter for frequency or period measurements, the multimeter uses .00001.

%_resolution parameter	Selects gate time	Digits of resolution
.00001	1 s	7
.0001	100 ms	7
.001	10 ms	6
.01	1 ms	5
.1	100 µs	4

For sampled ACV or ACDCV, random sampling (SETACV RNDM) has a fixed resolution of 4.5 digits that cannot be changed. For synchronous sampling (SETACV SYNC), a *%_resolution* parameter of 0.001 = 7.5 digits; 0.01 = 6.5 digits; 0.1 = 5.5 digits; and 1= 4.5 digits.

For all other functions (except DSAC, DSDC, SSAC, and SSDC): *%_resolution* is ignored for these functions), the multimeter multiplies *%_resolution* times the present measurement range (1 V, 10 V, 100 V, etc.) to determine the resolution. To compute the *%_resolution* parameter, use the equation:

%_resolution = (actual resolution/range) × 100.

For example, suppose you are measuring DC voltage on the 10 V range and you want 100 µV of resolution. The equation evaluates to:

%_resolution = (.0001 /10) × 100 = .001

Power-on *%_resolution* none. At power-on, the resolution is determined by the NPLC command which produces 8 ½ digits. (The power-on value for NDIG masks 1 display digit causing the multimeter to display only 7 ½ digits. You can use the NDIG 8 command to display all 8 ½ digits.)

Default *%_resolution*:

For frequency or period measurements, the default *%_resolution* is .00001 which selects a gate time of 1 s and 7 digits of resolution.

For sampled ACV or ACDCV, the default *%_resolution* is 0.01% for SETACV SYNC or 0.4% for SETACV RNDM.

For all other measurement functions, the default resolution is determined by the present integration time.

Remarks

- For analog measurements, the *%_resolution* parameter of the RES command operates slightly differently than the *%_resolution* parameter of a function command (FUNC, ACV, DCV, etc.) or the RANGE command. When used with the RES command, *%_resolution* is multiplied times the range to determine the actual resolution. When used with a function command or the RANGE command, *%_resolution* is multiplied times that command's *max._input* parameter. The *max._input* parameter may or may not be the value of a measurement range.
- **Query command**: The RES? query command returns the specified *%_resolution*. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: ACDCI, ACDCV, ACI, ACV, APER, DCI, DCV, FREQ, FUNC, NPLC, OHM, OHMF, PER, RANGE

Examples

In the following program, line 10 allows *%_resolution* in line 30 to control the resolution.

```
10 OUTPUT 722;"NPLC 0" !SETS PLCS TO MINIMUM
20 OUTPUT 722;"DCV 6," !SELECTS DC VOLTS, 10 V RANGE
30 OUTPUT 722;"RES .001" !100 µV OF RESOLUTION ON THE 10 V RANGE
40 END
```

In the following program, line 10 sets the number of PLCs to 1000. This corresponds to maximum resolution (7.5 digits) and prevents the RES command in line 30 from affecting the measurement. The requested resolution in line 30 is 10 m**Ω**. However, because of line 10, the actual resolution is 100 µ**Ω**.

```
10 OUTPUT 722;"NPLC 1000" !SETS PLCS TO MAXIMUM
20 OUTPUT 722;"OHM 1E3 !SELECTS 2-WIRE OHMS, 1 kΩ RANGE
30 OUTPUT 722;"RES .001 !REQUESTS 10 mΩ RESOLUTION
40 END
```

RESET

Allows you to set the multimeter to the power-on state without cycling power.

Syntax

RESET

Remarks

– The RESET command does the following:

  Aborts readings in process.
  Clears error and auxiliary error registers.
  Clears the status register except the Power-on SRQ bit (bit 3).
  Clears reading memory.

  In addition, the RESET command also executes these commands:

```
ACBAND 20,2E6
AZERO ON
DCV AUTO
DEFEAT OFF
DELAY -1
DISP ON
EMASK 32767 (all enabled)
END OFF
EXTOUT ICOMP,NEG
FIXEDZ OFF
FSOURCE ACV
INBUF OFF
LEVEL 0,AC
LFILTER OFF
LFREQ (line frequency rounded to
50 or 60 Hz)
LOCK OFF
MATH OFF
MEM OFF (last memory operation
set to FIFO)
MFORMAT SREAL
MMATH OFF
NDIG 7
NPLC 10
NRDGS 1,AUTO
OCOMP OFF
OFORMAT ASCII QFORMAT NORM
RATIO OFF
RQS 0
SETACV ANA
SLOPE POS
SSRC LEVEL,AUTO
```

```
ALL math registers set to 0 except:

   DEGREE = 20        REF = 1
   SCALE  = 1         RES = 50
   PERC   = 1
```

- Although RESET can be used from remote, it is intended primarily for front panel use. RESET configures the multimeter to a good starting point for local operation. Executing the RESET command from the alphabetic menu resets the multimeter as shown above. Pressing the shifted front panel **Reset** key, however, has the same effect as cycling the multimeter's power. This stores the present state as state 0, any compressed subprograms are destroyed, stored readings are destroyed, the power-on SRQ bit is set in the status register, and the power-on sequence is performed.
- When attempting to send the RESET command from remote, it is possible that the multimeter is busy or the GPIB bus is being held. In either case, the multimeter will not respond immediately to the remote RESET command. For this reason, you should send the GPIB device clear command before you send the multimeter's RESET command. This is shown in the example below.
- **Related commands**: PRESET

Example

```
10 CLEAR 722              !CLEARS THE MULTIMETER IMMEDIATELY
20 OUTPUT 722;"RESET"     !RESETS THE MULTIMETER
30 END
```

REV?

Revision query. Returns two numbers separated by a comma. The first number is the multimeter's master processor firmware revision. The second number is the slave processor firmware revision.

Syntax

REV?

Example

```
10 OUTPUT 722; "REV?" !READ FIRMWARE REVISION NUMBERS
20 ENTER 722; A, B !ENTER NUMBERS
30 PRINT A, B !PRINT NUMBERS
40 END
```

RMATH

Recall math. Reads and returns the contents of a math register.

Syntax

RMATH [*register*]

register

The *register* parameter choices are:

register parameter	Numeric query equiv.	Register contents
DEGREE	1	Time constant for FILTER and RMS
LOWER	2	Smallest reading in STATS
MAX	3	Upper Limit for PFAIL operation
MEAN	4	Average of readings in STATS
MIN	5	Lower limit for PFAIL
NSAMP	6	Number of samples in STATS

register parameter	Numeric query equiv.	Register contents
OFFSET	7	Subtrahend in NULL and SCALE operations
PERC	8	% value for PERC operation
REF	9	Reference value for DB operation
RES	10	Reference impedance for DBM operation
SCALE	11	Divisor in the SCALE operation
SDEV	12	Standard deviation in STATS
UPPER	13	Largest reading in STATS
HIRES	14	Not used by any math operation (extra register)
PFAILNUM	15	The number of reading that passed PFAIL before a failure was encountered

Power-on *register* = none.
Default *register* = DEGREE.

Remarks

- Math register contents are always output in the ASCII output format regardless of the specified output format. Afterwards, the output format returns to that previously specified (SINT, DINT, SREAL, DREAL, or ASCII).
- **Related commands**: MATH, MMATH, SMATH

Example

```
10 OUTPUT 722;"TRIG HOLD" !SUSPENDS TRIGGERING
20 OUTPUT 722;"MEM FIFO" !ENABLE READING MEMORY, FIFO MODE
30 OUTPUT 722;"NRDGS 10" !TEN READINGS PER TRIGGER
40 OUTPUT 722;"DCV 3" !DC VOLTAGE, 10 V RANGE
50 OUTPUT 722;"MATH STAT" !ENABLES STATISTICS MATH OPERATION
60 OUTPUT 722;"TRIG SGL" !TRIGGERS THE MULTIMETER ONCE
70 OUTPUT 722;"RMATH SDEV" !READS STANDARD DEVIATION
80 ENTER 722;A !ENTERS STANDARD DEVIATION
```

```
90 PRINT A !PRINTS STANDARD DEVIATION
100 END
```

RMEM

Recall memory. Reads and returns the value of a reading or group of readings stored in reading memory. RMEM leaves stored readings intact (not cleared from memory).

Syntax

RMEM [*first*][,*count*][,*record*]

first

Designates the beginning reading.

Power-on *first* = none.
Default *first* = 1.

count

Designates the number of readings to be recalled, starting with *first*.

Power-on *count* = none.
Default *count* = 1.

record

Designates the record from which to recall readings. Records correspond to the number of readings specified by the NRDGS command. For example, if NRDGS specifies three readings per trigger, each record will contain three readings.

Power-on *record* = none.
Default *record* = 1.

Remarks

- The RMEM command automatically shuts off reading memory (MEM OFF). This means all previously stored readings remain intact and new readings are not stored. You can re-enable reading memory without destroying any stored readings using the MEM CONT command.
- The multimeter assigns a number to each reading in reading memory. The most recent reading is assigned the lowest number (1) and the oldest reading

has the highest number. Numbers are always assigned in this manner regardless of whether you're using the FIFO or LIFO mode. Records are also numbered in this manner—the most recent record is record number 1.

- When you execute the RMEM command from the front panel, readings are copied, one at a time, to the display. After viewing the first reading, you can view others by using the up or down arrow key. Use the left and right arrow keys to view the reading number (left side of display) and the reading (right side of display).
- In addition to the RMEM command, you can also recall readings using the "implied read." Refer to Recalling readings in Chapter 4 for more information.
- **Related commands**: MCOUNT?, MEM, MFORMAT, MSIZE, NRDGS

Example

```
10 OUTPUT 722;"TARM HOLD" !SUSPENDS TRIGGERING
20 OUTPUT 722;"DCV" !DC VOLTAGE MEASUREMENTS
30 OUTPUT 722)"TRIG AUTO" !AUTOMATIC TRIGGERING
40 OUTPUT 722;"NRDGS 3 ,AUTO" !3 READINGS PER SAMPLE EVENT (AUTO)
50 OUTPUT 722;"MEM FIFO" !ENABLES READING MEMORY, FIFO MODE
60 OUTPUT 722;"TARM SGL, 10" !10 GROUPS OF READINGS
70 OUTPUT 722;"RMEM 1,3,6" !READS 1ST - 3RD READINGS of 6TH GROUP
80 ENTER 722;A,B,C !ENTERS READINGS INTO A, B, & C VARIABLES
90 PRINT A,B,C !PRINTS READINGS
100 END
```

RQS

Request service. Enables one or more status register conditions. When a condition is enabled and that condition occurs, it sets the GPIB SRQ line true.

Syntax

RQS [*value*]

value

You enable a condition by specifying its decimal weight as the value parameter. For more than one condition, specify the sum of the weights. The conditions and their weights are:

Decimal weight	Bit number	Enables condition
1	0	Program Memory Execution Completed
2	1	Hi or Lo Limit Exceeded
4	2	SRQ Command Executed
8	3	Power-On SRQ
16	4	Ready for Instructions
32	5	Error (Consult Error Register)
64	6	Service Requested (you cannot disable this bit)
128	7	Data Available

Power-on *value*: If Power-On SRQ was enabled when power was removed, value = 8; otherwise, value = 0.
Default *value* = 0 (no conditions enabled).

Remarks

- You can control the errors that will set bit 5 with the EMASK command.
- The power-on SRQ bit is stored in continuous memory. All other bits are cleared at power-on.

- **Query command**: The RQS? query command returns the weighted sum of all enabled bits in the status register.
- **Related commands**: CSB, SPOLL (GPIB command), STB?

Examples

```
OUTPUT 722;"RPS 4" !ENABLES THE FRONT PANEL SRQ CONDITION
OUTPUT 722;"RQS 40" !ENABLES POWER-ON SRQ (8) & !ERROR (32) CONDITIONS
OUTPUT 722;"RQS 255" !ENABLES ALL CONDITIONS
OUTPUT 722;"RQS 0" !DISABLES ALL CONDITIONS
```

RSTATE

Recall state. Recalls a stored state from memory and configures the multimeter to that state. States are stored using the SSTATE command.

Syntax

RSTATE [*name*]

name

State name. A state name may contain up to 10 characters. The name can be alpha, alphanumeric, or an integer in the range of 0 to 127. Refer to the SSTATE command for details.

Power-on *name* = none.
Default *name* = 0.

Remarks

- Whenever the multimeter's power is removed, the present state is stored in state 0. After a power failure, the multimeter can be configured to its previous state by executing RSTATE 0.
- If the NULL real-time math operation was enabled in a stored state, after recalling the state, the first reading is placed in the OFFSET register (refer to NULL in Chapter 4 for more information).
- From the front panel, you can review the names of all stored states by pressing the **Recall State** key and by using the up and down arrow keys. When you have found the desired state, press the **Enter** key to recall that state.

– **Related commands**: MSIZE, PURGE, SCRATCH, SSTATE

Example

```
OUTPUT 722; "RSTATE B2" !RECALLS STORED STATE NAMED B2
```

SCAL

This is a calibration command. Refer to the *3458A Calibration Manual* for details.

SCRATCH

Clears all subprograms and stored states from memory.

Syntax

SCRATCH

Remarks

– Individual subprograms can be cleared with the DELSUB command. Individual states can be cleared with the PURGE command.

– **Related commands**: DELSUB, PURGE, RSTATE, SSTATE, SUB

Example

```
OUTPUT 722;"SCRATCH" !CLEARS ALL SUBPROGRAMS AND STORED STATES
```

SECURE

Security code. Allows the person responsible for calibration to enter a security code to prevent accidental or unauthorized calibration or autocalibration (autocal). (Refer to the ACAL command for details on autocal.)

Syntax

SECURE *old_code, new_code*[,*acal_secure*]

old_code

This is the multimeter's previous security code. The multimeter is shipped from the factory with its security code set to 3458A.

new_code

This is the new security code. The code is an integer from -2.1E9 to 2.1E9. If the number specified is not an integer, the multimeter rounds it to an integer value.

acal_secure

Allows you to secure autocalibration. The choices are:

acal_secure parameter	Numeric query equiv.	Description
OFF	0	Disables autocal security; no code required for autocal
ON	1	Enables autocal security; the security code is required to perform autocal (see ACAL for example).

Power-on *acal_secure* = Previously specified value (ON is the factory setting).
Default *acal_secure* = OFF.

Remarks

- Specifying 0 for the *new_code* disables the security feature making it no longer necessary to enter the security code to perform a calibration or autocal.
- The front panel's **Last Entry** key will not display the codes used in a previously executed SECURE command.
- **Related commands**: ACAL, CAL, CALNUM?, CALSTR, SCAL

Examples

Changing the code

```
OUTPUT 722;"SECURE 3458A,4448,0 n" !CHANGE FACTORY SECURITY CODE TO
4448,
!ENABLE AUTOCAL SECURITY
```

Disabling security

```
OUTPUT 722;"SECURE 3458A,0" !DISABLES SECURITY FOR CALIBRATION AND
AUTOCAL
```

SETACV

Set ACV. Selects the RMS conversion technique to be used for AC or AC+DC voltage measurements.

Syntax

SETACV [*type*]

type

The *type* parameter is used to select the measurement method: analog, random sampling, or synchronous sampling. The parameters are:

type parameter	Numeric query equiv.	Description
ANA	1	Analog RMS conversion
RNDM	2	Random sampling conversion
SYNC	3	Synchronous sampling conversion

Power-on *type* = ANA.
Default *type* = ANA.

Remarks

- Bandwidth limitations vary with the conversion technique selected. See the "Appendix A: Specifications" on page 415 for details.
- **Query command**: The SETACV? query command returns the present AC measurement method. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: ACBAND, ACDCV, ACV, FUNC, SSRC

Example

```
10 OUTPUT 722; "SETACV SYNC" !SPECIFIES SYNCHRONOUS SAMPLING (DC
COUPLED)
20 OUTPUT 722;"ACDCV" !SELECTS AC+DC VOLTAGE MEASUREMENTS
30 END
```

SLOPE

SLOPE is used in conjunction with the LEVEL command and specifies which slope of the signal will be used by the level-detection circuitry.

Syntax

SLOPE [*slope*]

slope

Selects the positive-going or negative-going slope of the input signal for use by the level detection circuitry. The choices are:

slope Parameter	Numeric query equiv.	Description
NEG	0	Selects negative-going slope
POS	1	Selects positive-going slope

Power-on *slope* = POS.
Default *slope* = POS.

Remarks

- **Query command**: The SLOPE? query command returns the present slope. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: LEVEL, LFILTER, NRDGS, SSRC, TRIG

Example

```
OUTPUT 722;"SLOPE POS" !SELECTS THE POSITIVE GOING SLOPE FOR
!LEVEL DETECTION
```

SMATH

Store math. Places a number in a math register.

Syntax

SMATH [*register*][,*number*]

register

The registers that can be written to are:

register parameter	Numeric query equiv.	Register contents	Power-on value
DEGREE	1	Time constant for FILTER and RMS	20
LOWER	2	Smallest reading in STATS	0
MAX	3	Upper limit for PFAIL operation	0
MEAN	4	Average of readings in STATS	0
MIN	5	Lower limit for PFAIL	0
NSAMP	6	Number of samples in STATS	0
OFFSET	7	Subtrahend in NULL and SCALE operations	0
PERC	8	% value for PERC operation	1
REF	9	Reference value for DB operation	1
RES	10	Reference impedance for DBM operation	50
SCALE	11	Divisor in the SCALE operation	1
UPPER	13	Largest reading in STATS	0
HIRES	14	Not used by any math operation	0
PFAILNUM	15	The number of readings that passed PFAIL before a failure was encountered	0

Default *register* = DEGREE.
Power-on *register* = see above listing.

number

The *number* parameter is the value to be placed in the register.

Default *number* = last reading.
Power-on *number* = see above listing.

Remarks

- You can use the SMATH command to place a number into one of the registers that store readings (UPPER, LOWER, etc.); however, that value will be replaced with a reading if the corresponding math function is enabled (e.g. STATS).
- You cannot use -1 (minus 1) to default the *number* parameter. If you specify -1, you will actually write -1 to the register.
- **Related commands**: MATH, MMATH, RMATH

Examples

```
OUTPUT 722;"SMATH 11,1E-3" !PLACES "1E-3" IN THE SCALE REGISTER
```

In the following program, lines 10 and 20 configure for a resistance measurement. Line 30 triggers the resistance measurement. Line 40 defaults the *number* parameter causing the resistance reading to be stored in the RES register. Line 50 instructs the operator to connect the voltage source to the multimeter. Line 80 enables the DBM math operation. This program displays the power delivered to the resistance in DB (result of the DBM math operation).

```
10 OUTPUT 722;"PRESET NORM" !TARM AUTO, TRIG SYN, NRDGS 1,AUTO
20 OUTPUT 722;"OHM" !SELECTS 2-WIRE OHMS
30 OUTPUT 722;"TRIG SGL" !TRIGGERS ONCE
40 OUTPUT 722;"SMATH RES" !PLACES READING IN RES REGISTER
50 DISP "CONNECT SOURCE; PRESS CONT" !OPERATOR PROMPT
60 PAUSE !SUSPENDS PROGRAM EXECUTION
70 OUTPUT 722;"ACV" !SELECTS AC VOLTAGE
80 OUTPUT 722;"MATH DBM" !ENABLES DBM MATH OPERATION
90 OUTPUT 722;"TRIG AUTO" !TRIGGERS AUTOMATICALLY
100 END
```

SRQ

Service request. Sets bit 2 in the multimeter's status register. If bit 2 is enabled to assert SRQ (RQS 4 command), executing the SRQ command will set the GPIB SRQ line.

Syntax

SRQ

– **Related commands**: CSB, EXTOUT, RQS, SPOLL (GPIB command), STB?

Example

```
10 OUTPUT 722;"RQS 4" !ENABLE STATUS REGISTER BIT 2 TO ASSERT SRQ
20 OUTPUT 722;"SRQ" !SET BIT 2, ASSERT SRQ
30 END
```

SSAC, SSDC

Sub-sampling. Configures the multimeter for sub-sampled voltage measurements (digitizing). The SSAC function measures only the AC component of the input waveform. The SSDC function measures the combined AC and DC components of the waveform. Otherwise, the two functions are identical. The input signal must be periodic (repetitive) for sub-sampled measurements. Sub-sampled measurements use the track/hold circuit (2 nanoseconds aperture) and a wide bandwidth input. path (12 MHz bandwidth).

Syntax

SSAC [*max._input*] [,*% resolution*]

SSDC [*max._input*] [,*%_resolution*]

max._input

Selects the measurement range (you cannot use autorange for sub-sampled measurements). To select a range, you specify *max._input* as the input signal's expected peak amplitude. The multimeter then selects the correct range. The following table shows the *max._input* parameters and the ranges they select.

max._input parameter	Selects range	Full scale
0 to .012	10 mV	12 mv
>.012 to .120	100 mV	120 mV
>.120 to 1.2	1 V	1.2 V
>1.2 to 12	10 V	12 V
>12 to 120	100 V	120 V
>120 to 1E3	1000 V	1050 V

Power-on *max._ input* = not applicable.
Default *max._input* = 10 V.

% resolution

Is ignored by the multimeter when used with the SSAC or SSDC command. This parameter is allowed in the command syntax to be consistent with the other function commands (FUNC, ACI, DCV, etc.).

Remarks

- Autozero and autorange do not function for sub-sampled measurements. Executing the SSAC or SSDC command suspends autozero and autorange operation.
- As with direct-sampling, you can specify a level triggering voltage up to 500% of the range. The required SINT format, however, cannot handle samples greater then 120% of range.
- If reading memory is disabled when you execute the SSAC or SSDC command, the multimeter automatically sets the output format to SINT (the memory format is not changed). Later, where you change to another measurement function, the output format returns to that previously specified. You must use the SINT output format when sub-sampling and outputting samples directly to the GPIB. You can, however, use any output format if the samples are first placed in reading memory (see next Remark). To do this, you should enable reading memory before executing the SSAC or SSDC command (executing SSAC or SSDC does not change the output format to SINT when reading memory is enabled).

- When sub-sampling with reading memory enabled, reading memory must be in FIFO mode, must be empty (executing MEM FIFO clears reading memory), and the memory format must be SINT prior to the occurrence of the trigger arm event. If not, the multimeter generates the SETTINGS CONFLICT error when the trigger arm event occurs and no samples are taken.
- For sub-sampling, the trigger event and the sample event are ignored (these events are discussed in Chapter 4). The only triggering events that apply to sub-sampling are the trigger arm event (TARM command) and the sync source event.
- In sub-sampling, samples are taken on more than one period of the input waveform. When the samples are sent directly to reading memory (MEM command), the multimeter automatically reconstructs the samples producing a composite waveform. When the samples are sent to the output buffer, the controller must use an algorithm to reconstruct the composite waveform. parameters for this algorithm are provided by the SSPARM? command.
- The *effective_interval* between samples and the total number of samples taken are specified by the SWEEP command. (You cannot use the NRDGS command for sub-sampling.) In sub-sampling, the multimeter will use as many periods of the input signal as necessary to achieve the specified *effective_interval*. The minimum *effective_interval* for sub-sampling is 10 nanoseconds. (Refer to Sub-Sampling in Chapter 5 for a detailed description of the process.)
- **Related commands**: DSAC, DSDC, FUNC, ISCALE?, LEVEL, LFILTER, MEM FIFO, SLOPE, PRESET FAST, PRESET DIG, SSDC, SSPARM?, SSRC, SWEEP, TARM

Examples

In the following program, the sub-sampled data is sent to reading memory using the required SINT memory format. The multimeter places the samples in memory in the corrected order. The samples are then transferred to the controller using the DREAL output format (when placing sub-sampled data in reading memory first, you are not restricted to using the SINT output format).

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 REAL Samp(1:200) BUFFER !CREATE BUFFER ARRAY
30 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
40 ASSIGN @Samp TO BUFFER Samp(*) !ASSIGN BUFFER
50 OUTPUT @Dvm;"PRESET FAST" !TARM SYN, TRIG AUTO, DINT FORMATS
```

```
60 OUTPUT @Dvm; "MEM FIF0" !FIRST-IN-FIRST-OUT READING MEMORY
70 OUTPUT @Dvm; "MFORMAT SINT" !SINT MEMORY FORMAT
80 OUTPUT @Dvm; "OFORMAT DREAL" !DOUBLE REAL OUTPUT FORMAT
90 OUTPUT @Dvm; "SSDC 10" !SUB-SAMPLING, 10 V RANGE, DC-COUPLED
100 OUTPUT @Dvm; "SWEEP 5E - 6,200" !5 µs EFF. INTERVAL, 200 SAMPLES
110 TRANSFER @Dvm TO @Samp;WAIT !TRANSFER SAMPLES TO CONTROLLER BUFFER
120 FOR I=1 TO 200
130 IF ABS(Samp(I))=1E+38 THEN !DETECT OVERLOAD
140 PRINT "Overload Occurred" !PRINT OVERLOAD MESSAGE
150 ELSE !IF NO OVERLOAD OCCURRED:
160 Samp(I)=DROUND(Samp(I),5) !ROUND TO 5 DIGITS
170 PRINT Samp(I) !PRINT EACH SAMPLE
180 END IF
190 NEXT I
200 END
```

In the program on the following page, the SSAC command is used to digitize a 10 kHz signal with a peak value of 5 V. The SWEEP command instructs the multimeter to take 1000 samples (Num_samples variable) with a 2 µs *effective_interval* (Eff_int variable). The measurement uses the default level triggering for the sync source event (trigger from input signal, 0%, AC-coupling, positive slope). Line 120 generates a SYN event and transfers the samples directly to the computer. Lines 240 through 410 sort the sub-sampled data to produce the composite waveform. The composite waveform is stored in the Wave_form array.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_samples,Inc,I,J,K,L !DECLARE VARIABLES
30 Num_samples=1000 !DESIGNATE NUMBER OF SAMPLES
40 Eff_int=2.0E-6 !DESIGNATE EFFECTIVE INTERVAL
50 INTEGER Int_samp(1:1000) BUFFER !CREATE INTEGER BUFFER
60 ALLOCATE REAL Wave_form(1:Num_samples) !CREATE ARRAY FOR SORTED DATA
70 ALLOCATE REAL Samp(1:Num_samples) !CREATE ARRAY FOR SAMPLES
80 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
90 ASSIGN @Int_samp TO BUFFER Int_samp(*) !ASSIGN BUFFER I/O PATH NAME
```

```
100 OUTPUT @Dvm;"PRESET FAST;LEVEL;SLOPE;SSRC LEVEL;SSDC 10"
101 !FAST OPERATION, TARM SYN, LEVEL SYNC SOURCE 0 V, POSITIVE SLOPE
105 !(DEFAULT VALUES) SUB-SAMPLING(SINT OUTPUT FORMAT), 10 V RANGE
110 OUTPUT @Dvm;"SWEEP ";Eff_int,Num_samples
115 !2 µs EFFECTIVE INTERVAL, 1000 SAMPLES
120 TRANSFER @Dvm TO @Int_samp;WAIT !SYN EVENT,TRANSFER READINGS INTO
121 !INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
125 !SINT,NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
130 OUTPUT @Dvm;"ISCALE?" !QUERY SCALE FACTOR FOR SINT FORMAT
140 ENTER @Dvm; S !ENTER SCALE FACTOR
150 OUTPUT @Dvm;"SSPARM?" !QUERY SUB-SAMPLING PARAMETERS
160 ENTER @Dvm;N1,N2,N3 !ENTER SUB-SAMPLING PARAMETERS
170 FOR I=1 TO Num_samples
180 Samp(I)=Int_samp(I) !CONVERT EACH INTEGER READING TO REAL
190 !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
190 R=ABS(Samp(I)) !USE ABSOLUTE VALUE TO CHECK FOR OVLD
200 IF R>=32767 THEN PRINT "OVLD" !IF OVLD, PRINT OVERLOAD MESSAGE
210 Samp(I)=Samp(I)*S !MULTIPLY READING TIMES SCALE FACTOR
220 Samp(I)=DROUND(Samp(I),4) !ROUND TO 4 DIGITS
230 NEXT I
235 !-------------------------SORT SAMPLES----------------------------
240 Inc=N1+N2 !TOTAL NUMBER OF BURSTS
250 K=1
260 FOR I=1 TO N1
270 L=I
280 FOR J=1 TO N3
290 Wave_form(L)=Samp(K)
300 K=K+1
310 L=L+Inc
```

```
320 NEXT J
330 NEXT I
340 FOR I=N1+1 TO N1+N2
350 L=I
360 FOR J=1 TO N3-1
370 Wave_form(L)=Samp(K)
380 K=K+ 1
390 L=L+Inc
400 NEXT J
410 NEXT I
420 END
```

SSPARM?

Sub-sampling parameters query. Returns the parameters necessary to reconstruct a sub-sampled waveform (SSAC or SSDC command) when the samples are sent directly to the GPIB output buffer. (Reconstruction is automatic when the samples are sent directly to reading memory.)

The first parameter returned by SSPARM? is the number of bursts that contained *N* samples. The second parameter is the number of bursts that contained *N-1* samples. The third parameter returned is the value of *N*. For example, assume you are sub-sampling a 10 kHz signal and specify 22 samples with an *effective_interval* of 5 µs. In this example, the multimeter must use a total of 4 bursts: 2 bursts contain 6 samples each and 2 bursts contain 5 samples each. The values returned by SSPARM? are then 2, 2, and 6.

Syntax

SSPARM?

Remarks

- **Related commands**: SSAC, SSDC, SSRC, SWEEP

Example

See the SSDC example on the preceding page.

SSRC

Sync source. For sub-sampling (SSAC or SSDC command), the SSRC command allows you to synchronize bursts to an external signal or to a voltage level on the input signal.

For synchronous ACV or ACDCV (SETACV SYNC command), the SSRC command allows you to synchronize sampling to an external signal. You can also use the HOLD parameter to prevent the measurement method from changing to random should level triggering not occur within certain time limits. The time limits are determined by the AC bandwidth (ACBAND command) setting.

Syntax

SSRC [*source*][,*mode*]

source

The *source* parameter choices are:

source parameter	Numeric query equiv.	Description
EXT	2	Synchronize to external input on the rear panel Ext Trig connector
LEVEL[a]	7	Synchronize to a voltage Level (LEVEL command> on the input signal using the slope specified by the SLOPE command.

[a] For synchronous ACV or ACDCV, the level triggering voltage (LEVEL command) and the slope (SLOPE command) are determined automatically and cannot be specified.

Power-on *source* = LEVEL
Default *source* = LEVEL

mode

The *mode* parameter applies only to synchronous ACV or ACDCV. The choices are:

mode parameter	Numeric query equiv.	Description
AUTO[a]	1	For synchronous AC or ACDCV (SETACV SYNC) using level triggering (default mode), if the input signal is removed during a reading and does not return within a certain amount of time, the measurement method changes to random so that the reading can be completed. (After the reading, the measurement method returns to SYNC.)
HOLD	4	The measurement method will not automatically change from synchronous to random when the input signal is removed.

[a] The time limit for synchronous AC or ACDCV is determined by the bandwidth specified using the ACBAND command.

Power-on *mode* = AUTO
Default *mode* = AUTO

Remarks

- For sub-sampling, the trigger event and the sample event are ignored. The only triggering events that apply to sub-sampling are the trigger arm event (TARM command) and the sync source event (SSRC command). For synchronous ACV or ACDCV measurements (SETACV SYNC command), the specified trigger arm event (TARM command), trigger event (TRIG command), and sample event (NRDGS command) must all be satisfied before the sync source event can initiate sampling.
- For sub-sampling and synchronous AC measurements, bursts of samples are taken on more than one period of the waveform. The sync source event synchronizes these bursts to the periods of the input signal (that is, a sync source event should typically occur once for each period).
- **Query command**: The SSRC? query command returns two responses separated by a comma. The first response is the present *source*. The second response is the present *mode*. Refer to Query commands near the front of this chapter for more information.

– **Related commands**: LEVEL, LFILTER, SETACV SYNC, SLOPE, SSAC, SSDC

Examples

In the program on the following page, the SSAC command is used to digitize a 10 kHz signal with a peak value of 5 V. The SWEEP command instructs the multimeter to take 1000 samples (Num_samples variable) with a 2 µs *effective_interval* (Eff_int variable). The measurement uses the default level triggering for the sync source event (trigger from input signal, 0%, AC-coupling, positive slope). Line 120 generates a SYN event and transfers the samples directly to the computer. Lines 240 through 410 sort the sub-sampled data to produce the composite waveform. The composite waveform is stored in the Wave_form array.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_samples,Inc,I,J,K,L !DECLARE VARIABLES
30 Num_samples=1000 !DESIGNATE NUMBER OF SAMPLES
40 Eff_int=2.0E-6 !DESIGNATE EFFECTIVE INTERVAL
50 INTEGER Int_samp(1:1000) BUFFER !CREATE INTEGER BUFFER
60 ALLOCATE REAL Wave_form(1:Num_samples) !CREATE ARRAY FOR SORTED
70 DATA ALLOCATE REAL Samp(1:Num_samples) !CREATE ARRAY FOR SAMPLES
80 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
90 ASSIGN @Int_samp TO BUFFER Int_samp(*) !ASSIGN BUFFER I/O PATH NAME
100 OUTPUT @Dvm;"PRESET FAST;LEVEL;SLOPE;SSRC LEVEL;SSDC 10"
101 !FAST OPERATION, TARM SYN, LEVEL SYNC SOURCE 0 V, POSITIVE SLOPE
105 !(DEFAULT VALUES) SUB-SAMPLING(SINT OUTPUT FORMAT), 10 V RANGE
110 OUTPUT @Dvm;"SWEEP ";Eff_int,Num_samples
115 !2 µs EFFECTIVE INTERVAL, 1000 SAMPLES
120 TRANSFER @Dvm TO @Int_samp;WAIT !SYN EVENT,TRANSFER READINGS INTO
121 !INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
125 !SINT, NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
130 OUTPUT @Dvm;"ISCALE?" !QUERY SCALE FACTOR FOR SINT FORMAT
140 ENTER @Dvm; S !ENTER SCALE FACTOR
150 OUTPUT @Dvm;"SSPARM?" !QUERY SUB-SAMPLING PARAMETERS
160 ENTER @Dvm;N1,N2,N3 !ENTER SUB-SAMPLING PARAMETERS
```

```
170 FOR I=1 TO Num_samples
180 Samp(I)=Int_samp(I) !CONVERT EACH INTEGER READING TO REAL
190 !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
190 R=ABS(Samp(I)) !USE ABSOLUTE VALUE TO CHECK FOR OVLD
200 IF R>=32767 THEN PRINT "OVLD" !IF OVLD, PRINT OVERLOAD MESSAGE
210 Samp(I)=Samp(I)*S !MULTIPLY READING TIMES SCALE FACTOR
220 Samp(I)=DROUND(Samp(I),4) !ROUND TO 4 DIGITS
230 NEXT I
235 !-------------------------SORT SAMPLES----------------------------
240 Inc=N1+N2 !TOTAL NUMBER OF BURSTS
250 K=1
260 FOR I=1 TO N1
270 L=1
280 FOR J=1 TO N3
290 Wave_form(L)=Samp(K)
300 K=K+1
310 L=L+Inc
320 NEXT J
330 NEXT I
340 FOR I=N1+1 TO N1+N2
350 L=I
360 FOR J=1 TO N3-1
370 Wave_form(L)=Samp(K)
380 K=K+ 1
390 L=L+Inc
400 NEXT J
410 NEXT I
420 END
```

In the following program, the SSRC EXT event is used with synchronous AC voltage measurements. After the trigger event occurs (the trigger arm and sample

events are AUTO), the first low-going TTL transition on the Ext Trig connector initiates the first burst. Each successive external trigger will then initiate a burst until the necessary number of bursts are completed.

```
10 OUTPUT 722;"PRESET NORM" !TARM AUTO, TRIG SYN, NRDGS 1,AUTO
20 OUTPUT 722;"ACV 10" !AC VOLTAGE, 10 V RANGE
30 OUTPUT 722;"SETACV SYNC" !SYNCHRONOUS METHOD
40 OUTPUT 722;"SSRC EXT" !EXTERNAL SYNC SOURCE EVENT
50 ENTER 722;A !TRIGGER READING (TRIG SYN), ENTER READING
60 PRINT A !PRINT READING
70 END
```

SSTATE

Store state. Stores the multimeter's present state and assigns it a name. States are recalled using the RSTATE command.

Syntax

SSTATE *name*

name

State name. A state name may contain up to 10 characters. The name can be alpha, alphanumeric, or an integer in the range of 0 to 127. When using an alphanumeric name, the first character must be alpha. Alpha or alphanumeric state names must not be the same as multimeter commands or parameters or the name of a stored subprogram. The characters _ and ? can also be used in an alpha or alphanumeric name.

When using an integer state name (0 - 127), the multimeter assigns the prefix *STATE* to the integer when the state is stored. This differentiates an integer state name from an integer subprogram name. For example, a state stored with the name *8* will be recorded as *STATE8*. The state can be recalled later using either the name *8* or *STATE8*. State 0 is reserved for the multimeter's power-down state (see first Remark below).

Power-on *name* = none.
Default *name* = none; parameter required.

Remarks

- Whenever the multimeter's power is removed, the present state is stored in state 0. After a power failure, the multimeter can be configured to its previous state by executing RSTATE 0.
- All states are stored in continuous memory (not lost when power is removed).
- Subprograms, the contents of reading memory, user-defined keys, and the front panel MENU mode are not included as part of a stored state. The contents of the following math registers are stored when you store a state (all other math registers are set to 0):

DEGREE	REF
LOWER	RES
OFFSET	SCALE
PERC	UPPER

- The multimeter has 14k-bytes of state memory. Each state occupies approximately 300 bytes allowing a maximum of 46 stored states. State 0 is reserved for storing the multimeter's state when power is removed. State 0 may be also be used for storing other states, but the stored state will be overwritten with the present state when power is removed.
- From the front panel, you can review the names of all stored states by pressing the **Recall State** key and using the up and down arrow keys. When you have found the desired state, press the **Enter** key to recall that state.
- **Related commands**: MSIZE, PURGE, RSTATE, SCRATCH

Example

```
OUTPUT 722;"SSTATE B2" !STORES PRESENT STATE WITH NAME B2
```

STB?

Status byte query. The status register contains seven bits that monitor various multimeter conditions. When a condition occurs, the corresponding bit is set in the status register. The STB? (status byte?) command returns a number representing the set bits. The returned number is the weighted sum of all set bits.

Syntax

STB?

Status register conditions

The status register conditions and their weights are:

Decimal weight	Bit number	Status register condition
1	0	Subprogram Execution Completed
2	1	Hi or Lo Limit Exceeded
4	2	SRQ Command Executed
8	3	Power On
16	4	Ready for Instructions
32	5	Error (Consult Error Register)
64	6	Service Requested (you cannot disable this bit)
128	7	Data Available

Remarks

- When you execute the STB? Command, the ready bit (bit 4) is always clear (not ready) because the multimeter is processing the STB? command.
- The CSB command clears the status register (bits 4, 5, and 6 are not cleared if the condition(s) that set the bit(s) still exist). The RQS command designates which status register conditions will assert SRQ on the GPIB bus.
- **Related commands**: CSB, EXTOUT, RQS, SPOLL (GPIB command)

Example

```
10 OUTPUT 722;"STB?" !RETURNS THE WEIGHTED SUM OF ALL SET BITS
20 ENTER 722 !ENTERS RESPONSE INTO COMPUTER'S A VARIABLE
30 PRINT A !PRINTS RESPONSE
40 END
```

Assume the above program returns the weighted sum 24. This means the bits with weighted values 8 (power-on) and 16 (ready for instructions) are set.

SUB

Subprogram. Stores a series of commands as a subprogram and assigns the sub-program name.

Syntax

SUB *name*

name

Subprogram name. A subprogram name may contain up to 10 characters. The name can be alpha, alphanumeric, or an integer from 0 to 127. When using an alphanumeric name, the first character must be alpha. Alpha or alphanumeric subprogram names must not be the same as multimeter commands or parameters or the name of a stored state. The characters _ and ? can also be included in an alpha or alphanumeric name.

When using an integer subprogram name (0 - 127), the multimeter assigns the prefix *SUB* to the integer when the subprogram is stored. This differentiates an integer subprogram name from an integer state name. For example, a sub-program stored with the name *15* will be recorded as *SUB15*. The subprogram can be accessed later using either the name *15* or *SUB15*. A subprogram named 0 (zero) is designated the autostart subprogram (see 7th Remark following).

Power-on *name* = none.
Default *name* = none; parameter required.

Remarks

- Subprogram entry is terminated by the SUBEND command. The CALL command is used to execute a subprogram, and the PAUSE and CONT commands suspend and resume subprogram execution, respectively.
- When you store a new subprogram using the name of an existing subprogram, the new subprogram overwrites (replaces) the old subprogram.
- Entering (storing) a subprogram from the front panel is not recommended since front panel utilities (e.g., up and down arrows) can inadvertently be stored in the subprogram. Once you have executed the SUB command from the front panel, the display shows SUB ENTRY MODE until the SUBEND command is executed or the RESET key is pressed. The SUBEND command does not appear in the front panel menu unless you are storing a subprogram.
- If a SCRATCH, DELSUB, a second SUB command, or the GPIB Device Clear command occurs in a subprogram, the multimeter does not store the command but does store the rest of the subprogram. Subprogram execution will be aborted if the RESET command is encountered (do not store RESET in a subprogram).
- You can not store a subprogram with less than 800 bytes of subprogram/state memory remaining.
- Subprogram execution will be aborted if an error is detected or the GPIB Device Clear command is received. The GPIB Device Clear command will also abort the process of storing a subprogram.
- The only way to take readings within a subprogram is to use the TARM SGL or TRIG SGL command. When either of these commands is encountered, the multimeter will not execute the next command in the subprogram until all specified readings are taken. (This also means all configuration and other triggering commands must occur before the TARM SGL or TRIG SGL command.) Any other trigger arm or trigger events (except TARM EXT, see next Remark) will be executed in a subprogram, but the readings will not be initiated until the subprogram is complete.
- Whenever the TARM EXT command is encountered in a subprogram, the multimeter waits until an external trigger is received on its Ext Trig connector before executing the next line of the subprogram. This allows you to synchronize subprogram execution to external equipment.

- Any subprogram named *0* will be automatically executed whenever the multimeter has finished its power-on sequence. This is useful to recall the multimeter's previous state (RSTATE 0) following a power failure.
- Subprograms are stored in continuous memory (not lost when power is removed). If you compress a subprogram, however, (COMPRESS command) the subprogram is removed from continuous memory and will be destroyed when power is removed.
- **Related commands**: CALL, COMPRESS, CONT, DELSUB, PAUSE, SCRATCH, SUBEND

Examples

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 DIM RDGS(5) !DIMENSION ARRAY FOR 5 READINGS
30 OUTPUT 722;"SUB DCCUR2" !STORES FOLLOWING LINES NAMED DCCUR2
40 OUTPUT 722;"PRESET NORM" !PRESETS
50 OUTPUT 722;"MEM FIFO" !ENABLES FIFO MODE OF READING MEMORY
60 OUTPUT 722;"DCV, 10, .01" !DC VOLTAGE, 10 V RANGE, .01% RESOLUTION
70 OUTPUT 722; "NRDGS,5,AUTO" !5 READINGS PER TRIGGER, AUTO EVENT
80 OUTPUT 722;"TRIG SGL" !SPECIFIES THE SINGLE TRIGGER MODE
90 OUTPUT 722; "SUBEND" !SIGNALS THE END OF SUBPROGRAM STORAGE
100 OUTPUT 722;"DISP MSG 'CALLING SUBPROGRAM'"
110 OUTPUT 722; "CALL DCCUR2"
120 ENTER 722;Rdgs(*)
130 PRINT Rdgs(*)
140 END
```

When the following subprogram is called (CALL EXTPACE), the multimeter executes it line-by-line until it encounters TARM EXT (line 70). Subprogram execution then ceases until an external trigger occurs. This allows you to synchronize subprogram execution to some external event. After the first external trigger is received, subprogram execution resumes. When the next line is encountered (TRIG SGL), subprogram execution ceases until the 1000 readings are taken. After the readings are taken, the subprogram changes the measurement function to 2-wire ohms and the number of readings to 100. When the second TARM EXT command is encountered (line 100), subprogram execution

ceases until another external trigger occurs. After the external trigger is received, the TRIG SGL command is encountered which suspends subprogram execution until the 100 readings are taken. After the readings are taken, the message TEST FINISHED is displayed.

```
10 OUTPUT 722; "SUB EXTPACE" !STORE LINES 20-110 AS SUBPROGRAM
20 OUTPUT 722; "PRESET NORM" !PRESET, SUSPEND READINGS
30 OUTPUT 722; "MEM FIFO" !ENABLE READING MEMORY, FIFO MODE
40 OUTPUT 722; "DCV 10" !DC VOLTAGE MEASUREMENTS, 10 V RANGE
50 OUTPUT 722; "NRDGS 1000, AUTO" !1000 READINGS/TRIGGER,AUTO SAMPLE
EVENT
60 OUTPUT 722; "TARM EXT" !EXTERNAL TRIGGER ARM EVENT
70 OUTPUT 722; "TRIG SGL" !SINGLE TRIGGER EVENT
80 OUTPUT 722; "OHM 1E3" !2-WIRE OHMS, 1 kΩ RANGE
90 OUTPUT 722; "NRDGS 100, AUTO" !100 READINGS/TRIGGER, AUTO SAMPLE
EVENT
100 OUTPUT 722;"TARM EXT" !EXTERNAL TRIGGER ARM EVENT
110 OUTPUT 722;"TRIG SGL" !SINGLE TRIGGER EVENT
120 OUTPUT 722;"DISP MSG,'TEST FINISHED'" !INDICATE SUBPROGRAM IS DONE
130 OUTPUT 722;"SUBEND"
140 END
```

SUBEND

Subprogram end. Signals the end of a subprogram.

Syntax

SUBEND

Remarks

- When storing a subprogram, SUBEND signals the end of the subprogram. When a subprogram has been executed, SUBEND sets bit 1 (if enabled) in the status register which signals the subprogram's completion.
- **Related commands**: CALL, COMPRESS, CONT, DELSUB, PAUSE, SCRATCH, SUB

Example

See the SUB example on the preceding page.

SWEEP

The SWEEP command specifies the *effective_interval* between samples (readings and the total number of samples taken per trigger event [most measurement functions] or per trigger arm event (sub-sampling only).

Syntax

SWEEP [*effective_interval*] [,*#_samples*]

effective_interval

For sub-sampling (SSAC or SSDC), this parameter specifies the spacing of samples in the reconstructed waveform (see Chapter 5 for details). For all other measurement functions, this parameter specifies the actual time interval from one sample to the next. For sub-sampling, the valid range of this parameter is 10E-9 to 6000 seconds with 10 ns increments; for all other measurement functions the range is (1/maximum reading rate) to 6000 seconds in 100 ns increments.

Power-on *effective_interval* = 100E-9
Default *effective_interval* = 20 µs

#_samples

Specifies the number of samples to be taken. The valid range for this parameter is 1 to 1.67E+7.

Power-on *#_samples* = 1024
Default *#_samples* = 1024

Remarks

- The minimum effective interval for DC voltage measurements is 10 µs; for direct-sampling, 20 µs; for sub-sampling, 10 nanoseconds.
- The SWEEP command can be used to replace the NRDGS *n*,TIMER command and the TIMER command. The SWEEP and NRDGS are interchangeable; the multimeter uses whichever command was executed last in the programming. Executing the SWEEP command automatically sets the sample event to TIMER. In the power-on, RESET, or PRESET state, the multimeter uses the

NRDGS command. The power-on values for SWEEP can only be used for sub-sampling (since NRDGS does not apply to sub-sampling).

- You cannot use the SWEEP or TIMER functions for AC or AC+DC voltage measurements using the synchronous or random methods (SETACV SYNC or RNDM) or for frequency or period measurements.
- When using the SWEEP command (or TIMER event), autoranging is suspended (typically you should select a fixed range when using SWEEP).
- **Query command**: The SWEEP? query command returns two responses separated by a comma. The first response is the specified *effective_interval*. The second response is the specified *#_samples*. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: FUNC, NRDGS, TIMER

Example

In the program on the following page, the SSAC command is used to digitize a 10 kHz signal with a peak value of 5 V. The SWEEP command instructs the multimeter to take 1000 samples (Num_samples variable) with a 2 µs *effective_interval* (Eff_int variable}. The measurement uses the default level triggering for the sync source event (trigger from input signal, 0%, AC-coupling, positive slope).

Line 120 generates a SYN event and transfers the samples directly to the computer. Lines 240 through 410 sort the sub-sampled data to produce the composite waveform. The composite waveform is stored in the Wave_form array.

```
10 OPTION BASE 1 !COMPUTER ARRAY NUMBERING STARTS AT 1
20 INTEGER Num_samples,Inc,I,J,K,L !DECLARE VARIABLES
30 Num_samples=1000 !DESIGNATE NUMBER OF SAMPLES
40 Eff_int=2.0E-6 !DESIGNATE EFFECTIVE INTERVAL
50 INTEGER Int_samp(1:1000) BUFFER !CREATE INTEGER BUFFER
60 ALLOCATE REAL Wave_form(1:Num_samples) !CREATE ARRAY FOR SORTED DATA
70 ALLOCATE REAL Samp(1:Num_samples) !CREATE ARRAY FOR SAMPLES
80 ASSIGN @Dvm TO 722 !ASSIGN MULTIMETER ADDRESS
90 ASSIGN @Int_samp TO BUFFER Int_samp(*) !ASSIGN BUFFER I/O PATH NAME
100 OUTPUT @Dvm;"PRESET FAST;LEVEL;SLOPE;SSRC LEVEL;SSDC 10"
101 !FAST OPERATION, TARM SYN, LEVEL SYNC SOURCE 0 V, POSITIVE SLOPE
```

```
105 !(DEFAULT VALUES) SUB-SAMPLING(SINT OUTPUT FORMAT), 10 V RANGE
110 OUTPUT @Dvm;"SWEEP ";Eff_int,Num_samples
115 !2 µs EFFECTIVE INTERVAL, 1000 SAMPLES
120 TRANSFER @Dvm TO @Int_samp;WAIT !SYN EVENT,TRANSFER READINGS INTO
121 !INTEGER ARRAY; SINCE THE COMPUTER'S INTEGER FORMAT IS THE SAME AS
125 !SINT, NO DATA CONVERSION IS NECESSARY HERE (INTEGER ARRAY REQUIRED)
130 OUTPUT @Dvm;"ISCALE?" !QUERY SCALE FACTOR FOR SINT FORMAT
140 ENTER @Dvm; S !ENTER SCALE FACTOR
150 OUTPUT @Dvm;"SSPARM?" !QUERY SUB-SAMPLING PARAMETERS
160 ENTER @Dvm;N1,N2,N3 !ENTER SUB-SAMPLING PARAMETERS
170 FOR I=1 TO Num_samples
180 Samp(I)=lnt_samp(I) !CONVERT EACH INTEGER READING TO REAL
190 !FORMAT (NECESSARY TO PREVENT POSSIBLE INTEGER OVERFLOW ON NEXT
LINE)
190 R=ABS(Samp(I)) !USE ABSOLUTE VALUE TO CHECK FOR OVLD
200 IF R>=32767 THEN PRINT "OVLD" !IF OVLD, PRINT OVERLOAD MESSAGE
210 Samp(I)=Samp(I)*S !MULTIPLY READING TIMES SCALE FACTOR
220 Samp(I)=DROUND(Samp(I),4) !ROUND TO 4 DIGITS
230 NEXT I
235 !-------------------------SORT SAMPLES----------------------------
240 Inc=N1+N2 !TOTAL NUMBER OF BURSTS
250 K=1
260 FOR I=1 TO N1
270 L=1
280 FOR J=1 TO N3
290 Wave_form(L)=Samp(K)
300 K=K+1
310 L=L+Inc
320 NEXT J
330 NEXT I
```

```
340 FOR I=N1+1 TO N1+N2
350 L=I
360 FOR J=1 TO N3-1
370 Wave_form(L)=Samp(K)
380 K=K+1
390 L=L+Inc
400 NEXT J
410 NEXT I
420 END
```

T

T is an abbreviation for the TRIG command.

Syntax

T [*event*]

Refer to the TRIG command for more information.

TARM

Trigger arm. Defines the event that enables (arms) the trigger event (TRIG command). You can also use this command to perform multiple measurement cycles.

Syntax

TARM [*event*][,*number_arms*]

event

The *event* parameter choices are:

event parameter	Numeric query equiv.	Description
AUTO	1	Always armed
EXT	2	Arms following a low-going TTL transition on the Ext Trig connector. (Executing TARM EXT clears the trigger buffer if TBUFF is ON).
SGL	3	Arms once (upon receipt of TARM SGL) then becomes HOLD
HOLD	4	Triggering is disabled
SYN	5	Arms when the multimeter's output buffer is empty, reading memory is off or empty, and the controller requests data.

Power-on *event* = AUTO.
Default *event* = AUTO.

number_arms

The *number_arms* parameter is valid only with the SGL trigger arm event; in this case, the valid range is 0 - 2.1E+9. Specifying 0 or 1 with the SGL event has the same effect as using the default value (1): the trigger is armed once and then reverts to the HOLD state (disabled). When you specify a number greater than 1 as the *number_arms* parameter, you have selected “multiple arming.” In multiple arming, the multimeter generates enough single trigger arms to satisfy the *number_arms* parameter. Refer to “multiple arming” in the Remarks section below for more information.

Power-on *number_arms* = 1 (multiple arming disabled)
Default *number_arms* = 1 (multiple arming disabled)

Remarks

- For all measurement functions except sub-sampling (see Chapter 5), the trigger arm event operates along with the trigger event (TRIG command) and the sample event (NRDGS or SWEEP command). To make a measurement, the trigger arm event must occur first, followed by the trigger event, and finally the sample event.
- The trigger arm event does not necessarily trigger the multimeter. It merely enables the trigger event, making it possible for the multimeter to respond to

the trigger event. Refer to Triggering Measurements in Chapter 4 for an in-depth discussion of the interaction of the various events.

- Multiple arming: When using multiple arming, the trigger arm event must be specified as SGL. When the multimeter executes a TARM command specifying multiple arming, it holds the GPIB bus until all measurement cycles are complete. For example, if you specify *number_arms* as 5, and 10 readings per cycle (NRDGS command), there are 5 measurement cycles of 10 readings each. Since it holds the bus, the TARM command must be the last line in the program and you cannot use the synchronous trigger event or sample event.
- **Query command**: The TARM? query command returns the currently selected trigger arm event. Refer to Query commands near the front of' this chapter for more information.
- **Related commands**: NRDGS, SWEEP, TRIG

Examples

```
OUTPUT 722; "TARM AUTO, 0" !AUTO TRIGGER ARMING (ALWAYS ARMED)
```

```
10 OUTPUT 722; "TARM HOLD" !SUSPENDS MEASUREMENTS
20 OUTPUT 722; "OHM" !SELECTS 2-WIRE OHMS MEASUREMENTS
30 OUTPUT 722; "MEM FIFO !ENABLES READING MEMORY, FIFO MODE
40 OUTPUT 722; "NRDGS 5" !5 READINGS PER SAMPLE EVENT (AUTO)
50 OUTPUT 722; "TARM SGL" !ENABLES ONE SERIES OF MEASUREMENTS
60 END
```

```
10 OUTPUT 722; "DCV" !SELECTS DC VOLTAGE MEASUREMENTS
20 OUTPUT 722; "TARM HOLD" !SUSPENDS MEASUREMENTS
30 OUTPUT 722; "TRIG AUTO" !SELECTS AUTO AS THE TRIGGER EVENT
40 OUTPUT 722; "MEM FIFO" !ENABLES READING MEMORY, FIFO MODE
50 OUTPUT 722; "NRDGS 3, AUTO" !3 READINGS PER SAMPLE EVENT (AUTO)
60 OUTPUT 722; "TARM SGL,5" !SELECTS MULTIPLE ARMING FOR 5 CYCLES
70 END
```

In this program, line 60 arms the trigger once for each measurement cycle. This occurs five times. After the fifth cycle, trigger arming reverts to HOLD. This

program places 15 readings (3 readings per trigger event, 5 times) into reading memory.

Unless the input buffer is enabled, line 60 causes the GPIB bus to be held until all measurement cycles are complete. If you want to regain control of the bus immediately, suppress the cr lf by replacing line 60 with:

```
60 OUTPUT 722 USING "#,K"TARM SGL, 5;"
```

In the above line, the # image specifier suppresses the *cr lf*. The K image specifier suppresses trailing or leading spaces and outputs the command in free-field format. Notice the semicolon following the TARM SGL.5. This indicates the end of the command to the multimeter and must be present when you suppress *cr lf*.

TBUFF

Trigger buffer. Enables or disables the multimeter's external trigger buffer.

Syntax

TBUFF [*control*]

control

The *control* parameter choices are:

control parameter	Numeric query equiv.	Description
OFF	0	Disables the trigger buffer which enables the TRIGGER TOO FAST error
ON	1	Enables and clears the trigger buffer which disables the TRIGGER TOO FAST error

Power-on *control* = OFF.
Default *control* = OFF.

Remarks

– Setting TBUFF to ON corrects for a TRIGGER TOO FAST error that can occur when using an external EXT trigger arm, trigger, or sample event. With TBUFF OFF, any external trigger occurring during a reading generates the TRIGGER

TOO FAST error and the trigger(s) are ignored. With TBUFF ON, the first external trigger occurring during a reading is stored and no error is generated by this or any successive triggers. After the reading is complete, the stored trigger satisfies the EXT event if the multimeter is so programmed.

- Executing the RESET command sets TBUFF to OFF.
- **Query command**: The TBUFF? query command returns the present trigger buffering mode. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: EXTOUT, NRDGS, TRIG

Example

```
OUTPUT 722;"TBUFF ON" !DISABLES THE TRIGGER TOO FAST ERROR
```

TEMP?

Temperature query. Returns the multimeter's internal temperature in degrees Centigrade.

Syntax

TEMP?

Remarks

- Monitoring the multimeter's temperature is helpful to determine when to perform autocalibration.
- **Related commands**: ACAL, CAL, CALSTR

Example

```
10 OUTPUT 722; "TEMP?" !READ TEMPERATURE
20 ENTER 722; A !ENTER RESULT
30 PRINT A !PRINT RESULT
40 END
```

TERM

On previous multimeters, the TERM command internally connected or disconnected the multimeter's input terminals. The 3458A accepts the TERM command to maintain language compatibility with these multimeters, but does not respond since the 3458A's input terminals cannot be controlled from remote.

Syntax

TERM [*source*]

source

The *source* parameter choices are:

source parameter	Numeric query equiv.	Description
OPEN	0	Generates error message
FRONT	1	Generates error message if Terminals switch is set to Rear
REAR	2	Generates error message if Terminals switch is set to Front

Power-on *source* = none.
Default *source* = FRONT.

Remarks

- **Query command**: The TERM? query command returns a response indicating which input terminals (FRONT or REAR) are selected by the front panel Terminals switch.

TEST

Causes the multimeter to perform a series of internal self-tests.

Syntax

TEST

Remarks

- Always disconnect any input signals before you run self-test. If you leave an input signal connected to the multimeter, it may cause a self-test failure.
- If a hardware error is detected, the multimeter sets bit 0 in the error register and a more descriptive bit in the auxiliary error register. The display's ERR annunciator illuminates whenever an error register bit is set. You can access the error registers using ERRSTR? (both registers), ERR? (error register only), or AUXERR? (auxiliary error register only).
- **Related commands**: AUXERR?, ERR?, ERRSTR?

Example

```
OUTPUT 722;."TEST" !RUNS SELF-TEST
```

TIMER

The TIMER command defines the time interval for the TIMER sample event in the NRDGS command. When using the TIMER event, the time interval is inserted between readings.

Syntax

TIMER [*time*]

time

The valid range of the *time* parameter is (1 /maximum sampling rate) to 6000 seconds in 100 ns increments.

Power-on *time* = 1 second.
Default *time* = 1 second.

Remarks

- When using the TIMER event, the first reading occurs without the time interval. However, you can insert a time interval before the first reading using the DELAY command.
- When using the TIMER event, autoranging is suspended (typically you should select a fixed range when using the TIMER event). If autoranging was enabled when you specified the TIMER sample event, autoranging will resume when you specify another sample event.
- The SWEEP command can be used to replace the two commands: NRDGS*n*,TIMER and TIMER *n* for any measurement function. The SWEEP and NRDGS are interchangeable; the multimeter uses whichever command was executed last in the programming. Executing the SWEEP command automatically sets the sample event to TIMER. In the power-on, RESET, or PRESET state, the multimeter uses the NRDGS command. The power-on values for SWEEP can only be used for sub-sampling (since NRDGS does not apply to sub-sampling).
- You cannot use the TIMER (or SWEEP) event for AC or AC+DC voltage measurements using the synchronous or random methods (SETACV SYNC or RNDM) or for frequency or period measurements.
- **Query command**: The TIMER? query command returns the present time interval, in seconds, for the NRDGS timer event.
- **Related commands**: DELAY, NRDGS, SWEEP

Example

```
10 OUTPUT 722;"TRIG HOLD" !SUSPENDS MEASUREMENTS
20 OUTPUT 722;"INBUF ON" !ENABLES THE INPUT BUFFER
30 OUTPUT 722;"DCV 10" !DC VOLTAGE, 10 V RANGE
40 OUTPUT 722;"NPLC .1" !SELECTS .1 PLC OF INTEGRATION TIME
50 OUTPUT 722;"AZERO OFF" !DISABLES AUTOZERO
60 OUTPUT 722;"MEM FIFO" !ENABLES READING MEMORY (FIFO MODE)
70 OUTPUT 722;"TIMER 2" !SELECTS 2 SECOND INTERVAL
80 OUTPUT 722;"NRDGS 10 TIMER" !10 READINGS PER SAMPLE EVENT (TIMER)
90 OUTPUT 722;"TRIG SGL" !TRIGGERS ONCE
100 END
```

TONE

Causes the multimeter to beep once. The multimeter then returns to the previous BEEP mode (either OFF or ON).

Syntax

TONE

Related commands: BEEP

Example

```
OUTPUT 722; "TONE" ! BEEPS
```

TRIG

Specifies the trigger event.

Syntax

TRIG [*event*]

event

The *event* parameter choices are:

event parameter	Numeric query equiv.	Description
AUTO	1	Triggers whenever the multimeter is not busy
EXT	2	Triggers on low-going TTL signal on the Ext Trig connector
SGL	3	Triggers once (upon receipt of TRIG SGL) then reverts to TRIG HOLD)
HOLD	4	Disables readings
SYN	5	Triggers when the multimeter's output buffer is empty, memory is off or empty, and the controller requests data.
LEVEL[a]	7	Triggers when the input signal reaches the voltage specified by the LEVEL command on the slope specified by the SLOPE command.
LINE[b]	8	Triggers on a zero crossing of the AC line voltage

[a] The LEVEL trigger event can be used only for DC voltage and direct-sampled measurements.

[b] The LINE trigger event cannot be used for sampled AC or AC+DC voltage measurements (SETACV RDDM or SYNC) or for frequency or period measurements.

Power-on *event* = AUTO.
Default *event* = SGL.

Remarks

- For all measurements except sub-sampling (see Chapter 5), the trigger event operates along with the trigger arm event (TARM command) and the sample event (NRDGS command). (The trigger event and the sample event are ignored for sub-sampling.) To make a measurement, the trigger arm event must occur first, followed by the trigger event, and finally the sample event. The trigger event does not initiate a measurement. It merely enables a measurement, making it possible for a measurement to take place. The measurement is initiated when the sample event (NRDGS or SWEEP command) occurs. Refer to Triggering Measurements in Chapter 4 for an in-depth discussion of the interaction of the various events for most measurement functions. Refer to Chapter 5 for information on sub-sampling.
- **Query command**: The TRIG? query command returns the specified trigger event. Refer to Query commands near the front of this chapter for more information.
- **Related commands**: LEVEL, LFILTER, NRDGS, SLOPE, SWEEP, T, TARM, TBUFF

Examples

```
OUTPUT 722; "TRIG AUTO" !SELECTS AUTO TRIGGER
```

The following program shows a method to suspend measurements until the multimeter is properly configured. Line 20 suspends measurements by setting the trigger event to HOLD. Lines 30 and 40 configure for 30 DC voltage readings per trigger event. Line 50 generates a single trigger causing the multimeter to make thirty readings. After the readings are complete, the trigger event reverts to HOLD.

```
10 OUTPUT 722;“RESET" !RETURN TO POWER-ON STATE
20 OUTPUT 722;"TRIG HOLD" !SUSPEND READINGS
```

```
30 OUTPUT 722;"DCV 10" !DC VOLTAGE MEASUREMENTS,10 V RANGE
40 OUTPUT 722;"NRDGS 30,AUTO" !30 READINGS PER SAMPLE EVENT (AUTO)
50 OUTPUT 722;"TRIG SGL" !GENERATES A SINGLE TRIGGER
60 END
```

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Introduction

This chapter describes the BASIC commands supported by the 3458A's internal BASIC language operating system. With this feature, many of your special requirements can be easily satisfied by writing and downloading a simple BASIC subprogram to customize the multimeter's behavior. The following is a list of possible situations where you might find the internal BASIC language to be useful.

- Customize the front-panel display readouts for enhanced user-friendliness.
- Add new measuring functions, math operations, or specialized transducer linearizations.
- Configure the multimeter to run extra high-throughput system measurements.
- Perform GPIB intensive data reduction internal to the multimeter.
- Download your Motorola 68000 binary programs for FFTs, etc.
- Keysight custom binary programs to satisfy your special needs.

How It Works

Simply create a new subprogram in the 3458A's program memory space using the multimeter's SUB command. You may include any multimeter commands as discussed in chapter 6. You may also include any of the new BASIC language commands described in this supplement to build simple BASIC programs. *It's that easy – and yes, these commands will work with all revisions of the* 3458A*'s instrument firmware (except as noted).*

Subprograms can be called from the GPIB bus, assigned to a front-panel user-defined key (F0 through F9) for a single key press operation, or called from within another subprogram.

The 3458A's BASIC language *does not* support the following concepts.

- String variables and operations
- Line numbers
- GOTO statements
- GOSUB statements
- Local variables (all variables are global)
- Parameter passing
- Any other BASIC commands not listed in this supplement.

BASIC Language Commands

This section gives you an overview of the BASIC language commands that are supported by the 3458A's internal BASIC language operating system. Refer to the later sections in this chapter for more detailed information and examples on these commands.

Variables and arrays

NOTE All array indexes are 0 to *size* (option base 0).

LET *user_variable = expression*

REAL *variable_l, variable_2, . . .* Declares a type real user variable. Also accepts REAL *variable_l (size)* for declaring a real array. REAL is a 64-bit value.

INTEGER *variable_l, variable_2, . . .* Declares a type integer user variable. Also accepts INTEGER *variable_1 (size)* for declaring an integer array. INTEGER is a 16-bit value.

DIM *array_name (size), . . .* Dimensions an array.

FILL *array_name, list* Fills the named array with data from the following number list. Filled arrays are stored in *volatile* memory space.

NOTE

RESTRICTIONS ON USING VARIABLES IN SUBPROGRAMS

ALL subprograms that refer to a given variable must define it. The definition for a given variable must match all other definitions for the same variable name. If the definition for a user variable varies between subprograms, you may have problems when you cycle power. This is due to the way that the subprograms are stored internally to conserve memory. The subprogram executable code is actually rebuilt internally during the multimeter's power-on start-up routines.

Use the FILL command carefully. It does not work if power is cycled, the command is effectively deleted from the subprogram at this time. Use separate LET statements for each value assigned.

Math operations

```
Numeric Operations: +, -, *, /, ^
                    =,   >,   <,   >=,   <=,   <>
                    DIV, MOD, ABS, SQR, LOG, EXP, LGT, SIN, COS, ATN
Binary Operations: AND, OR, EXOR, NOT, BINAND, BINCMP, BINEOR,
                    BINIOR, BIT, ROTATE, SHIFT
```

Subprogram definition/deletion

SUB *sub_name* Identifies where the subprogram begins and assigns the name to the subprogram.

SUBEND *sub_name* Identifies where the subprogram ends and also terminates the entry of the subprogram.

DELSUB *sub_name* Deletes the specified subprogram from internal memory.

SCRATCH Deletes (scratches) all 3458A subprograms, variables, and arrays from internal memory.

CAT Lists the names of all 3458A subprograms, simple variables, stored states, and arrays that are presently stored in internal memory (limited to 400 characters).

LIST *sub_name* Lists the specified subprogram (limited to 400 characters).

COMPRESS *sub_name* Removes the text of the specified subprogram from memory.

Subprogram execution commands

CALL *sub_name* Executes the named subprogram and waits for completion before executing other commands.

PAUSE Pauses the most recent subprogram executed with the CALL command.

CONT Resumes subprogram execution after a PAUSE command is executed.

Looping and branching

FOR *counter =initial_value* **TO** *final-value* [**STEP** *step_size*]
NEXT counter

WHILE *expression*
ENDWHILE

IF expression **THEN**
[**ELSE**]
ENDIF

Binary programs

CALLARRAY *array name, integer_list* Fetches the internal address of the specified array and begins execution there.

The array must have been previously loaded with data (*converted to ASCII*) using the FILL command. The binary data must be Motorola 68000 executable code written using relative addressing.

New Multimeter Commands

The following commands are not documented in chapter 6 but are included in this supplement for your convenience. These commands will work with all revisions of the 3458A's instrument firmware (except as noted).

ENTER *user_variable* Transfers a reading from the multimeter's reading memory to a user variable. The multimeter reading is erased after execution. *Example:* ENTER Dmm

OUTPUT *user_variable* Outputs the present value of a user variable. The data is sent to either to the display or GPIB output buffer based on the source from which the subprogram was executed. *Example*: OUTPUT Result

U_RANGE Up ranges once in the present function.

D_RANGE Down ranges once in the present function.

DSP *string* or *user_variable* Outputs to the multimeter's front-panel display both text and user variable data (*available only in REV 2.1 firmware and greater*).

DSP? Reads the present front-panel display.

SCROLL LEFT | **RIGHT** Scrolls the present front-panel display one character to the left or right. This applies only to text sent with the DISP command (for more information see chapter 6).

ECHO *string* Echoes the specified string back to either the multimeter's front-panel display or GPIB. The data is sent to either to the display or GPIB output buffer based on the source from which the subprogram was executed.

RETURN Used in a subprogram to return before the SUBEND statement.

RMATHV *register, user_variable* Reads a standard multimeter math register into a user variable (*available only in REV 5. 1 firmware and greater*).

WAIT *msec* Wait before executing the next command (32 seconds maximum).

3458A BASIC Language Example Program

The following example program illustrates the use of the 3458A's internal BASIC language along with the use of new multimeter commands. This program example uses a Series 300 BASIC computer for program development and for downloading the program to the multimeter over the GPIB interface. The multimeter's bus address is 22 and the computer's GPIB interface address is set to 700.

```
 10 !
 20 ! The following program uses the 3458A to calculate
 30 ! the mean (throwing away the largest and smallest values).
 40 ! Four BASIC language commands are used:
 50 ! RMATHV, LET, REAL, and OUTPUT.
 60 !
 70 !
 80 ! RMATHV - Fills a variable with the present value of
 90 !          a math register; similar to RMATH.
100 !
110 ! OUTPUT - Returns the value to the source from which the command
120 !          was executed (since the example called the
130 !          subprogram from the GPIB bus, the value of
140 !          AVG is sent over the bus).
150 !
160 ! LET and REAL - Assign values to the specified variables.
170 !
180 !
190 !
200 DIM Rdgs(1:300)               ! Dimension data array in computer
210 ASSIGN @Dvm TO 722            ! Set up GPIB address
220 !
230 CLEAR @Dvm
240 OUTPUT @ Dvm; "RESET"
250 WAIT 0.5
260 !
270 OUTPUT @Dvm; "PRESET FAST"
280 OUTPUT @Dvm; "OHM 1000"
290 OUTPUT @Dvm; "APER 167E-6"
300 OUTPUT @ Dvm; "OFORMAT ASCII"
310 OUTPUT @Dvm; "MEM FIFO"
320 OUTPUT @Dvm; "NRDGS 300,TIMER"   ! Set up to acquire 300 readings
330 OUTPUT @Dvm; "TIMER 0.0002"      ! 5000 Rdgs/sec sample rate
340 !
350 !
```

```
360 !
370 OUTPUT @Dvm; "SUB CALC_MEAN"        ! Start of DMM subprogram
380 OUTPUT @Dvm; "REAL BIG,SMALL,AVG"   ! Dimension user variables
390 OUTPUT @Dvm; "MMATH STAT"
400 OUTPUT @Dvm; "RMATHV MEAN, AVG"     ! New DMM command
410 OUTPUT @Dvm; "RMATHV UPPER, BIG"    ! New DMM command
420 OUTPUT @Dvm; "RMATHV LOWER, SMALL"  ! New DMM command
430 OUTPUT @Dvm; "LET M=(AVG*300-BIG-SMALL)/298" !Expression to calc M
440 OUTPUT @Dvm; "OUTPUT M"             ! Send calc'ed result to bus
450 OUTPUT @Dvm; "SUBEND"               ! End of DMM subprogram
460 OUTPUT @Dvm; "TARM SGL"             ! Trigger dmm acquisition
470 T0=TIMEDATE                         ! Store start time
480 T1=TIMEDATE
490 OUTPUT @ Dvm; "CALL CALC_MEAN"      ! Tell DMM to execute sub
500 ENTER @Dvm; Mean                    ! Read M into computer
510 T2=TIMEDATE                         ! Store end time
520 PRINT"MEAN";Mean;"TRANSFER AND CALCULATION SPEED";T2-T1-(T1 -T0)
530 PRINT
540 END
```

Sample results from program execution:

```
MEAN 54.73391112 TRANSFER AND CALCULATION SPEED .399963378906
```

Variables and Arrays

The 3458A employs two forms of numeric variables: simple variables (also called "scalars") and subscripted arrays. Variable usage in the 3458A is very similar to variable usage in an enhanced BASIC language. The 3458A *does not* provide string variables. All variables are global among front panel, GPIB. and subprogram operations. This means that you can dynamically change variable values.

Type declarations

The 3458A uses two data types for its variables: Integer or Real. All variables are real unless you declare them as integer. The valid range for real numbers is:

$-1.797\ 693\ 134\ 862\ 315 \times 10^{308}$ to $1.797\ 693\ 134\ 862\ 315 \times 10^{308}$

The smallest non-zero real value allowed is:

$\pm 2.225\ 073\ 858\ 507\ 202 \times 10^{-308}$

A real number can have a value of zero.

An integer can have any whole-number value from:

–32767 through +32767

The DIM command declares real arrays. The INTEGER command declares integer variables or arrays. The REAL command declares real variables or arrays.

The following program statement declares real array A with 10 elements (numbered 0 through 9).

```
OUTPUT 722; "DIM A(9)"
```

The following program statement declares integer array IARRAY with 10 elements (numbered 0 through 9) and integer variable B.

```
OUTPUT 722; "INTEGER IARRAY(9),B"
```

The following program statement declares real array RARRAY with 10 elements (numbered 0 through 9) with real variable C.

```
OUTPUT 722; "REAL RARRAY(9), C"
```

The 3458A declares variables automatically when a variable name appears in an assignment statement with the LET command. For example, the following statements automatically declare the variable names specified.

```
OUTPUT 722; "LET A=SIN(.223)"
```

```
OUTPUT 722; "LET B=3.14159"
```

Some 3458A commands expect a specific variable type when defining variables for parameters. For example, the TIME command expects a real number. Similarly, commands which return numeric results will return specific number types. The LINE? command returns an integer number. Measurements returned are real numbers. All variables are REAL unless otherwise specified.

NOTE

PROGRAMMING HINT

Once you declare an array type, you cannot re-declare it as a different type without scratching memory first (see the SCRATCH command in chapter 6). If you refer to a real number within a command that expects an integer, the 3458A converts the real number to an integer. Likewise, if you refer to an integer number within a command that expects a real number, the 3458A converts the integer number to a real number. Therefore, you can minimize system overhead time by allocating variables according to their use. For example,
OUTPUT 722; "REAL TIME_INT; LET TIME_INT=2.25; TIMER TIME_INT"

Type conversions

The 3458A automatically converts between real and integer values whenever necessary. When real numbers are converted to integer representations, information may be lost. Two potential problem areas exist in this conversion, rounding errors and range errors.

- When a real number is converted to an integer, the real value is rounded to the closest integer value. All information to the right of the decimal point is lost.
- Range errors exist when converting real values to integer values. While real values range from approximately -10^{308} to $+10^{308}$,the integer range is only from –32768 to +32767 (approximately -10^{4} to $+10^{4}$). Therefore, not all real numbers can be rounded to an equivalent integer value. This problem can generate “Integer Overflow” error.

Using variables

Simple variable and array names may contain up to 10 characters. The first character must be a letter (A–Z) but the remaining nine characters can be letters, numbers (0–9), the underscore character ("_"), or the question mark ("?"). Upper case is the same as lower case. *Variable names must not be the same as* 3458A *commands, parameters, or stored state names.*

You can assign any numeric variable with the LET command (the keyword "LET" is required). For example, the following statements are equivalent.

```
OUTPUT 722; "LET TIME_INT = 120E-3"

OUTPUT 722; "LET TIME_INT =40*3E-3"
```

Variables can replace numeric parameters in any 3458A command that uses numeric parameters. Two examples uses are (1) numeric data storage and (2) numeric calculations. The following sections discuss these two uses.

Variables for data storage

At power-on, numeric output data generated by the 3458A is placed into the GPIB output buffer where it can be sent to the system controller. However, for some applications you may want to store the output data directly into the multimeter's internal memory. The ENTER command takes one reading out of reading memory (destructively) and places the value in the specified variable or array location.

The following program uses the ENTER command within a 3458A subroutine to store readings.

```
10 OUTPUT 722; "SUB DMM_CONF"
20 OUTPUT 722; "NRDGS 100"
30 OUTPUT 722; "TRIG SGL"
40 OUTPUT 722; "INTEGER I"
50 OUTPUT 722; "FOR I = 1 TO 100"
60 OUTPUT 722; " ENTER A[I]"
70 OUTPUT 722; "NEXT I"
80 OUTPUT 722; "SUBEND"
90 !
100 OUTPUT 722; "CALL DMM_CONF"
110 END
```

Numeric calculations

Any variables, whether simple or array, can be used in numeric calculations. Several math functions are available in the 3458A command set to allow you to manipulate data. The 3458A's math functions are described in more detail later in this supplement.

Reading multimeter values

The OUTPUT command returns the value of a specified variable. An example is included below to illustrate the use of the OUTPUT command.

```
10 DIM A$[50]!Dimension controller variable
20 OUTPUT 722; "LET VAL=COS(.5235)!Compute value
30 OUTPUT 722; "OUTPUT VAL"!Read result into variable
40 ENTER 722: A$!Enter result
50 PRINT A$!Print result
60 END
```

Arrays

You can allocate memory space in the 3458A for one-dimensional arrays. For real arrays, use either the DIM *name(size)* or REAL *name(size)* commands to define the array. For integer arrays, use the INTEGER *name(size)* command. All arrays have a lower bound of zero (option base 0). Arrays do not have a default size. For example, to create a 10-element array, specify a size of 9 as shown below.

```
OUTPUT 722; "DIM TESTER(9)"
```

Array names are subject to the same rules as numeric variable names. To specify a particular array element, you must specify the subscript enclosed in parentheses. The range of subscripts is an integer from 0 through 999, but the maximum array size is determined by available 3458A memory (approximately 10 kbytes if no stored states or subprograms are stored). A non-integer subscript is rounded to the nearest integer.

Arrays may be resized by re-declaring them. This initializes each element in the array to a value of zero. You cannot, however, redefine the type of array (real or integer) without scratching memory first (refer to the SCRATCH command in chapter 6). Array elements may be used in the same ways simple variables are used.

Filling arrays

Array elements are initialized to zero when they are declared (DIM, REAL, or INTEGER commands) or are re-sized. Once you have dimensioned an array, use the FILL command to load your values into the array. The FILL command has the following syntax:

```
FILL array_name, list
```

The following program fills an integer array with integer values.

```
10 OUTPUT 722; "INTEGER LIST(9)"
20 OUTPUT722; "FILL LIST 0,100,200,300,400,500,600,700,800,900"
30 END
```

NOTE Use the FILL command *carefully*. It does not work if power is cycled. The command is effectively deleted from the subprogram at this time. Use separate LET statements for each value assigned.

Array size

The SIZE? query command returns the number of elements in the specified array. This number is one more than the index of the last element in the array due to the option base 0 convention used by the 3458A. Thus, if you dimension a 10-element array (e.g., DIM LIST(9)), the SIZE? command will return "10".

The following program defines an integer array with 10 elements and then verifies the array size using the SIZE? command.

```
10 OUTPUT 722; "INTEGER IARRAY(9)"
20 OUTPUT 722; "SIZE? IARRAY"
30 ENTER 722; A
40 PRINT A
50 END
```

Purging arrays and variables

All variables and arrays are stored in 3458A volatile memory. If the 3458A loses power, all variables and arrays are lost. The SCRATCH command also purges all variables, arrays, subprograms, and stored state names (stored states are explained in chapter 3).

General Purpose Math

You can use general purpose math expressions, following standard BASIC language conventions, from either the front-panel keyboard, the system controller, or within 3458A subprograms. The standard math operators, general math functions, trigonometric functions, and binary functions are available. The 3458A also has a simple calculator mode.

Math operators

In addition to the standard math operators (+ – * / ^), two additional arithmetic operators exist in the 3458A. These operators are DIV (integer division) and MOD (modulo). Unary minus operations should be written as:

```
A = 0-B
```

The DIV command returns the integer portion of a division. Normal division takes place but all digits to the right of the decimal point are truncated (not rounded). The following program divides 7 by 3 and displays the integer portion of the division (2) on the system controller.

```
10 OUTPUT 722; "OUTPUT(7 DIV 3)"
20 ENTER 722; A
30 PRINT "DIV Result ="; A
40 END
```

Typical Printout:

```
DIV Result = 2
```

The MOD command returns the remainder portion of a division. As with the DIV command, normal division takes place; however, MOD returns only the remainder. The following program divides 7 by 3 and displays the remainder portion of the division (1) on the system controller.

```
10 OUTPUT 722; "OUTPUT(7 MOD 3)"
20 ENTER 722; A
30 PRINT "MOD Result="; A
40 END
```

Typical Printout:

```
MOD Result=1
```

Relational math operators (< > <= >= <>) and logical operators (AND and OR) are allowed in any expression.

General math functions

The following table lists the general math functions available in the 3458A. The arguments (denoted by "X" and "Y") may be numbers, numeric variables, functions, array elements, or numeric expressions in parentheses.

Function/Argument	Meaning
ABS(X)	Absolute value of argument.
SQR(X)	Positive square root of argument.

Logarithmic functions

The 3458A can compute both natural and common logarithms. The logarithmic functions are shown in the following table.

Function/Argument	Meaning
LOG(X)	$Log_e(X)$: Natural logarithm of a positive argument to the base e (2.71828).
EXP(X)	e^X: Natural antilogarithm. Raises e to the power of the argument.
LGT(X)	Log_{10}: Common logarithm of a positive argument to the base 10.

Trigonometric Functions

Three trigonometric functions are provided in the 3458A. The trigonometric functions are shown in the following table.

Function/Argument	Meaning (X in radians)
SIN(X)	Sine of argument.
COS(X)	Cosine of argument.
ATN(X)	Arctangent of argument.

Logical functions

The 3458A has four logical functions: AND (inclusive-AND), OR (inclusive-OR), EXOR (exclusive-OR), and NOT (logical inverse). The first three functions compare the two arguments and return either a “0” or a “1” based on the respective truth table. Any non-zero value (positive or negative) in an argument is considered a logical “1”. Only zero is treated as a logical “0”.

The logic function commands have the following syntax. The truth tables for the four functions are shown below.

argument **AND** *argument*

argument **OR** *argument*

argument **EXOR** *argument*

NOT argument

A	B	A AND B	A OR B	A EXOR B	NOT A	NOT B
0	0	0	0	0	1	1
0	1	0	1	1	1	0
1	0	0	1	1	0	1
1	1	1	1	0	0	0

Binary functions

The 3458A provides seven binary functions. These can help in digital pattern generation. When using the binary functions, argument values ("X" and "Y") of real variables are rounded to integers in the range –32768 to +32767. The binary functions are shown in the table below.

Function/Argument	Meaning
BINAND(X,Y)	Bit-by-bit logical AND of the arguments.
BINCMP(X)	Bit-by-bit binary complement of the argument.
BINEOR(X,Y)	Bit-by-bit logical Exclusive-OR of the arguments.
BINIOR(X.Y)	Bit-by-bit logical Inclusive-OR of the arguments.

Function/Argument	Meaning
BIT(X,position)	Returns “0” or “1” representing the logic value of the specified bit of the argument. The bit position is in the range 0 (lsb) to 15 (msb).
ROTATE(X,displacement)	Returns an integer obtained by rotating the argument a specified number of positions *with bit wraparound*[a]
SHIFT(X,displacement)	Returns an integer obtained by rotating the argument a specified number of positions *without bit wraparound*.*

[a] If the displacement is positive, rotating or shifting is toward the least significant bit. If the displacement is negative, rotating or shifting is toward the most significant bit.

Math hierarchy

The 3458A evaluates parenthetical expressions before evaluating any math functions outside of parentheses. If two or more operations of the same priority are in the expression, the hierarchy is from left to right

.

Highest Priority	Parentheses
	Functions: SIN, COS, etc.
	Exponentiation
	*, /, MOD, DIV
	+, –
Lowest Priority	Relational Operators: <, >, < =, >=, etc.
	logical operators: AND, OR, etc.

Math errors

When evaluating a math expression, the following errors may occur. The 3458A treats math errors just like any other execution errors. Refer to chapter 3 for more information on handling errors.

Error description
Division by Zero
Real Overflow
Real Underflow
Integer Overflow
Square Root of a Negative Number
Log of a Non-Positive Number
Illegal Real Number
Trig Argument Out of Range
BCD Exponent Too Big
HEX, Octal, or Decimal Argument Error

Making comparisons work

If you are making mathematical comparisons between integer numbers, no special precautions are necessary. However, if you are comparing REAL numbers, especially those which are the results of calculations, it is possible that you might run into problems due to rounding and other limitations inherent in the system. For example, consider the use of the IF...THEN statement to check for equality in any situation resembling the following example.

```
10 OUTPUT 722; "SUB TESTER"
20 OUTPUT 722; "LET A=25.3765477"
30 OUTPUT 722; "IF SIN(A)^2 + COS(A)^2 = 1 THEN"
40 OUTPUT 722; " DISP 'EQUAL'"
50 OUTPUT 722; "ELSE"
60 OUTPUT 722; " DISP'NOT EQUAL'"
70 OUTPUT 722; " ENDIF"
80 OUTPUT 722; "SUBEND"
```

```
90 !
100 OUTPUT 722; "CALL TESTER"
110 END
```

You may find that the equality test fails due to rounding errors or other errors caused by the inherent limitations of finite machines. A repeating decimal or irrational number cannot be represented exactly in any finite machine like the 3458A.

A good example of equality error occurs when multiplying or dividing numbers. A product of two non-integer values nearly always results in more digits to the right of the decimal point than existed in either of the two numbers being multiplied.

Subprograms

The 3458A can store and execute BASIC language subprograms. These subprograms can either be downloaded into 3458A memory from a remote system controller (such as one of the HP Series 200/300 computers) or you can enter the subprogram from the front-panel keyboard. This section acquaints you with the structure and usage of subprograms. It also discusses specific commands, which are used within subprograms.

A subprogram is a series of 3458A commands beginning with the SUB command and ending with the SUBEND command. The SUB command assigns a name to the subprogram which you use to execute the subprogram at a later time. Subprograms are stored in 3458A non-volatile memory.

Subprograms downloaded into the 3458A can be executed later with a single command from the system controller or front-panel keyboard. This allows the system controller to perform other tasks while the 3458A is busy with other activities. This provides multi-tasking capability to your system controller because the 3458A is acting like a separate computer running tasks by itself. Also, commands within an 3458A subprogram execute faster than those same commands received over the GPIB because of the way the 3458A stores the subprogram commands internally.

What Commands Are Allowed Within a Subprogram?

Most commands for the 3458A may be stored and executed inside a subprogram. The only commands which cannot be stored are CONTINUE, COMPRESS, DELSUB, and SCRATCH. Three conditional and looping commands are provided for use within subprograms.

How Many Different Subprograms Can Be Stored?

The exact number of subprograms which can be stored in 3458A memory depends on the individual sizes of the subprograms. A typical subprogram containing 10 commands (including the SUB and SUBEND commands) might average about 600 bytes. Refer to chapter 3 for more information on memory usage.

Can I Nest Subprograms?

Yes! Nesting subprograms is the ability to have one subprogram call (execute) another subprogram. You can nest up to 10 subprograms.

Writing and Loading Subprograms

The subprogram example programs in this section illustrate relatively simple 3458A operations which you can copy and use in more complex mainline programs of your own design. This section also shows how to create and edit subprograms.

NOTE

PROGRAMMING HINT

You should execute the SCRATCH command and download the subprograms from your system controller at the beginning of your test system program. This helps memory management for the 3458A and ensures that the subprograms are downloaded and ready when they are needed.

Executing the SUB command instructs the 3458A to store all subsequent commands, until the SUBEND command, in the specified subprogram.

Subprogram names may contain up to 10 characters. The first character must be a letter (A–Z) but the remaining nine characters can be letters, numbers (0–9), the underscore character ("_"), or the question mark ("?"). Subprogram names must not be the same as 3458A commands or parameters, previously defined array or variable names, or stored state names.

The following program shows how to create a simple subprogram which configures the multimeter to make three dc voltage measurements.

```
10 OUTPUT 722; "SUB DMM_CONF"
20 OUTPUT 722; "DCV8,0.00125"
30 OUTPUT 722; "NRDGS 3"
40 OUTPUT 722; "TRIG SGL"
50 OUTPUT 722; "SUBEND"
60 END
```

The two statements SUB DMM_CONF and SUBEND along with the three commands on line 20, 30, and 40 form the subprogram named DMM_CONF.

When a subprogram is entered, the 3458A checks for syntax errors just like any other commands. If the syntax is not correct, an error is generated and the command is not stored in the subprogram. You must then edit your subprogram in the system controller and download it again. The 3458A stores the subprogram in non-volatile memory. You can then execute the subprogram from either the front-panel keyboard or the system controller. The subprogram will not be stored

if a subprogram nesting error exists when the SUBEND command is executed (e.g., if one of the called subprograms does not exist in 3458A memory).

If you create or download a subprogram using a subprogram name which already exists in 3458A memory, the new subprogram overwrites the previous subprogram.

Subprogram Command Types

The 3458A's subprogram-related commands are used only within subprograms. Subprogram definition and deletion commands deal with the storage. viewing, and deletion of subprograms from internal memory. Execution commands control execution of subprograms from inside or outside a subprogram.

Definition/Deletion commands

Subprogram definition and deletion commands identify the beginning and end of subprograms, store and delete subprograms from memory, and list the subprograms presently stored in internal memory.

The syntax statements for the subprogram definition and deletion commands are shown below.

SUB *sub_name*

SUBEND

DELSUB *sub_name*

SCRATCH

CAT

LIST *sub_name*

COMPRESS *sub_name*

SUB/SUBEND

Every 3458A subprogram must contain a SUB and SUBEND command. The SUB command must be the first line in all 3458A subprograms. It identifies where the subprogram begins and assigns the name to the subprogram. When the SUB command is executed, the 3458A begins storing the subprogram in internal memory.

The SUBEND command must be the last line in all 3458A subprograms. It identifies where the subprogram ends and also terminates the entry of the subprogram. Commands listed between the SUB and SUBEND commands are executed, in order, every time the subprogram is executed.

Only one SUB and one SUBEND command is allowed in any one subprogram. Additional SUB or SUBEND commands will generate errors.

DELSUB

The DELSUB (delete subprogram) command deletes the specified subprogram from internal memory but does not delete the subprogram name itself from the catalog listing of subprograms (CAT command).

SCRATCH

The SCRATCH command deletes (scratches) all 3458A subprograms, variables, and arrays from internal memory. It also deletes all name definitions from the catalog listing (CAT command). If SCRATCH is executed when a subprogram is running, an error is generated but the subprogram is not purged from memory.

CAT

The CAT (catalog) command lists the names of all 3458A subprograms, simple variables, stored states, and arrays that are presently stored in internal memory. If there are no more arrays or subprograms to be listed, the CAT command returns the word “DONE”. Refer to chapter 3 for more information on stored states. The format for the catalog is:

For Subprograms: **SUB** *sub_name*

For Integer Arrays: **IARRAY** *array_name*

For Real Arrays: **RARRAY** *array_name*

For Stored States: **STATE** *state_name* (non-volatile memory)

For Simple Variables: **INT** *variable_name*
REAL *variable_name*

The following program shows how to use the CAT command.

```
10 DIM A$[80]
20 OUTPUT 722; "CAT"
30 REPEAT
40   ENTER 722; A$
50   PRINT A$
60 UNTIL A$="DONE"
70 END
```

LIST

The LIST command allows you to list the specified subprogram. Keep in mind that you cannot edit subprograms from the front panel; you must edit them from your

system controller. The following program shows how to list the subprogram DMM_CONF to your system controller.

```
10 DIM A$[100]
20 OUTPUT 722; "LIST DMM_CONF"
30 REPEAT
40   ENTER 722; A$
50   PRINT A$
60 UNTIL A$="SUBEND"
70 END
```

COMPRESS

The COMPRESS command removes the text of the specified subprogram from internal memory (the subprogram is no longer stored in non-volatile memory and is lost when power is removed). This saves space in internal memory but eliminates the ability to list (LIST command) the subprogram. The COMPRESS command should be used only after the subprogram has been debugged and tested.

Execution Commands

Subprogram execution commands control the execution of a subprogram. The syntax statements for the subprogram execution commands are shown below.

CALL *sub_name*

PAUSE

CONT

Subprogram CALL

The CALL command executes the named subprogram and waits for completion before executing other commands This means that no subsequent commands are accepted (either from the GPIB interface or the front-panel keyboard) until the subprogram finishes. The Ready Bit (bit 4 in the 3458A Status Register) remains "0" while the subprogram is executing. When the subprogram finishes execution, the Ready Bit is set to "1" indicating that the 3458A is ready to receive additional commands.

The CALL command may also be used in a subprogram to call another subprogram. This provides the expanded capability of "nested" subprograms. When using nested subprograms, the calling subprogram is suspended so that

only one subprogram is running at a time. Subprograms can be nested up to 10 deep.

Subprogram PAUSE

The PAUSE command pauses the most recent subprogram executed with the CALL command. Once a subprogram has been paused, you must execute the CONT (continue) command to resume execution. The CONT command allows the subprogram to continue running to completion, starting with the next command after the PAUSE command.

The 3458A will generate an error if you attempt to execute the CONT command when a subprogram is not paused.

Knowing When a Subprogram is Paused

The PAUSED? query command returns a "1" if the subprogram is currently paused or a "0" if the subprogram is running (or finished running). The following program shows how to use the PAUSED? command.

```
10 OUTPUT 722; "RUN DMM_CONF;PAUSE"
20 OUTPUT 722; "PAUSED?"
30 ENTER 722; A
40 IF A=1 THEN PRINT "SUBPROGRAM IS PAUSED"
50 IF A=0 THEN PRINT "SUBPROGRAM IS NOT PAUSED"
60 END
```

Aborting a Subprogram

The GPIB CLEAR command (see Appendix B) aborts execution of a subprogram executed with the CALL command. This returns control to the GPIB command input buffer or the front-panel keyboard.

Exiting a Subprogram

A subprogram will continue to execute until it reaches the SUBEND command. Control then reverts back to either the subprogram that called it (nested subprograms) or to the GPIB input buffer or front-panel keyboard (whichever executed the subprogram). The RETURN command can also be used to end the subprogram. For example, if you want to have a conditional termination of the subprogram, place RETURN within an IF...THEN loop in the subprogram. The RETURN command returns control to the caller without executing the SUBEND command. For example,

```
10 OUTPUT 722; "SUB DMM_CONF"
20 OUTPUT 722; "DCV 8, 0.00125"
30 OUTPUT 722; "TRIG SGL"
40 OUTPUT 722; "ENTER A'
60 OUTPUT 722; "IF A<5.06 THEN; RETURN"
70 OUTPUT 722; "ELSE"
80 OUTPUT 722; "TRIG SGL"
90 OUTPUT 722; "ENDIF"
100 OUTPUT 722; "SUBEND"
110 !
120 OUTPUT 722; "CALL DMM_CONF"
130 END
```

Nesting Subprograms

One subprogram may call a second (nested) subprogram for execution before the first subprogram finishes execution. When the second subprogram executes the SUBEND command, the first subprogram continues with the next command following the embedded CALL command.

The 3458A has two requirements for nesting subprograms. First, the subprogram called from within another subprogram must be stored in internal memory before the subprogram doing the calling is stored. This is because the 3458A checks the syntax of each command as it stores the subprogram. When it encounters an embedded CALL command, the 3458A checks to see if a subprogram by that name exists in memory. If not, it generates an error. Second, subprograms may not be nested more than 10 levels deep. You cannot place one subprogram inside of another subprogram. For example, the following program will generate an error.

```
10 OUTPUT 722; "SUB DMM_CONF"
20 OUTPUT 722;"DCV8,0.00125"
30 OUTPUT 722; "SUB TESTER" !This results in an error
40 OUTPUT 722; "SUBEND"
50 !
60 OUTPUT 722; "CALL DMM_CONF"
70 END
```

Conditional Statements in Subprograms

The 3458A provides three BASIC language statements for conditional branching and looping. Use these statements only within 3458A subprograms. Conditional branching and looping statements provide for repetitive tests, initializing arrays, etc.

The three conditional statements are: FOR...NEXT, WHILE...ENDWHILE, and IF...THEN. These statements are similar to those used in an enhanced BASIC language. The only exception is that 3458A subprograms do not have line numbers or GOTO statements for branching. Looping and conditional branching statements may be nested seven deep.

FOR...NEXT Loops

The FOR...NEXT command defines a loop which is repeated until a loop counter passes a specified value. The syntax statement for the FOR...NEXT command is shown below.

FOR *counter* = *initial_value* TO *final_value* [STEP *step_size]*

program segment

NEXT *counter*

The *counter* parameter is a variable name which acts as the loop counter. The *initial_value* parameter and *final_value* parameter may be numbers, numeric variables, or numeric expressions. The optional *step_size* parameter may be a number or numeric expression which specifies the amount the loop counter is incremented for each pass through the loop. A negative value for *step_size* decrements the loop counter. The program segment is repeatedly executed until the loop counter exceeds the *final_value*.

```
10 OUTPUT 722; "SUB DMM_CONF"
20 OUTPUT 722; "NRDGS 100"
30 OUTPUT 722; "TRIG SGL"
40 OUTPUT 722; "INTEGER I"
50 OUTPUT 722; "FOR I = 1 TO 100"
60 OUTPUT 722; " ENTER A[ I]"
70 OUTPUT 722; "NEXT I"
80 OUTPUT 722; "SUBEND"
90 !
```

```
100 OUTPUT 722; "CALL DMM_CONF"
110 END
```

WHILE Loops

The WHILE command defines a loop which is repeated as long as the specified numeric expression is true. The syntax for the WHILE command is shown below.

WHILE *expression*

program segment

ENDWHILE

The WHILE operation depends on the result of a test performed at the start of the loop. If the test is true (not equal to zero), the program segment between the WHILE and ENDWHILE statements is executed and a branch is made back to the WHILE statement. If the test is false (equal to zero), program execution continues with the statement following the ENDWHILE statement.

```
 10 OUTPUT 722; "SUB DMM_CONF"
 20 OUTPUT 722; "INTEGER I"
 30 OUTPUT 722; "LET I=1"
 40 OUTPUT 722; "NRDGS 100"
 50 OUTPUT 722; "TRIG SGL"
 60 OUTPUT 722; "WHILE I <=100"
 70 OUTPUT 722; " ENTER A[I]"
 80 OUTPUT 722; " LET I=I+1"
 90 OUTPUT 722; "ENDWHILE"
100 OUTPUT 722; "SUBEND"
110 !
120 OUTPUT 722; "CALL DMM_CONF"
130 END
```

IF...THEN Branching

The IF...THEN command provides conditional branching within 3458A subprograms. The syntax statements for the IF...THEN command is shown below.

IF *expression* THEN

program segment

[ELSE]

[program segment]

ENDIF

The ENDIF statement must follow the IF...THEN statement somewhere in the subprogram. ELSE is an optional statement, but if used must appear before the ENDIF statement. All commands after the IF...THEN statement and before the ELSE and ENDIF statements will be executed if the expression evaluates to true (not equal to zero).

If the expression is true, execution continues with the program segment between IF...THEN and ELSE. If the expression is false, execution continues with the segment after ELSE. In either case, when the program segment is completed, assuming there are no other loops or conditional branches, program execution continues with the statement following the ENDIF statement.

```
10 OUTPUT 722; "SUB DMM_CONF"
20 OUTPUT 722; "INTEGER I"
30 OUTPUT 722; "LET I=1"
40 OUTPUT 722; "NRDGS 100"
50 OUTPUT 722; "TRIG SGL"
60 OUTPUT 722; "IF I<100 THEN"
70 OUTPUT 722; " ENTER A[I] "
80 OUTPUT 722; " LET 1=1+1"
90 OUTPUT 722; "ENDIF"
100 OUTPUT 722; "SUBEND"
110 !
120 OUTPUT 722; "CALL DMM_CONF"
130 END
```

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A Specifications

For the specifications and characteristics of the 3458A multimeter (RoHs Compliance), refer to the datasheet at http://literature.cdn.keysight.com/litweb/pdf/5965-4971E.pdf.

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B GPIB Commands

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Introduction

The BASIC language GPIB commands in this appendix are specifically for HP Series 200/300 computers. Any IEEE-488 controller can send these messages; however, the syntax may be different from that shown here. The IEEE-488 terminology is shown in parentheses following each command title. All syntax statements and examples assume an interface select code of 7 and the device address of 22. Table B-1 shows the multimeter's GPIB capabilities.

Table B-1 GPIB capabilities

IEEE 488.1 function	Code	Description
Source handshake	SH1	Allows the multimeter to properly transfer multiline messages.
Acceptor handshake	AH1	Allows the multimeter to guarantee proper reception of multiline messages.
Talker	T5	Allows the multimeter to be a “talker” which means it can send data over the GPIB. This also allows the multimeter to respond to serial poll.
Listener	L4	Allows the multimeter to be a “listener” which enables it to receive information over the GPIB
Service request	SR1	Allows the multimeter to asynchronously send a service request to the controller.
Remote/Local	RL1	Allows the multimeter to be programmed over the GPIB or from its front panel.
Parallel poll	PP0	No capability.
Device clear	DC1	Allows the multimeter to be initialized to a cleared state by the Device Clear command issued from the controller.
Device trigger	DT1	Allows the multimeter to be triggered over the GPIB
Controller function	C0	No capability.
Driver electronics	E2	Describes the electrical drivers used by the multimeter (E2 = tri-state, 1MByte/second max.)

ABORT 7 (IFC)

Clears the multimeter's interface circuitry.

Syntax

ABORT 7

Example

```
ABORT 7        !CLEARS THE MULTIMETER'S INTERFACE CIRCUITRY
```

CLEAR (DCL or SDC)

Clears the multimeter, preparing it to receive a command. The CLEAR command does the following:

- Clears the output buffer.
- Clears the input buffer.
- Aborts subprogram execution.
- Clears the status register (bits 4, 5, and 6 are not cleared if the condition(s) that set the bit(s) still exist).
- Clears the display
- Disables triggering (the previous triggering mode can be resumed by sending any multimeter command).

Syntax

CLEAR 7
CLEAR 722

Examples

```
CLEAR 7    !CLEARS ALL DEVICES (DCL) ON THE BUS (SELECT CODE 7)
CLEAR 722  !CLEARS THE DEVICE (SDC) AT ADDRESS 22 (SELECT CODE 7)
```

LOCAL (GTL)

Removes the multimeter from the remote state and enables its keyboard (provided the keyboard has not been disabled with the multimeter's LOCK command).

Syntax

LOCAL 7
LOCAL 722

Remarks

– If the multimeter's LOCAL key is disabled by LOCAL LOCKOUT. the LOCAL 722 command enables the keyboard, but a subsequent remote command disables the keyboard. Sending the LOCAL 7 command, however, returns front panel control even after a subsequent remote message.

Examples

```
LOCAL 7 !SETS GPIB REN LINE FALSE (ALL DEVICES GO TO LOCAL). (YOU MUST
NOW EXECUTE REMOTE 7 TO RETURN TO REMOTE MODE).

LOCAL 722 !ISSUES GPIB GTL TO DEVICE AT ADDRESS 22. (AFTERWARDS,
EXECUTING ANY MULTIMETER COMMAND OR REMOTE 722 RETURNS THE MULTIMETER TO
REMOTE MODE.
```

LOCAL LOCKOUT (LLO)

Disables the multimeter's LOCAL key.

Syntax

LOCAL LOCKOUT 7

Remarks

– If the multimeter is in the local state when you send LOCAL LOCKOUT, it remains in local. If the multimeter is in the remote state when you send LOCAL LOCKOUT, its LOCAL key and keyboard are disabled immediately.

– After disabling the LOCAL key with LOCAL LOCKOUT, you can only enable it by sending the GPIB LOCAL 7 command or by cycling power. If the multimeter's LOCAL key is disabled by LOCAL LOCKOUT, the LOCAL 722 command enables

the keyboard but a subsequent remote command disables it. Sending the LOCAL 7 command, however, enables the LOCAL key and keeps it enabled even after a subsequent remote message.

– If the multimeter's keyboard is disabled by both LOCAL LOCKOUT and the LOCK command, you must clear both to regain control of the keyboard. LOCAL LOCKOUT is cleared with the LOCAL command. LOCK is cleared by setting LOCK to OFF.

Examples

```
10 REMOTE 722 !SETS DEVICE AT ADDRESS 22 TO REMOTE STATE
20 LOCAL LOCKOUT 7 !SENDS LOCAL LOCKOUT (LLO) TO ALL
30 END !DEVICES ON THE BUS
```

REMOTE

Sets the GPIB REN line true.

Syntax

REMOTE 7
REMOTE 722

Remarks

– The REMOTE 722 command places the multimeter in the remote state. The REMOTE 7 command, does not. by itself. place the multimeter in the remote state. After sending the REMOTE 7 command, the multimeter will only go into the remote state when it receives its listen address.

– In most cases. you will only need the REMOTE command after using the LOCAL command. REMOTE is independent of any other GPIB activity and is sent on a single bus line called REN. Most controllers set the REN line true when power is applied or when reset.

Examples

```
REMOTE 7 !SETS GPIB REN LINE TRUE
```

The above line does not, by itself, place the multimeter in the remote state. The multimeter will only go into the remote state when it receives its listen address (e.g., sending OUTPUT 722;"BEEP").

```
REMOTE 722 !SETS REN LINE TRUE AND ADDRESSES DEVICE 22
```

The above line places the multimeter in the remote state.

SPOLL (Serial Poll)

The SPOLL command, like the STB? command (multimeter command set), returns a number representing the set bits in the status register (status byte). The returned number is the weighted sum of all set bits.

Syntax

P=SPOLL (722)

Status register bits

The bits and their corresponding weights are:

Bit number	Decimal weight	Description
0	1	Subprogram execution completed
1	2	Hi or lo limit exceeded
2	4	SRQ command executed
3	8	Power - on SRQ occurred
4	16	Ready for Instructions
5	32	Error (consult error register)
6	64	Service requested
7	128	Data available

Remarks

– If the SRQ line is set true when you send SPOLL, all bits in the status register are cleared provided the condition that set. the bit(s) is no longer present. If the SRQ line is false when you send SPOLL, the status register's contents are not changed.

– The SPOLL command differs from the STB? command in that STB? interrupts the multimeter's microprocessor. Thus, with STB? the multimeter always appears to be busy (bit 4 clear). SPOLL simply extracts the status byte without interrupting the microprocessor. Therefore, you can use SPOLL to monitor the readiness of the multimeter for further instructions.

– If data is in the output buffer when you send the SPOLL command, that data remains intact. If data is in the output buffer when you send the STB? command, however, the data is replaced by the status data.

Examples

```
10 P=SPOLL (722) !SENDS SERIAL POLL, PLACES RESPONSE INTO P
20 DISP P!DISPLAYS RESPONSE
30 END
```

TRIGGER (GET)

If triggering is armed (see TARM command), the TRIGGER command (Group Execute Trigger) triggers the multimeter once, and then holds triggering.

Syntax

TRIGGER 7
TRIGGER 722

Remarks

– The TRIGGER command generates a single trigger just as if the TRIG SGL command was executed. It will not, however, trigger the multimeter if triggering is not armed (TARM command).

– If subprogram memory execution is suspended by the PAUSE command (multimeter command set), the TRIGGER command resumes subprogram execution but does not generate a single trigger.

Examples

```
TRIGGER 7 !SENDS GROUP EXECUTE TRIGGER (GET)
TRIGGER 722 !SENDS GROUP EXECUTE TRIGGER (GET) TO THE DEVICE AT ADDRESS
22
```

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C Procedure to Lock Out Front/Rear Terminals and Guard Terminal Switches

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Introduction

Either or both the Front/Rear Terminals and Guard Terminal switches can be locked out to prevent changing their settings. To do this, first remove all covers from the 3458A. Then, remove the pushrods from the Front/Rear and Guard switches. Next, place switch covers over the holes where the pushrods previously protruded through. The switch covers are in the Front/Rear Terminal and Guard Switch Lockout kit. Last, reinstall the instrument covers.

WARNING **The following procedures are to be performed by qualified service-trained personnel only. To avoid personal injury, do not perform the procedures unless you are qualified to do so.**

Tools Required

You need:

1. #1 Pozidriv screwdriver
2. #TX 15 Torx driver
3. #TX10 Torx driver

Procedure

The procedure to install the lockout kit is separated into the following:

- Covers Removal Procedure
- Guard Pushrod Removal Procedure
- Front/Rear Pushrod Removal Procedure
- Switch Cap Installation Procedure
- Covers Installation Procedure

Covers removal procedure

Do the following:

1. Remove any connections to the 3458A.
2. Remove ac power from the 3458A.
3. Refer to Figure C-1. Turn the instrument so its right side faces you (as seen from the front).

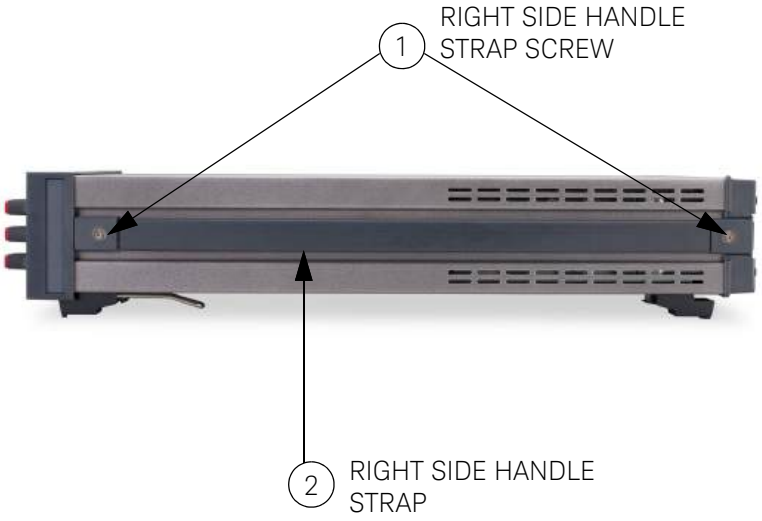


Figure C-1 3458A right side

4 Use the #1 Pozidriv to remove the right side handle strap screws. Then remove the strap.

5 Refer to Figure C-2. Turn the instrument so its left side faces you.

6 Use the #1 Pozidriv to remove the left side handle strap screws. Then remove the strap.

7 Use the #TX10 Torx driver to remove the top and bottom covers ground screws, as shown in Figure C-3.

8 Refer to Figure C-4. Turn the instrument so its back faces you.

9 Use the #TX15 Torx driver to remove the rear bezel screws. Then remove the rear bezel.

10 Remove the top cover. Pull the cover toward the rear and away from the instrument.

11 Turn the 3458A over so its top sits on your workbench. Remove the bottom cover. Pull the cover toward the rear and away from the instrument. Leave the instrument in its present position.

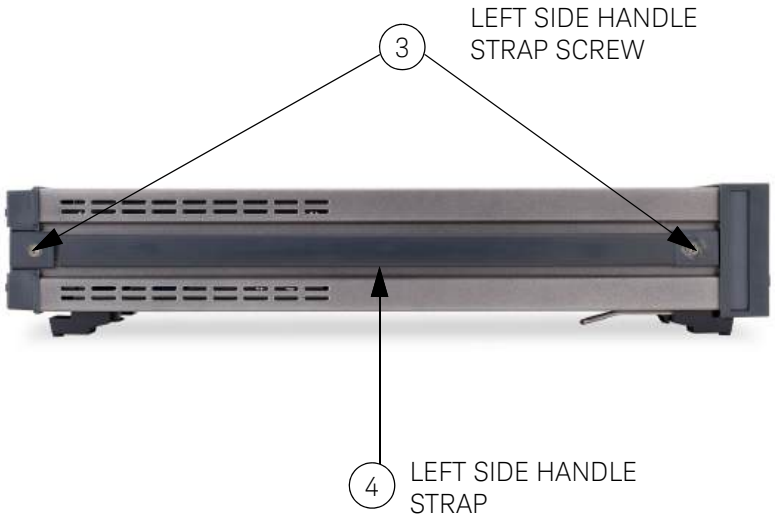


Figure C-2 3458A left side

Figure C-3 Covers ground screws

Figure C-4 3458A rear view

Guard pushrod removal procedure

If you DO NOT wish to lockout the Guard switch, continue with the next paragraph.

1. Refer to Figure C-5. Use the #TX 10 Torx driver to remove the bottom shield screw. Then remove the shield. Pull the shield toward the rear of the instrument until the shield retainers line up with the slots in the shield. Lift the shield off.
2. Refer to Figure C-6, Locate the pushrod for the Guard switch. Pull the pushrod off. You may need to pry the pushrod loose with a small flat blade screwdriver. Set the switch in the position it is to be used.
3. Refer to Figure C-5. Replace the bottom shield. Line up the slots on the shield with the shield retainers. Then push the shield toward the front of the instrument until the shield screw hole lines up with the screw hole in the chassis. Use the #TX 10 Torx driver to reinstall the shield screw.

Front/Rear pushrod removal procedure

If you DO NOT wish to lockout the Front/Rear Terminal switch. continue with the next paragraph.

1. Refer to Figure C-7. Turn the instrument over so its bottom sits on your work bench.
2. Use the #TX10 Torx driver to remove the top shield screw. Then remove the shield. Pull the shield toward the rear of the instrument until the shield retainers line up with the slots in the shield. Lift the shield off.

Figure C-5 3458A inside bottom view

Figure C-6 Guard switch and pushrod location

Figure C-7 3458A inside top view

3 Refer to Figure C-8. Locate the pushrod for the Front/Rear Terminal switch. Pull the pushrod off. You may need to pry the pushrod loose with a small flat blade screwdriver, Set the switch in the position it is to be used.

4 Refer to Figure C-7. Replace the top shield. Line up the slots on the shield with the shield retainers. Then push the shield toward the front of the instrument until the shield screw hole lines up with the hole in the chassis. Use the #TX 10 Torx driver to reinstall the shield screw.

Switch cap installation procedure

Do the following:

1. Refer to Figure C-9. Turn the instrument so its front faces you.
2. Locate the holes for the Front/Rear terminal and Guard switches.
3. Locate the little square covers that came in the switch lockout kit. as shown in Figure C-9.
4. Line up the tabs on the covers with the top and bottom sides of either the Front/Rear Terminal or Guard switch hole.
5. Squeeze the tabs on the cover together and push the cover all the way into the switch hole. Lock it in place.
6. Do the same in steps 4 and 5 for the other switch hole, if necessary.

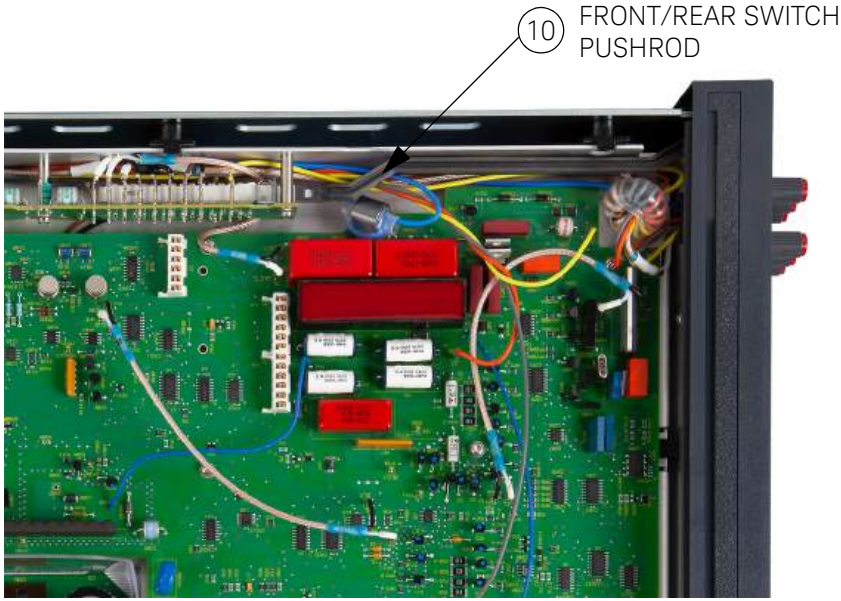
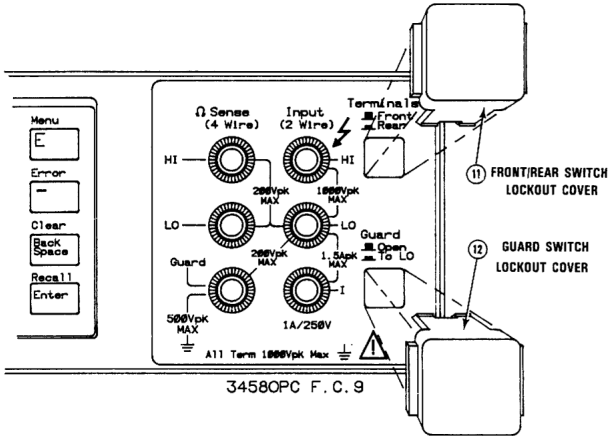


Figure C-8 Front/rear terminal switch and pushrod location

For Serial Number SG59350366 and MY59357708 and below.



For Serial Number SG59350386 and MY59358376 and above.

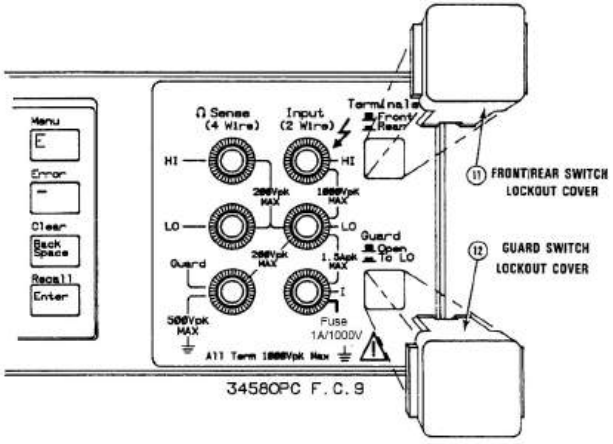


Figure C-9 Switch covers installation

Covers installation procedure

Do the following:

1. Turn the 3458A over so its top sits on your workbench.
2. Install the bottom cover by placing it into the slots of the instrument side castings, Then push the cover toward the front of the instrument into the front panel bezel.
3. Turn the 3458A over so the bottom sits on your workbench.
4. Install the top cover by placing it into the slots of the instrument side castings. Then push the cover toward the front of the instrument into the front panel bezel.
5. Refer to Figure C-4. Turn the instrument so its back faces you.
6. Reinstall the rear bezel. Use the #TX15 Torx driver to reinstall the rear bezel screws.
7. Refer to Figure C-3. Turn the instrument so its left side faces you. Use the #TX10 Torx driver to reinstall the top and bottom covers ground screws.

WARNING **For safety purposes and proper operation, it is very imperative that the cover grounding screws be reinstalled.**

8. Refer to Figure C-2. Reinstall the left side handle strap. Use the #1 Pozidriv to reinstall side handle strap screws.
9. Refer to Figure C-1. Turn the instrument so its right side faces you.
10. Reinstall the right side handle strap. Use the #1 Pozidriv to reinstall side handle strap screws.
11. Your instrument is now ready for use. Keysight suggests that after you apply power that you perform an automatic calibration on the instrument. To do this. use the “ACAL ALL” command.

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D Optimizing Throughout and Reading Rate

Introducing the 3458A 440
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Purpose 443
DC Volts, DC Current and Resistance 444
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Optimizing the Testing Process Through Task Allocation 455
A Benchmark 458

(From Product Note 3458A-1)

In the past decade and a half, microcomputers have greatly improved both their internal speed and their speed of communication with other equipment. The actual clock rates of microcomputers used in instrumentation has gone from under 1 MHz to over 12 MHz and the data bus has gone from 8 bits to 16 bits.

During this same time period, the system multimeter has undergone an even more remarkable evolution in terms of both its speed of operation and its reading rate. In 1975, 24 readings per second with 5 1/2 digits of resolution was considered very fast; today the 3458A multimeter (RoHs Compliance) can make 50,000 readings per second with 5 1/2 digits-- two thousand times faster. This extraordinary increase in speed is attributable not simply to faster microcomputers, but to advances in the analog to digital conversion process, a better utilization of the microcomputer, and a better understanding of the application needs of the system user.

Introducing the 3458A

The 3458A multimeter (RoHs Compliance) now has reading rates from 4 1/2 digit DC Volts measurements at 100,000 per second, to 8 1/2 digit DC Volts measurements at 6 per second, or anywhere in between with a trade-off of less speed for more resolution. Even the traditionally slower measurement functions, such as AC Volts, are quicker with the 3458A. For example, you can measure true rms ACV at up to 50 readings per second with full accuracy for input frequencies greater than 10 kHz. That a multimeter's increased reading rate results in increased test throughput is clear. Not as obvious, but strongly affecting throughput as well, is the operating speed of the multimeter when changing function, range, reading speed (integration time), or interfacing mode. The 3458A can change function and range, take a measurement, and output the result at 200 per second.

Application oriented command language

Attempts to make measurement more application oriented and less hardware dependent resulted in advances in the command language of multimeters that often yielded easier, more friendly programming. However, these advances also required increased overhead and slower response to the command language. The 3458A multimeter (RoHs Compliance) has been specifically designed to overcome this problem by offering fast command response with an application-oriented command language that is also easy to use.

Intrinsically slow measurements

It is well known that some measurements are inherently not amenable to fast treatment. Examples of these are high impedance measurements, frequency measurements of low frequency events, root mean square (rms) AC voltage and current measurements, and accurate measurements in the presence of noise. Nonetheless, despite their inherent slowness, substantial increases in throughput can be achieved in test system requiring these measurements. The 3458A provides this improved throughput by offering a wide range of alternatives that can improve the speed of testing. For example, in many systems accuracy can be traded for speed; or flexibility in timing the measurement can lead to real increases in the rate of rms AC measurements with good accuracy. The set of trade-offs one may make with the 3458A multimeter (RoHs Compliance) is covered in detail in this Product Note.

Maximizing the Testing Speed

Program memory

The speed of the testing process can also be maximized by tailoring the communication path between the 3458A and the computer. The dmm is generally the fastest instrument in the system; hence to perform a series of measurements, the computer may be compelled to take more time with other instruments. Several features of the 3458A multimeter (RoHs Compliance) allow the allocation of measurement tasks to be split optimally between the computer and the dmm. Its unique, non-volatile Program Memory allows sequences of measurement to be performed dynamically using external events such as external, auxiliary, or GPIB[1] triggers to step through the measurement sequence. In addition, using Program Memory, complete measurement sequences can be programmed and initiated from the front panel for standalone operation without a controller.

State storage

State Storage permits a static instrument state to be totally defined and recalled from memory with a simple program command. In addition, the 3458A transfers high-speed measurement data over GPIB or into and out its standard 10,000 (or optional 75,000) Reading Memory at 100,000 readings per second.

Reading analysis

Additional flexibility is provided by the 3458A's capability to perform data analysis internally to speed throughput and still give you the data you need for statistica1 quality control or for simple limit checking. Program Memory can perform the pass/fail math function and alert the computer to out-of-limits measurements with an interrupt flag. Alternatively, the many available math functions may be used to post-process the data acquired in memory, without loss of the maximum reading rate. These include statistical functions (mean, standard deviation, maximum, minimum, number of readings), dB and dBm, thermistor linearization, RTD linearization, scale, filter functions, and others. The choice of whether to perform data analysis in the computer or in the dmm depends on the testing task

[1] GPIB is an implementation of the IEEE Standard 488 and the identical ANSI Standard MC1.1 “Digital interface for programmable instrumentation”.

and the convenience offered to the user by having these analysis functions available with a simple programming command.

Task grouping and sequence

Further gains in test throughput can be obtained by tailoring the measurement sequence to group similar measurements together, thus minimizing the number of instrument configuration changes between measurements. Custom programs written without the aid of automatic program generators can be so structured. Program generators are usually optimized for ease of programming and offer a simplistic approach to the testing task that lets you choose limits for each group of tests but do not necessarily group the tests for the fastest throughput. Functional test management software like the FTM300 allows the tests to be customized for throughput and still provides 70% of the overhead programming like Statistical Quality Control (SQC) and inventory management.

System uptime

Longer system up-time also means higher test system throughput. The 3458A multimeter (RoHs Compliance) performs a complete self-calibration of all functions, including AC, using high-stability internal standards. This self- or auto-calibration eliminates measurement errors due to time drift or temperature changes in your rack or on your bench for superior accuracy. When it's time for periodic calibration to external standards, simply connect a precision 10 V DC source and a precision 10 kΩ resistor. All ranges and functions, including AC, are automatically calibrated using precision internal ratio transfer measurements relative to the external standards. (The subject of calibration is treated in detail in Product Note 3458A-3)

A system's up-time is also increased as a result of the increased reliability of its components. the 3458A's reliability is a product of Keysight's “10 X” program of defect reduction. Through environmental, abuse, and stress testing during the design stages of product development, Keysight has reduced the number of defects and early failure in its instruments by a factor of ten over the past ten years.

Purpose

The purpose of this Product note is to illustrate how you can use the revolutionary speed and accuracy of the 3458A multimeter (RoHs Compliance) to achieve the best possible test throughput and reading rates for your application. This is achieved by providing an explanation of the trade-offs offered by the instrument, and its optimal use with the HP 9000 Series 200/300 computers.

Topics covered in the product note include:

- DC measurements (Volts, current, ohms) - the available trade-offs of speed, resolution, and accuracy for their optimal use in your test system.
- AC measurements (analog ACV, synchronous ACV, random ACV, current) - choosing the best mode and specifications for your application.
- frequency and period - selecting gate time to achieve desired speed, accuracy, or resolution.
- optimizing the testing process through task allocation - using built-in math functions or post-processed math, the readings memory, states memory, and Program Memory to best organize and allocate tasks between the dmm and the computer, with program examples.
- benchmarks with properly structured programs for maximum throughput using pass-fail limit checking and statistics.

DC Volts, DC Current and Resistance

The 3458A offers two separate measurement paths: the standard DCV path direct to the Analog to Digital Converter and a path to the track-and hold circuit (track-and-hold path). The DCV path is limited to 150 kHz bandwidth, the track-and-hold path can accept signals up to 12 MHz. The track-and-hold path is limited to 16 bits of resolution unless repeated measurements are made. The DCV path can present up to 8 1/2 digits (27 bits) resolution.

Optimizing through the DCV path

The classic trade-offs one can make with the 3458A are measurement speed versus measurement resolution. Because of early design decisions to reduce the intrinsic Johnson noise associated with real resistive components in the input path of the 3458A, the resolution of the integrated measurement is 3 times better than with dmms of previous generations. For example, with the 3457A one may make a 6 1/2 digit (3,000,000 count) measurement with one power line cycle of integration (PLC) or 17 ms; with the equivalent integration period, the 3458A may make a 7 1/2 digit measurement (12,000,000 counts). Similarly, extreme care is taken to insure the linearity is excellent, a factor of 10 times better than the 3457A. The result is faster, more accurate measurements than ever before. It also means that one can take advantage of the increased accuracy and resolution and make measurements at 1 PLC with the 3458A that previously would have taken 10 PLC.

For the measurement that requires only high speed, or a trade-off of resolution and accuracy without line noise as an issue, the 3458A provides a range of alternatives from 4 1/2 digits at 500 nanoseconds aperture to 8 1/2 digits at 1 seconds aperture and anywhere in between in 100 nanosecond steps. Figure D-1 shows the aperture versus measurement speed, noise, resolution and accuracy.

From the graph in Figure D-1, one can see the influence of the actual aperture or integration period on reading rate; hidden is the influence of the HPML commands on throughput and some of the basic operating methods of the 3458A. HPML is an application-oriented command set. The basic philosophy behind this command set is that you don't need know what the 3458A is doing to make the measurement but need only to understand the measurement you want to make. To optimize throughput for any complex application, however, requires more understanding of the operation of the 3458A than simply to make a measurement. Many of the trade-offs you will make involve trading speed for accuracy and

convenience. The HPML commands that most affect the throughput speed from a measurement viewpoint are:

```
FUNC<DCV, DCI, OHM, FOHM>,<range>,<resolution in %>
NPLC #
APER<integration period s>
RES <resolution in %>
AZERO,<on or off>
```

In Table D-1 you'll see that NPLC and APER commands are somewhat interchangeable. The significant difference between these two commands is that NPLC actually uses the power line frequency to establish the integration period for the chosen multiple or submultiple of the line frequency. The APER command sets the integration period in fundamental units of seconds from 500 ns to 1 s in 100 ns steps. Operating at 60 Hz line frequency, for example, the choice of NPLC 1 is equal to APER 0.016666.

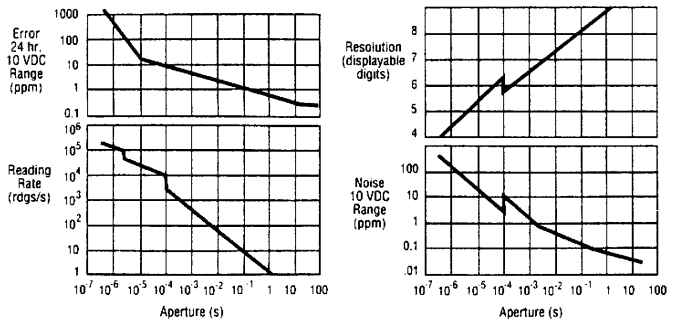

Figure D-1 Shows the dependency of accuracy, reading rate, resolution, and noise on aperture or NPLC selected

Table D-1 Integration time and query response

Command	Integration time (APER)		Query response (NPLC?)	
	50 Hz	60 Hz	50 Hz	60 Hz
NPLC0	500 ns	500 ns	25 E-6	29.99994 E-6
NPLC.5	10 ms	8.333 ms	500 E-3	499.99700 E-3
NPLC 1	20 ms	16.6667 ms	1	1
NPLC10	200 ms	166.667 ms	10	10
NPLC 11[a]	200 ms	166.667 ms	20	20

[a] For NPLC > 10, the continuous integration period is equal to the integration period of NPLC 10, but more than one reading is taken. The resulting average is output to the display or to the GPIB.

If NPLC is in the interval from 1 to 10, inclusive, then the NPLC is rounded up to the next integer. If NPLC > 10, then the actual value of NPLC is rounded up to the next integer multiple of 10. For values of NPLC <1, the value selected is used much the same as aperture except that the integration period is scaled in terms of the line frequency. For example, if the value selected for NPLC is .1 PLC, the 3458A actually sets the integration period to .1X (line period to the nearest 100 ns> or .0016666 s (60 Hz operation). The query NPLC? returns 99.9958E-3 PLC. If the value of 2.5 is selected for NPLC, then the 3458A sets the integration period to 3 PLC. If the value of 21 is selected for NPLC, then the integration period is set to 30 PLC. NPLC 0 always selects the shortest integration period possible, 500 ns or 29.99994E-6 PLC(60 HZ operation).

Another command that affects the integration period is the resolution command, RES, which selects the number of digits of the reading displayed as a function of a percentage of the maximum input parameter. The resolution of the measurement is selected as a part of the function command or as the RES command. It sets the integration period to a value that will allow the ADC to convert the measurement to the resolution requested.

For example,

```
DCV,20,.001   !(using the resolution parameter of this command)
```

and

```
DCV,20;RES.001
```

(omitting the resolution parameter of the DCV command and using the RES command) both set the 3458A to DCV, the 100 V range, the integration period to 8 µs, and set the resolution to .001% of 20 V. The reading rate can be doubled simply by turning the auto zero operation off. Auto zero on (AZERO,ON) is the default condition of the 3458A. In this condition, to eliminate any thermally generated offset voltage on the input of the 3458A, internally, the input is shorted and a measurement is made to establish the offset voltage. The measured DC offset is subtracted from the actual input voltage and presented to the output as the final answer. Hence, there are really two measurement cycles normally involved in one measurement. This procedure ensures the specified accuracy of the 3458A, but it can produce measurements only half as fast as just measuring the input voltage. In a thermally stable environment, very little reduction in accuracy over a short period of time (10 minutes or so) results from disabling this function. Hence, beyond reducing the integration period, AZERO OFF is the most significant command you may use to increase reading rate.

DC current

The same general discussion for measuring DCV applies to current. With the exception that the current input is a separate terminal, the command DCI is used the same way that DCV is used. The current measurement path is selected with a series armature relay instead of the faster reed relays of DC volts and Ohms; hence, switching between current and other functions will take more time (in the neighborhood of 30 to 40 ms) than between DCV and Ohms.

Resistance

Resistance measurements require more settling time than DCV measurements. Above 10 kΩ longer settling time is introduced to make sure that the first reading is correct within specified limits. Again, if you wish to compromise the accuracy of the first reading, the settling time associated with the higher resistance measurements may be defeated by using the default delay. Before you change the program's delay setting to a lesser value, experiment with the application to determine the optimum settling time. Figure D-2 shows the general trend in increasing settling times as a function of increasing resistance for first reading right.

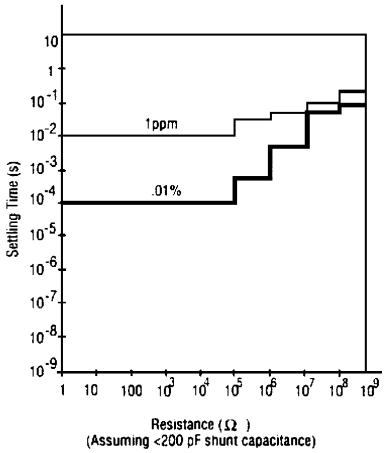

Figure D-2 Settling time characteristic for resistance measurements assuming <200 pF shunt capacitance in the circuit tested. For small values of resistance, there is no real advantage to setting the delay to less than the default values. Resistance above 100 kW require longer settling times to reach final values: hence settling delay times for these values may save measurement time at the expense of measurement accuracy.

Another feature of the 3458A is OffsetCompensated Ohms. Very much like auto zero in concept, offset-compensated Ohms makes a measurement of the input resistance without the current applied to measure any thermally generated DCV offsets. As shown in Figure D-3, the current is applied, the offset voltage is subtracted from the measurement of the unknown resistance and the result is presented to the display. Like auto zero, it takes two measurements to make a final determination of the unknown resistance. In reality, offsets like this are only encountered in lower values of resistance. The 3458A offers a 10 mA current source that will, at least, mask the effect of the thermally generated offset. Hence, in many cases Offset-Compensated Ohms may not be needed for lower resistance measurements.

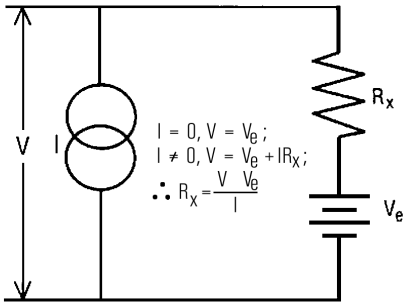

Figure D-3 Offset compensated ohms removes the effect of small series voltage sources such as thermocouple effects in the circuit. By measuring the voltage across the unknown resistance, Ve, with the current source off and then measuring the voltage across the unknown resistance with the current source on, the effect of Ve on the measurement is eliminated

Optimizing through the track-and-hold path (direct sampling and subsampling)

As stated earlier, the standard DCV path directs the signal to the A to D Converter. This path exhibits 150 kHz bandwidth and selectable resolution from 4 1/2 to 8 1/2 digits. The track-and- hold path exhibits 12 MHz bandwidth and 4 1/2 digits of resolution. This path uses a 16 bit track-and-hold circuit between the input and the A to D to take a "snapshot" of the input. DCV may be measured up to a maximum reading rate of 50,000 readings per second through this path. The commands for this choice of path are:

DSAC (direct sample, AC coupled)
DSDC (direct sample, DC coupled)
SSAC (subsampled, AC coupled)
SSDC (subsampled, DC coupled)

The Product Note 3458A-2, High Resolution Digitizing with the 3458A System Multimeter, covers the use of these commands in detail along with their associated trigger commands and constraints. In general, the aspects of these commands that most influence throughput are those associated with ACV, where the 3458A handles the task of measuring the rms value of either repetitive wave forms with the synchronous ACV or noise measurements with random ACV. A detailed look at the techniques and the trade-offs of the three methods of rms ACV measurement is in the next section.

AC Volts and AC Current

The 3458A multimeter (RoHs Compliance) has the unique capability of offering the user three different ways of measuring equivalent DCV heating value of an input wave form (true root-mean-square value) : analog ACV, synchronous ACV and random ACV. The input signal follows the track-and-hold path (see Figure D-4) where it may be routed into the analog AC-to-DC converter or the track-and-hold circuit.

Analog ACV

The analog ACV offers broadband 10 Hz to 2 MHz rms capability utilizing a monolithic AC to DC converter. Its accuracy, while good, is not as good as the synchronous ACV's; its bandwidth, while also good, is not as good as the random or the synchronous ACV's. But, it does offer the ability to measure more accurately, faster than either of the other methods over its measurement bandwidth. And, it can measure either repetitive wave forms or noise signals.

Synchronous ACV

Synchronous ACV offers 1 Hz to 10 MHz bandwidth with excellent 100 ppm best accuracy, but the input wave form must be repetitive. The reading rate is determined by the frequency of the input wave form and the desired accuracy and resolution. The technique is straightforward: a frequency measurement is made on the input wave form, the decision to sample the input sequentially, or in bursts at 20 µs intervals, is made based on the value of the frequency, and the measurements are processed statistically for the rms value. The number of samples taken, which is a measure of the speed, is determined by the resolution selected and also determines the accuracy of the measurement.

Random ACV

Random ACV offers the same upper measurement bandwidth that synchronous ACV offers, but the wave form can be noise or any non-repetitive signal. Since the resolution of the measurement is dependent upon the number of samples, this mode of operation is the least accurate and the slowest of the ACV functions for high resolution. Aliasing (discussed in detail in the Digitizing Product Note

3458A-2) is avoided by a random selection of sampling intervals from 20 to 40 µs in 10 ns increments.

Comparison of ACV modes

With all three ACV modes of operation, the user has the option of selecting accuracy versus speed if the input frequency allows. Referring to Table D-2, the frequency dependency of the reading rate is most pronounced for analog ACV: 1 reading per second from 10 Hz to 1 kHz, 10 readings per second from 1 kHz to 10 kHz, and 50 readings per second from 10 kHz to 2 MHz. These reading rates pertain to the specified accuracies for analog ACV. The reading rates of all three modes of operation can be increased by selecting either less resolution or by decreasing the delay time from the default times to a time interval of ten times the reciprocal of the highest frequency component present on the input signal. Hence, to capture a signal of 1 kHz, a delay time of at least 10 ms is needed for a representative measurement of the wave form.

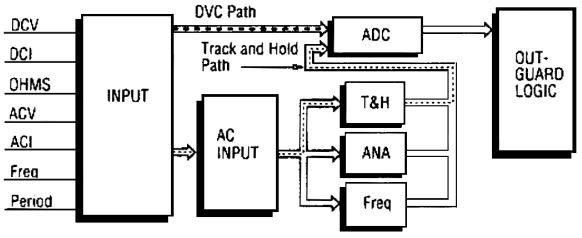

Figure D-4 Signal path block diagram offers three techniques for ACV measurement

Table D-2 Compares the ACV modes

	Analog	Synchronous	Random
Bandwidth	10 Hz to 2 MHz	1 Hz to 10 MHz	20 Hz to 10 MHz
Best Accuracy	300 ppm	100 ppm	1000 ppm
Reading Rate	50 rdgs/s	10 rdgs/s	40 rgds/s

Table D-2 Compares the ACV modes

	Analog	Synchronous	Random
Crest Factor	5:1	5:1	5:1
Waveforms	All	Repetitive	All

AC current

AC current measurements are made strictly through the analog ACV section with the voltage input being supplied by the DCI shunts. While there is no real decision to make regarding the mode of ACI measurement, you can decide to accept less accuracy and speed up the reading rate by decreasing the integration and settling time. As a rule of thumb, the AC to DC converter needs at least 10 cycles of the input wave form to give representative rms measurements. Hence, the frequency of the input has a direct impact on the reading rate. Characterization of the 3458A may be necessary to fine tune the measurement throughput for either ACV or ACI to fit your application.

Frequency and period

The track-and-hold path is also the route the signal must take for frequency and its reciprocal, period. The 3458A offers frequency response from 10 Hz to 10 MHz to 7½ digits with a maximum gate time of 1 second. One can trade speed for accuracy and resolution by selection of shorter gate times of the internal counter. Table D-3 shows the trade-off of resolution for each of the gate times.

Table D-3 Shows resolution trade off for each of the gate times.

Gate time	Resolution	Reading rate
1 second	7 1/2 digit	1 rdgs/s
0.1 s	6 1/2	10 rdgs/s
0.01 s	5 1/2	73 rdgs/s
0.001 s	4 1/2	215 rdgs/s
0.0001 s	3 1/2	270 rdgs/s

After one has optimized each individual measurement in terms of the minimum time for the measurement with sufficient accuracy, there is yet another factor to consider to improve test throughput: task allocation. This factor involves the controlling computer and other instrumentation in the system. As stated in the introduction to this product note, for the most part, the fastest instrument in the test system is the dmm. Hence, its measurement rate may not be the throughput bottleneck in the system. One can take advantage the high-speed measurement capability of the 3458A by letting it compute its own statistics, linearize its own thermistors, or check its own limits while the controller is controlling other instrumentation or is otherwise busy. The features of the 3458A dmm that make this possible are the built-in math functions, the Reading Memory, State Memory and Program Memory.

The time necessary to transfer measurements and commands to the computer is computer dependent. GPIB turnaround time, the time to process OUTPUT and ENTER operations will vary considerably from computer to computer. The features of Program Memory, Reading Memory, State Storage, and post-processing math operations all tend to decrease GPIB overhead and make the testing time far less computer dependent.

Optimizing the Testing Process Through Task Allocation

Math operations

Individually, math operations performed within the 3458A slow the measurement speed of the 3458A, but many times the combination of the 3458A with the controller will perform faster together to achieve final answers if the 3458A does some of the math itself. This is particularly true for pass/fail limit checking where The computer is alerted only if the test has failed. If statistics are important on the measurements, then it is a simple matter to let the 3458A assume the task of computation instead of having to write a program on the controller. The computer in the 3458A is a very powerful Motorola 68000 with a 8 MHz operating clock; therefore, many times it will have the same computational power that the controller has.

Data storage

The memory of the 3458A can be used to store measurements for later transfer to the controller for up to 10,000 readings (20 kBytes).The transfer rate into and out of the Reading Memory and the GPIB transfer rate using direct memory access with an HP 9000 Series 200/300 computer is 100,000 readings per second. The advantage of the memory is that one may access the data when it is convenient for the controller and not have to tie the system up waiting for the measurement to finish (a long integration period, a long settling time, or an average of multiple readings can cause even the fastest dmm to hold up the system).

Output formats

The 3458A offers five different data formats for both memory and GPIB output: single integer (SINT), double integer (DINT), IEEE-728 four byte single real (SREAL), IEEE-728 eight byte double real (DREAL), and ASCII. The fastest format for data transfer is the single integer. This is a 16 bit integer format so range information must be known to determine the placement of the decimal point. In addition, it only has 16 bits; hence, if more than 4 1/2 digits is desired from a measurement, one of the other formats must be used. The next highest speed format is double integer. This is a 32 bit integer format so, except for the range information, all the measurement data is transferred. SREAL transfers all the data, including the range information, in four eight-bit bytes. The controller must be

able to accept this format and translate it into ASCII to be able to use it. Finally, the slowest format is the ASCII format. Basically, each reading needs eighteen bytes of data plus carriage return/ line feed terminator to transfer into the controller. Many times it is important to acquire the data quickly but the actual transfer of the data can be comparatively slow, In this case, the ideal combination of data formatting is SREAL for measurements taken into memory and ASCII output to GPIB. The DINT and SINT formats are accepted directly without need for additional translation by the HP 9000 Series 200/300 computers. Almost any controller can accept ASCII formats.

In programs where functions or ranges are changed between measurement and the results are stored in the computer, it is probably best to lose a little speed and store the data in Reading Memory in either DREAL or SREAL. This avoids having to keep track of the scaling parameters needed for SINT and DINT.

State storage and program memory

A considerable savings in time at the right place in the testing task may be gained by the features of State Storage and Program Memory. State memory is used to establish a static state of the instrument with a single command transfer over GPIB. Initialization routines can set up the states that the programmer wishes to use in the test program during system dead time; then the state can be called at will.

Program Memory is dynamic memory. The state of the 3458A is dynamically changed as the sequence of operations programmed in Program Memory are stepped through as though the computer were controlling the sequence of events. The measurements taken can be stored in Reading Memory to be accessed at a convenient time either to be transferred in raw form to the computer or to be post processed in the 3458A. Again, once the command string is transferred to the memory of the 3458A, a simple command over GPIB initiates the measurement sequence. More important than the time saved by passing the simple command, the parsing routine of the 3458A actually compiles the Program Memory command string so that the measurement sequence can take place much faster than if the computer were controlling the operation. To ease some of the programming burden for lengthy set-ups, State Memory and other subprograms may be called from Program Memory.

Measurement list

The most efficient method of using the 3458A within a system is to establish a measurement list in Program Memory that corresponds with a channel list in the signal switching instrument. The 358A's External Output is connected to the Channel Advance input of the switching instrument and the Channel Closed output of the switching instrument is connected to the External Trigger input of the 3458A. Regardless of how long it takes to close a channel or make the measurement, the channel is always closed and the measurement is always had time for completion without programming additional WAIT statements or added delay. Further, the reduction in GPIB data messages results in faster, more convenient programming. In the Figure D-5, the circuit is tested to show the interaction of the 3458A with a switching unit, the 3488A, using External Trigger and External Output. The measurements are simple AC and DC Volts and resistance. In this case, the time to change a function or a range is important to the test set-up because the channel closure is relatively slow (the 3488A uses very versatile, but slow armature relays with switching speeds of about 25 ms per channel closure); therefore, multiple measurements are made on a test point. If reed relays were used, it would be generally faster to change test points and stay on the same function if the test situation allowed.

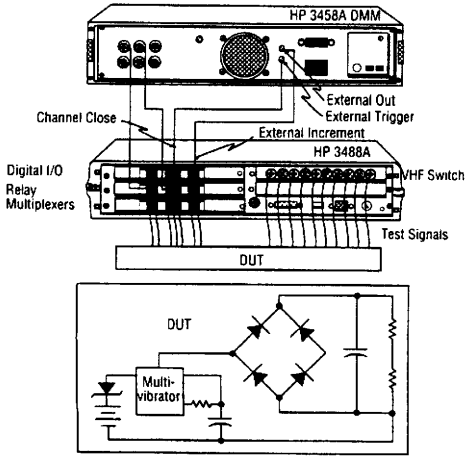

Figure D-5 Measurement list and scan list increase test throughput when used with External Increment tied to External Output and Channel close tied to external trigger

A Benchmark

The benchmark used to show the affect of the various functions of the 3458A multimeter (RoHs Compliance) will start with the most convenient, but least rapid, procedure of having the computer ask the dmm to change to a particular function, make a measurement, and transfer the measurement to the computer. The benchmark will assume that all of the measurements will be made through a FET scanner of infinitely fast switching speed and of infinite dynamic range. Hence, the benchmark represents an artificial situation, but one where the different modes of operation of the 3458A can be best illustrated. The computer used is the 9000 Series 200/300. Times for other computers will vary depending on the GPIB turnaround time of the computer. Results are shown in Figure D-6.

The DUT contains:

25 resistance measurements
15 < 10 kOhm ± 5%
8 < 100 kOhm ± 5%
2 < 10 kOhm ± .001%

10 DCV measurements
5 < 30 V± 1%
4 < 10 V± .01 %
1 < 1 V± .001%

3 ACV measurements
1 < 250 V @ 50 Hz @ ± 5%
1 < 10 V @ 25 kHz @ ± 0.1%
1 < 1 V @ 5 kHz @ ± 0.075%

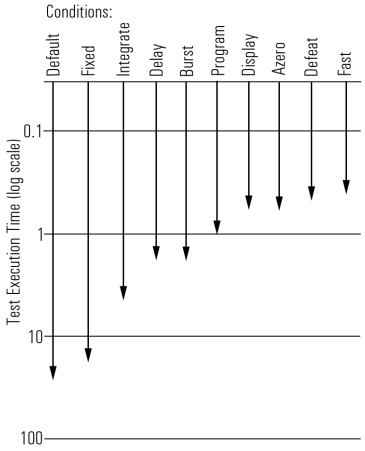

Figure D-6 Shows benchmark execution times for different configurations

The measurement sequence demands that the resistance values be checked before the circuit is powered. Then, the powerline voltage is checked for proper level. The output level 1 V at 5 kHz is checked to limits of ±.075%. Finally, the remaining voltages are checked in the following sequence:

```
2 DCV <10 V ±1%
1 DCV <10 V ±.01%
2 DCV <10 V ±1%
1 DCV <1 V ±.001%
1 ACV <10 V ±.1%
1 DCV <10 V ±1%
3 DCV <10 V ±.01%
```

Benchmark results

Default conditions: (Subprogram Default) time = 20.63 s.

```
560 SUB Default(REAL Dnld_time.Exe_time,Tns_time)
570 DIM A(37)
580 Exe_time=TIMEDATE
590 OUTPUT 722;"RESET;TRIG SYN"
600 OUTPUT 722;"OHM"
610 FOR I=1 TO 23
620 ENTER 722;A(1)
630 NEXT I
640 OUTPUT 722;"OHMF"
...
780 ENTER 722;A(I)
790 NEXT I
800 Exe_time=TlMEDATE-Exe_time
810 Dnld_time=O
820 Tns_time=0
830 SUBEND
```

The 3458A is placed in remote operation by the computer and is reset to its default conditions. The integration time is set to 10 PLC, the settling delays are set so that first reading after a function or a range change meets its specified accuracy. Auto range is on. The computer asks the dmm to change range, or function, or integration time for 10 of the 37 measurements. The others are measured in blocks in the same measurement configuration.

Fixed range: (Subprogram Fixed) time = 15.98 s.

```
840 SUB Fixed(REAL Dnld_time,Exe_time,Tns_time)
850 DIM A(37)
860 Exe_time=TIMEDATE
870 OUTPUT 722;"RESET;TRIG SYN"
880 OUTPUT 722;"OHM,lE4"
890 FOR I=1 TO 15
900 ENTER 722;A(I)
910 NEXT I
920 OUTPUT 722;"OHM,1E5

...
1110 ENTER 722:A(I)
1120 NEXTI
1130 Exe_time=TIMEDATE-Exe_time
```

```
1140 Dnld_time=0
1150 Tns_time=0
1160 SUBEND
```

The test situation is the same as the default situation but the ranges are set to the range necessary for the measurement instead of auto range.

Correct integration time: (Subprogram Integrate) time= 3.76 s.

```
1170 SUB Integrat(REAL Dnld_time,Exe_time,Tns_time)
1180 DIM A(37)
1190 Exe_time=TIMEDATE
1200 OUTPUT 722;"PRESET"
1210 OUTPUT 722;"OHM,lE4;NPLC 0"
1220 FOR I=1 TO 15
1230 ENTER 722;A(I)
1240 NEXT I
1250 OUTPUT 722;"OHM,1E5"

...

1410 ENTER 722;A(34)
1420 OUTPUT 722;"DCV,10;NPLC 0"
1430 FOR I=35 TO 37
1440 ENTER 722;A(I)
1450 NEXT I
1460 Exe_time=TIMEDATE-Exe_time
1470 Dnld_time=0
1480 Tns_time=0
1490 SUBEND
```

The test situation is the same as the fixed range situation, but the integration time selected for each measurement is correct for the required resolution and accuracy instead of the default of 10PLC.

Correct delay time: (Subprogram Delay) time = 1.48 s.

```
1500 SUB Delay(REAL Dnld_time,Exe_time,Tns_time)
1510 DIM A(37)
1520 Exe_time=TIMEDATE
1530 OUTPUT 722;"PRESET"
1540 OUTPUT 722;"OHM,1E4;NPLC 0;DELAY 0
1550 FOR I=1 TO 15

...

1730 OUTPUT 722;"ACV,10;ACBAND 5000;APER 20E-6;DELAY .01"
1740 ENTER 722;A(34)
```

```
1750 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0"
1760 FOR I=35 TO 37
1770 ENTER 722;A(I)
1780 NEXT I
1790 Exe_time=TIMEDATE-Exe_time
1800 Dnld_time=0
1810 Tns_time=0
1820 SUBEND
```

The test situation is the same as the situation with correct integration time, but now the delay time is set to a value that will produce measurements to the desired accuracy of each measurement instead of the default delays.

Using reading memory: (Subprogram Burst)
test execution time = 1.42 s
reading transfer time = .18 s

```
1830 SUB Burst(REAL Dnld_time,Exe_time,Tns_time)
1840 DIM A(37)
1850 Exe_time=TIMEDATE
1860 OUTPUT 722;"PRESET;MEM FIFO;MFORMAT SREAL
1870 OUTPUT 722;"OHM,1E4;NPLC 0;DELAY 0;NRDGS 15;TRIG SGL
1880 OUTPUT 722;"OHM,1E5;NRDGS 8;TRIG SGL

...

1940 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 3;TRIG SGL
1950 Exe_time=TIMEDATE-Exe_time
1960 Dnld_time=0
1970 Tns_time=TIMEDATE
1980 FOR I=1 TO 37
1990 ENTER 722;A(I)
2000 NEXT I
2010 Tns_time=TlMEDATE-Tns_time
2020 SUBEND
```

A marked change is effected in the structure of the program. Now the readings are stored in Reading Memory as the measurements are made. At the end of the measurement sequence, the readings are transferred from Reading Memory to the computer using a FOR NEXT loop. Except for the convenience of data transfer, there is no marked improvement in the speed of the measurement in this case. If the data were transferred via a TRANSFER statement to the computer, there would be more time savings.

Using program memory: (Subprogram Program)

test execution time = 1.06 s
program memory download time = .260 s
reading transfer time = .17 s

```
2030 SUB Program(REAL Dnld_time,Exe_time,Tns_time)
2040 DIM A(37)
2050 Dnld_time=TlMEDATE
2060 OUTPUT 722;"PRESET;MFORMAT SREAL"
2070 OUTPUT 722;"SUB 1;MEM FIFO;OHM,lE4;NPLC 0;DELAY0;NRDGS 15;TRIG
SGL"
2080 OUTPUT 722;"OHM,1E5;NRDGS 8:TRIG SGL"
2090 OUTPUT 722;"OHMF,1E3;APER 20E-6;DELAY-1;NRDGS 2;TRIG SGL
2100 OUTPUT 722;"ACV,250;ACBAND 250;DELAY.1;NRDGS 1;TRIG SGL"
2110 OUTPUT 722;"ACV 10;ACBAND 25000;DELAY .01;TRIG SGL
2120 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 6;TRIG SGL"
2130 OUTPUT 722:"ACV,10:ACBAND 5000;APER 20E-6;DELAY.01;NRDGS 1;TRIG
SGL
2140 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 3;TRIG SGL;SUBEND"
2150 Dnld_time=TlMEDATE-Dnld_time
2160 Exe_time=TIMEDATE
2170 OUTPUT 722;"CALL 1"
2180 Exe_time=TIMEDATE-Exe_time
2190 Tns_time=TIMEDATE
2200 FOR I=1 TO 37 2210ENTER 722:A(I)
2220 NEXT I
2230 Tns_time=TIMEDATE-Tns_time
2240 SUBEND
...
```

Again, the structure of the program is changed. Now the sequence of measurements with all of the variations imposed up to this point on each measurement is placed in a dmm subprogram SUB 1. The commands are transferred from the computer to the 3458A where they are compiled. Execution of the commands commence when the dmm subprogram is called with the CALL 1 command. The readings are transferred when the dmm subprogram is complete.

Note that the program halted while the dmm is completing this sequence. If continued program operation were wanted, the output statement to the dmm would be:

```
OUTPUT 722 USING "#,K"; "CALL 1"
```

By using the image “#,K”, the End-Of-Line (EOL) terminators are suppressed. When the 3458A receives the command without a terminator, it releases the computer so that the computer can continue the program while the 3458A continues with the operations it was requested to do. Note that the execution time for the benchmark is markedly less than just using Reading Memory.

Display off: (Subprogram Display)
test execution time = .500 s
program memory download time = .280 s
reading transfer time = .180 s

```
2250 SUB Disp(REAL Dnld_time,Exe_time,Tns_time)
2260 DIM A(37)
2270 Dnld_time=TIMEDATE
2280 OUTPUT 722;"PRESET;MFORMAT SREAL;DISP OFF,TESTING"
2290 OUTPUT 722;"SUB 1;MEM FIFO;OHM,1E4;NPLC 0;DELAY 0;NRDGS 15;TRIG
SGL"
2300 OUTPUT 722;"OHM,1E5;NRDGS 8;TRIG SGL"
2310 OUTPUT 722;"OHMF,1E3;APER 20E-6;DELAY -1 ;NRDGS 2;TRIG SGL"

...
```

This is the same program as the Subprogram Program, but the display is turned off. The test execution time is cut in half.

Azero off: (Subprogram Azero)
test execution time = .510 s
program memory download time = .280 s
reading transfer time = .180 s

This is the same program as the Subprogram Display, but Auto Zero is turned off. There is no real advantage in test of this type because the reading speed is so fast that there really isn't much difference between leaving auto Zero on or off. In some cases it may be faster when changing function or integration time to leave Auto Zero On.

Defeat on: (Subprogram Defeat)
test execution time = .470 s
program memory download time = .280 s
reading transfer time = .180 s

```
2690 SUB Defeat(REAL Dnld_time,Exe_time,Tns_time)
2700 DIM A(37)
2710 Dnld_time=TIMEDATE
2720 OUTPUT 722;"PRESET;DISP OFF,TESTING;MFORMAT SREAL;DEFEAT ON"
2730 OUTPUT 722;"SUB 1;MEM FIFO;OHM,1E4;NPLC 0;DELAY 0;NRDGS 15;TRIG
```

```
SGL"
2740 OUTPUT 722;"OHM,1E5;NRDGS 8;TRIG SGL"
```

This is the same program as the Subprogram Display, but the DEFEAT function is turned on. In this mode of operation, some of the overload detection and protection circuitry is defeated. If a voltage of greater than 300 V is detected, the defeat feature is turned off and the event is noted in the 3458A's memory. This feature allows faster function and range changes but should not be, as a matter of practice, abused.

Still faster

A considerable increase in throughput can be had if you use TRANSFER statements instead of OUTPUT and ENTER statements. Further, the juxtaposition of some commands improve the measurement speed. Notably, the sequence for DELAY and ACBAND when working with ACV can make a large difference in execution speed. The proper sequence is:

```
DELAY <#>;ACBAND <#,#>;ACV <range>.
```

If you want to change the default settling times when you change a function, always change the DELAY command first. It is also faster in many cases to remain on one integration time rather than change. For example, to get 6 1/2 digits resolution, the 3458A can be set to APER 10E-5 (100 µs), where it can take almost 10,000 readings per second. If measurement calls for only a few measurements with this resolution and a greater number with less resolution, it still may be faster to leave the integration time at 100 µs and take all the measurements there. It takes about 6 to 10 ms for the 3458A to change integration time. At about 10,000 readings per second, the 3458A can take one hundred 6 1/2 digit readings in that time.

This last program uses transfers and the proper command sequence to achieve the greatest possible throughput for the benchmark program.

Execution time = .360 s
Program Memory Download Time = .05 s
Reading Transfer time = .05 s

```
10 OPTION BASE 1

20 DIM Command$[1000] BUFFER

30 DIMA$[100],B$[100],C$[100],D$[100],E$(100],
   F$[100],G$[100],H$[100],I$[100],Set_up$[100]
```

```
 40 INTEGER I,M
 50 REAL Readings(37) BUFFER
 60 ASSIGN @Dmm TO 722
 70 ASSIGN @Buf_1 TO BUFFER Command$
 80 ASSIGN @Buf_2 TO BUFFER Readings(*)
 90 CLEAR 722
100 OUTPUT @Dmm;"RESET"
110 Set_up$="PRESET;MFORMAT SREAL;DEFEAT ON;APER 100E-6;DISP
    OFF,TESTING"
120 B$="SUB Try;MEM FIFO;DELAY O;OHM,1E4;NRDGS 15;TRIG SGL;"
130 C$="OHM,1E5;NRDGS 8;TRIG SGL;"
140 D$="DELAY -1;OHMF,1E3;NRDGS 2;TRIG SGL;"
150 E$="DELAY .1;ACBAND 50;ACV 250;NRDGS 1;TRIG SGL;
160 F$="DELAY .01;ACBAND 25000;ACV,10;TRIG SGL;"
170 G$="DELAY 0;DCV 10;NRDGS 6;TRIG SGL;"
180 H$="DELAY .01;ACBAND 5000;ACV 10;NRDGS 1; TRIG SGL;"
190 I$="DELAY 0;DCV 10;NRDGS 3;TRIG SGL;SUBEND"
200 Command$=B$&C$&D$&E$&F$&G$&H$&I$
210 Dnload:! Transfer commands to dmm
220 Dnld_time=TIMEDATE
230 OUTPUT @Dmm;Set_up$
240 TRANSFER @Buf_1 TO @Dmm
250 Dnld_time=TIMEDATE-Dnld_time
260 Execute: ! Dmm Execution time
270 Exe_time=TIMEDATE
280 OUTPUT @Dmm;"CALL Try"
290 Exe_time=TIMEDATE-Exe_time
300 Read:! Transfer the readings to the Computer
310 Tns_time=TIMEDATE
320 TRANSFER @Dmm TO @Buf_2
```

```
330 Tns_time=TIMEDATE-Tns_time
340 PRINT "DOWN LOAD TIME =";Dnld_time
350 PRINT "EXECUTION TIME =";Exe_time
360 PRINT "TRANSFER TIME = ";Tns_time
370 PRINT "TOTAL TIME= "; Dnld_time+Exe_time+Tns_time
380 END
 10 ! Bench Mark Test
 20 !
 30 COM Dnld_trme.Exe_time,Tns_time
 40 !
 50 CALL Default(Dnld_time,Exe_time,Tns_time)
 60 PRINT USING "36A.DD.DDD";"The execution time for default is
    ";Exe_time
 70 PRINT
 80 !
 90 CALL Fixed(Dnld_time.Exe_time,Tns_time)
100 PRINT USING "38A.DD.DDD":"The execution time for fixed range is
    ";Exe_time
110 PRINT
120 !
130 CALL Integrat(Dnld_time,Exe_time,Tns_time)
140 PRINT USING "51A,DD.DDD";"The execution time for correct
    integration time is";Exe_time
150 PRINT
160 !
170 CALL Delay(Dnld_time,Exe_time,Tns_time)
180 PRINT USING "44A,DD.DDD";"The execution time for correct delay time
    is";Exe_time
190 PRINT
200 !
210 CALL Burst(Dnld_time,Exe_time,Tns_time)
```

```
220 PRINT USING "44A,DD.DDD";"The execution time for storing readings
    is";Exe_time
230 PRINT USING "44A,DD.DDD";"The transfer time using FOR NEXT is
    ";Tns_time
240 PRINT USING "44A,DD,DDD";"The total time for memory IS
    ";Exe_time+Tns_time
250 PRINT
260 !
270 CALL Program(Dnld_time,Exe_time,Tns_time)
280 PRINT USING "44A,DD.DDD";"The execution time for program memory is
    ";Exe_time
290 PRINT USING "44A,DD,DDD";"The download time for transfering the SUB
    is";Dnld_time
300 PRINT USING "44A,DD.DDD";"The transfer time using FOR NEXT is
    ";Tns_time
310 PRINT USING "44A,DD.DDD";"The total time for program memory
    is";Exe_time+Dnld_time+ Tns_time
320 PRINT
330 !
340 CALL Disp(Dnld_time,Exe_time,Tns_time)
350 PRINT USING "44A,DD.DDD";"The execution time for program memory is
    ";Exe_time
360 PRINT USING "44A,DD.DDD";"The download time for transfering the SUB
    is";Dnld_time
370 PRINT USING "44A,DD.DDD";"The transfer time using FOR NEXT is
    ";Tns_time
380 PRINT USING "44A,DD.DDD";"The total time for display off
    is";Exe_time+Dnld_time+Tns_time
390 PRINT
400 !
410 CALL Azero(Dnld_time,Exe_time,Tns_time)
420 PRINT USING "44A,DD.DDD";"The execution time for program memory is
    ";Exe_time
```

```
430 PRINT USING "44A,DD.DDD";"The download time for transfering the SUB
    is";Dnld_time
440 PRINT USING "44A,DD,DDD";"The transfer time using FOR NEXT is
    ";Tns_time
450 PRINT USING "44A,DD.DDD";"The total time for AZERO off is";
    Exe_time+Dnld_time+ Tns_time
460 PRINT
470 !
480 CALL Defeat(Dnld_time,Exe_time,Tns_time)
490 PRINT USING "44A,DD.DDD";"The execution time for program memory is
    ";Exe_time
500 PRINT USING "44A,DD,DDD";"The download time for transfering the SUB
    is";Dnld_time
510 PRINT USING "44A,DD,DDD";"The transfer time using FOR NEXT is
    ";Tns_time
520 PRINT USING "44A,DD.DDD";"The total time for DEFEAT ON
    is";Exe_time+Dnld_time+Tns_time
530 PRINT
540 !
550 END
560 SUB Default(REAL Dnld_time,Exe_time, Tns_time)
570 DIM A(37)
580 Exe_time=TlMEDATE
590 OUTPUT 722:"RESET;TRIG SYN"
600 OUTPUT 722;"OHM"
610 FOR I=1 TO 23
620 ENTER 722;A(I)
630 NEXT I
640 OUTPUT 722;"OHMF"
650 ENTER 722;A(24)
660 ENTER 722;A(25)
670 OUTPUT 722;"ACV"
```

```
680 ENTER 722;A(26)
690 ENTER 722;A(27)
700 OUTPUT 722;"DCV"
710 FOR I=28 TO 33
720 ENTER 722;A(I)
730 NEXT I
740 OUTPUT 722;"ACV"
750 ENTER 722;A(34)
760 OUTPUT 722;"DCV"
770 FOR I=35 TO 37
780 ENTER 722;A(I)
790 NEXT I
800 Exe_time=TIMEDATE-Exe_time
810 Dnld time=0
820 Tns_time=0
830 SUBEND
840 SUB Fixed(REAL Dnld_time,Exe_time,Tns_time)
850 DIM A(37)
860 Exe_time=TIMEDATE
870 OUTPUT 722;"RESET;TRIG SYN"
880 OUTPUT 722;"OHM,1E4
890 FOR I=1 TO 15
900 ENTER 722;A(I)
910 NEXT I
920 OUTPUT 722;"OHM,1E5"
930 FOR I=16 TO 23
940 ENTER 722;A(I)
950 NEXT I
960 OUTPUT 722;"OHMF,1E3"
970 ENTER 722;A(24)
```

```
 980 ENTER 722;A(25)
 990 OUTPUT 722;"ACV,250;ACBAND 250"
1000 ENTER 722;A(26)
1010 OUTPUT 722;"ACV 10;ACBAND 25000"
1020 ENTER 722;A(27)
1030 OUTPUT 722;"DCV, 10"
1040 FOR I=28 TO 33
1050 ENTER 722;A(1)
1060 NEXT I
1070 OUTPUT 722;"ACV,10;ACBAND 5000"
1080 ENTER 722;A(34)
1090 OUTPUT 722;"DCV,10"
1100 FOR I=35 TO 37
1110 ENTER 722;A(I)
1120 NEXT I
1130 Exe_time=TIMEDATE-Exe_time
1140 Dnld time=0
1150 Tns_time=0
1160 SUBEND
1170 SUB Integrat(REAL Dnld_time,Exe_time, Tns_time)
1180 DIM A(37)
1190 Exe_time=TIMEDATE
1200 OUTPUT 722;"PRESET"
1210 OUTPUT 722;"OHM,1E4;NPLC 0"
1220 FOR I=1 TO 15
1230 ENTER 722;A(I)
1240 NEXT I
1250 OUTPUT 722;"OHM,1E5"
1260 FOR I=16 TO 23
1270 ENTER 722;A(1)
```

```
1280 NEXT I
1290 OUTPUT 722;"OHMF,1E3;APER 20E-6"
1300 ENTER 722;A(24)
1310 ENTER 722;A(25)
1320 OUTPUT 722;"ACV,250;ACBAND 250"
1330 ENTER 722;A(26)
1340 OUTPUT 722;"ACV 10;ACBAND 25000"
1350 ENTER 722;A(27)
1360 OUTPUT 722;"DCV,10;NPLC 0"
1370 FOR I=28 TO 33
1380 ENTER 722;A(I)
1390 NEXT I
1400 OUTPUT 722:"ACV,10;ACBAND 5000;APER 20E-6"
1410 ENTER 722;A(34)
1420 OUTPUT 722;"DCV,10;NPLC 0"
1430 FOR I=35 TO 37
1440 ENTER 722;A(I)
1450 NEXT I
1460 Exe_time=TIMEDATE-Exe_time
1470 Dnld_time=0
1480 Tns_time=0
1490 SUBEND
1500 SUB Delay(REAL Dnld_time,Exe_time,Tns_time)
1510 DIM A(37)
1520 Exe_time=TIMEDATE
1530 OUTPUT 722;"PRESET"
1540 OUTPUT 722;"OHM,1E4;NPLC 0;DELAY 0"
1550 FOR I=1 TO 15
1560 ENTER 722;A(I)
1570 NEXT I
```

```
1580 OUTPUT 722;"OHM,1E5"
1590 FOR I=16 TO 23
1600 ENTER 722;A(I)
1610 NEXT I
1620 OUTPUT 722;"OHMF,1E3;APER 20E-6;DELAY-1"
1630 ENTER 722;A(24)
1640 ENTER 722;A(25)
1650 OUTPUT 722;"ACV,250;ACBAND 250;DELAY.1"
1660 ENTER 722;A(26)
1670 OUTPUT 722;"ACV 10;ACBAND 25000;DELAY.01"
1680 ENTER 722;A(27)
1690 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0"
1700 FOR I=28 TO 33
1710 ENTER 722;A(I)
1720 NEXT I
1730 OUTPUT 722;"ACV,10;ACBAND 5000;APER 20E-6; DELAY .01"
1740 ENTER 722;A(34)
1750 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0"
1760 FOR I=35 TO 37
1770 ENTER 722;A(I)
1780 NEXT I
1790 Exe_tlme=TIMEDATE-Exe_time
1800 Dnld_time=0
1810 Tns_time=0
1820 SUBEND
1830 SUB Burst(REAL Dnld_time,Exe_time,Tns_time)
1840 DIM A(37)
1850 Exe_time=TIMEDATE
1860 OUTPUT 722;"PRESET;MEM FIFO;MFORMAT SREAL"
1870 OUTPUT 722;"OHM,1E4;NPLC 0;DELAY 0;NRDGS 15:TRIG SGL"
```

```
1880 OUTPUT 722:"OHM,1E5;NRDGS 8;TRIG SGL"
1890 OUTPUT 722;"OHMF,1ES;APER 20E-6;DELAY -1;NRDGS 2,TRIG SGL"
1900 OUTPUT 722;"ACV,250;ACBAND 250:DELAY.1;NRDGS 1;TRIG SGL"
1910 OUTPUT 722;"ACV 10;ACBAND 25000;DELAY.01;TRIG SGL"
1920 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 6;TRIG SGL"
1930 OUTPUT 722;"ACV,10;ACBAND 5000;APER 20E-6;DELAY .01;NRDGS 1;TRIG
     SGL"
1940 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 3;TRIG SGL"
1950 Exe_time=TIMEDATE-Exe_time
1960 Dnld_time=0
1970 Tns_time=TIMEDATE
1980 FOR I=1 TO 37
1990 ENTER 722:A(I)
2000 NEXT I
2010 Tns_time=TIMEDATE-Tns_time
2020 SUBEND
2030 SUB Program(REAL Dnld_time,Exe_time,Tns_time)
2040 DIM A(37)
2050 Dnld_time=TIMEDATE
2060 OUTPUT 722:"PRESET;MFORMAT SREAL"
2070 OUTPUT 722;"SUB 1:MEM FIFO;OHM.1E4;NPLC 0;DELAY 0:NRDGS 15;TRIG
     SGL"
2080 OUTPUT 722;"OHM.1E5;NRDGS 8;TRIG SGL"
2090 OUTPUT 722,"OHMF, 1E3;APER 20E-6:DELAY-1; NRDGS 2;TRIG SGL"
2100 OUTPUT 722;"ACV,250;ACBAND 250;DELAY.1;NRDGS 1; TRIG SGL"
2110 OUTPUT 722;"ACV10;ACBAND 25000;DELAY.01;TRIG SGL"
2120 OUTPUT 722:"DCV,10;NPLC 0;DELAY 0;NRDGS 6; TRIG SGL"
2130 OUTPUT 722;"ACV,10;ACBAND 5000;APER 20E-6; DELAY.01;NRDGS 1;TRlG
     SGL"
2140 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 3; TRIG SGL;SUBEND"
2150 Dnld_time=TIMEDATE-Dnld_time
```

```
2160 Exe_time=TIMEDATE
2170 OUTPUT 722;"CALL 1"
2180 Exe_time=TIMEDATE-Exe_time
2190 Tns_time=TIMEDATE
2200 FOR I=1 TO 37
2210 ENTER 722;A(I)
2220 NEXT I
2230 Tns_time=TIMEDATE-Tns_time
2240 SUBEND
2250 SUB Disp(REAL Dnld_time,Exe_time,Tns_time)
2260 DIM A(37)
2270 Dnld_time=TIMEDATE
2280 OUTPUT 722;"PRESET;MFORMAT SREAL;DISP OFF,TESTING"
2290 OUTPUT 722;"SUB 1;MEM FIFO;OHM,1E4;NPLC 0;DELAY 0;NRDGS 15;TRIG
     SGL"
2300 OUTPUT 722;"OHM,1E5;NRDGS 8;TRIG SGL"
2310 OUTPUT 722;"OHMF,1E3;APER 20E-6;DELAY -1;NRDGS 2;TRIG SGL"
2320 OUTPUT 722;"ACV,250;ACBAND 250;DELAY .1;NRDGS 1:TRIG SGL"
2330 OUTPUT 722;"ACV 10;ACBAND 25000;DELAY .01;TRIG SGL"
2340 OUTPUT 722:"DCV,10;NPLC 0;DELAY 0;NRDGS 6;TRIG SGL"
2350 OUTPUT 722;"ACV,10;ACBAND 5000;APER 20E-6;DELAY .01;NRDGS 1;TRIG
     SGL"
2360 OUTPUT 722:"DCV,10;NPLC 0;DELAY 0;NRDGS 3;TRIG SGL;SUBEND"
2370 Dnld_time=TIMEDATE-Dnld_time
2380 Exe_time=TIMEDATE
2390 OUTPUT 722;"CALL 1"
2400 Exe_time=TIMEDATE-Exe_time
2410 Tns_time=TIMEDATE
2420 FOR I=1 TO 37
2430 ENTER 722:A(I)
2440 NEXT I
```

```
2450 Tns_time=TIMEDATE-Tns_time
2460 SUBEND
2470 SUB Azero(REAL Dnld_time,Exe_time,Tns_time)
2480 DIM A(37)
2490 Dnld_time=TIMEDATE
2500 OUTPUT 722;"PRESET;MFORMAT SREAL;DISP OFF, TESTING;AZERO OFF"
2510 OUTPUT 722;"SUB 1;MEM FIFO;OHM,1E4;NPLC 0;DELAY 0;NRDGS 15;TRIG
     SGL"
2520 OUTPUT 722;"OHM,1E5;NRDGS 8;TRIG SGL"
2530 OUTPUT 722;"OHMF,1E3;APER 20E-6;DELAY-1; NRDGS 2;TRIG SGL"
2540 OUTPUT 722;"ACV,250:ACBAND 250;DELAY.1;NRDGS 1;TRIG SGL"
2550 OUTPUT 722;"ACV 10;ACBAND 25000;DELAY.01; TRIG SGL"
2560 OUTPUT 722;"DCV10;NPLC 0;DELAY 0;NRDGS 6; TRIG SGL"
2570 OUTPUT 722;"ACV,10;ACBAND 5000;APER 20E-6; DELAY.01;NRDGS 1;TRlG
     SGL"
2580 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 3; TRIG SGL;SUBEND"
2590 Dnld_time=TIMEDATE-Dnld_time
2600 Exe_time=TIMEDATE
2610 OUTPUT 722;"CALL 1"
2620 Exe_time=TIMEDATE-Exe_time
2630 Tns_tlme=TIMEDATE
2640 FOR I=1 TO 37
2650 ENTER 722;A(I)
2660 NEXT I
2670 Tns_time=TIMEDATE-Tns_time
2680 SUBEND
2690 Defeat(REAL Dnld_time,Exe_time,Tns_time)
2700 DIM A(37)
2710 Dnld_time=TIMEDATE
2720 OUTPUT 722;"PRESET;DISP OFF,TESTING;MFORMAT SREAL;DEFEAT ON"
```

```
2730 OUTPUT 722;"SUB 1;MEM FIFO;OHM.1E4;NPLC 0;DELAY 0:NRDGS 15;TRIG
     SGL"
2740 OUTPUT 722:"OHM.1E5:NRDGS 8;TRIG SGL"
2750 OUTPUT 722;"OHMF,1E3;APER 20E-6:DELAY -1; NRDGS 2:TRIG SGL"
2760 OUTPUT 722;"ACV,250;ACBAND 250;DELAY .1; NRDGS 1;TRIG SGL"
2770 OUTPUT 722;"ACV 10;ACBAND 25000;DELAY.01; TRIG SGL"
2780 OUTPUT 722;"DCV,10;NPLC 0;DELAY 0;NRDGS 6;TRIG SGL"
2790 OUTPUT 722;"ACV,10;ACBAND 5000;APER 20E-6;DELAY .01;NRDGS 1;TRIG
     SGL"
2800 OUTPUT 722;"DCV10;NPLC 0;DELAY 0;NRDGS 3;TRIG SGL;SUBEND"
2810 Dnld_time=TIMEDATE-Dnld_time
2820 Exe_time=TIMEDATE
2830 OUTPUT 722;"CALL 1"
2840 Exe_time=TIMEDATE-Exe_time
2850 Tns_time=TIMEDATE
2860 FOR I=1 TO 37
2870 ENTER 722;A(I)
2880 NEXT I
2890 Tns_time=TlMEDATE-Tns_time
2900 SUBEND


  10 !MAIN PROGRAM
  20 COM A(20),B(90),C(30),D(30),J$[80]
  30 CALL Test_58(Time58)
  40 END
  50 !
  60 !
  70 SUB Test_58(Time58)
  80 DIM A(20),B(90),C(30),D(30),J$[80]
  90 !SET UP SCANNER
 100 ASSIGN @Scan TO 709
```

```
110 ASSIGN @Dmm TO 722
120 CLEAR @Dmm
130 OUTPUT @Dmm;"RESET" !Sets the dmm to power-up state
140 OUTPUT @Dmm;"TRIG HOLD" ! Stops triggering
150 !
160 ! -------- ScannerSetup --------
170 !
180 OUTPUT @Scan;"RESET"
190 OUTPUT @Scan;"CLOSE 200,400,410;STORE 1"
200 OUTPUT @Scan;"CLOSE 308,309;STORE 2"
210 OUTPUT @Scan;"OPEN 200"
220 OUTPUT @Scan;"CLOSE 201; STORE 3"
230 OUTPUT @Scan;"OPEN 201"
240 OUTPUT @Scan;"CLOSE 206;STORE 4"
250 OUTPUT @Scan;"OPEN 206"
260 OUTPUT @Scan;"CLOSE 202;STORE 5"
270 OUTPUT @Scan;"OPEN 202"
280 OUTPUT @Scan:"CLOSE 205;STORE 6"
290 OUTPUT @Scan;"OPEN 205"
300 OUTPUT @Scan;"CLOSE 204;STORE 7"
310 OUTPUT @Scan;"OPEN 204"
320 OUTPUT @Scan;"CLOSE 203;STORE 8"
330 !
340 ! -------- Channel list --------
350 !
360 OUTPUT @Scan;"SLIST 1,2,3,3,4,4,5,5,6,6,7,8.8,0"
370 !    Setup the scan list for the states
380 !    that are automatically incremented
390 !    by the STEP command or the external
400 !    increment input signal
```

```
 410 OUTPUT @Scan;"DMODE 1,1,0,1"! Setup for external increment
 420 !    and channel close on the scanner.
 430 !
 440 ! -------- Measurement Setup --------
 450 !
 460 OUTPUT @Dmm;"PRESET;TARM HOLD"!Sets the dmm in its normal PRESET
 461 !    and holds the trigger arm
 462 OUTPUT @Dmm:"MFORMAT DREAL"! Stores the data in memory in IEEE
 463 !     double-real format
 470 OUTPUT @Dmm;"TRIG EXT"!Sets the dmm to trigger externally
 480 OUTPUT @Dmm;"APER 20E-6"!Sets the integrator aperture to 20 µs
 490 OUTPUT @Dmm;"TBUFF ON"! Sets-up the trigger buffer
 500 !      does not occur
 510 OUTPUT @Dmm;"DISP OFF !     Turns off the front panel display on
the dmm
 520 OUTPUT @DMM;”DELAY 0”!      Sets the time between trigger event
 530 !      and measurement start to 0 s
 540 !
 550 ! --------- Measurement List -------------
 560 !
 570 OUTPUT @Dmm;"SUB 1"! Start of the dmm program
 580 OUTPUT @Dmm;"MEM FIFO"!  Sets memory to first-in, first-out
 590 OUTPUT @Dmm;"DCV 10" !   Sets the dmm to dcV function and 10 volts
     max
 600 OUTPUT @Dmm;"TARM SGL"! (1) Initiates the measurement sequence once
     the
 610 !  TRIG EXT is satisfied and stops after just
 620 !  one trigger event occurs.
 630 OUTPUT @Dmm;"TARM SGL"!(2)   Repeats the sequence again.
 640 OUTPUT @Dmm;"TARM SGL"!(3)   And again
```

```
650 OUTPUT @Dmm;"ACBAND 1000"  !  Sets the lower frequency range to 1
    kHz
660 OUTPUT @Dmm;"ACV 10"!Sets the dmm to 10 volts maximum input in acV
670 OUTPUT @Dmm;"TARM SGL"! (3
680 OUTPUT @Dmm;"TARM SGL"! (4)
690 OUTPUT @Dmm:"DCV 10”
700 OUTPUT @Dmm;"TARM SGL"! (4)
710 OUTPUT @Dmm;"TARM SGL"! (5)
720 OUTPUT @Dmm;"ACV 10"
730 OUTPUT @Dmm;"TARM SGL"! (5)
740 OUTPUT @Dmm;"TARM SGL"! (6)
750 OUTPUT @Dmm;"DCV 10"
760 OUTPUT @Dmm;"TARM SGL"! (6)
770 OUTPUT @Dmm;"TARM SGL"! (7)
780 OUTPUT @Dmm;"OHM 3E3"!Sets the dmm to Ω function and 3 kΩ
790 OUTPUT @Dmm;"TARM SGL"! (8)
800 OUTPUT @Dmm;"OCOMP ON"!  Turns on offset compensation.
810 OUTPUT @Dmm;"TARM SGL"! (8)
820 OUTPUT @Dmm;"SUBEND" !End of dmm program memory
830 !
840 ! -------- Measurement Execution --------
850 !
860 OUTPUT @Dmm USING "#,K";"CALL 1;"! Calls the dmm program
870 OUTPUT @Scan;"STEP"!Moves to the first setup and triggers the dmm
880 !
890 !--Transfer readings from dmm to computer--
900 !
910 FOR I=1 TO 13
920 ENTER @Dmm;A(I)
930 PRINT USING "SD.DDDE";A(I)
```

```
940 NEXT I
950 SUBEND
```

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E High Resolution Digitizing With the 3458A

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High Speed Data Transfers 495
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(From Product Note 3458A-2)

Introduction

In your system or stand-alone with your computer, the 3458A can digitize wave forms with low distortion and very high resolution. The 3458A has the measurement speed and precise timing necessary for direct sampling of signals with frequency components up to 50 kHz or, with repetitive signals, subsampling up to 12 MHz with 16 bits of resolution and more.

In this product note you will learn how to:

1. Configure the 3458A to capture transient signals using direct sampling.
2. Configure the 3458A to capture repetitive signals using sequential sampling.
3. Use slope and level triggering to capture the data where you want.
4. Transfer measured signal data from the 3458A to your HP 9000 Series 200/300 Computer at 100 kSamples/s.
5. Use the 3458A's Program Memory to capture signals on multiple channels, store them in the 3458A's Reading Memory, interrupt the HP 9000 Series 200/300 Computer when the task is complete, and transfer the data from the multimeter to the computer for comparison, analysis, and graphic presentation.
6. Use the 3458A Option 005 Wave Form Analysis Library, to acquire, analyze, and present the digitized signals.
7. Interpret specifications that pertain to wave form digitizing and dynamic performance.

Speed with Resolution

- 16 bits @ 100 kSamples/s
- 18 bits @ 50 kSamples/s

The 3458A offers you complete flexibility for speed and resolution over the audio frequency bandwidth. The DCV measurement path can digitize your audio frequency signal with less than 175 ns trigger latency and less than 100 ps measurement-to-measurement jitter. Through the track-and-hold path, the 3458A can digitize repetitive signals up to 12 MHz at 50 kSamples/s with 16 bits resolution by using sequential sampling (subsampling).

Digitizing analog signals

Most digital signal processing systems may be represented as illustrated in Figure E-1.

In any digital processing system, there is a minimum allowable sampling rate called the Nyquist Rate and it is specified by the Sampling Theorem, summarized as follows:

- When digitizing an analog signal, the sampling rate must be a least twice as great as the highest frequency component (f_0) in the spectrum of the sampled signal. Frequency components higher than f_0 will “alias” down into the frequency range below f_0 and interfere with the accurate representation of the sampled signal. For example, since a square wave can be represented as an infinite sum of sinusoids (Fourier Series) and contains very high frequency components, attempting to digitize this signal without an anti-aliasing filter on the input will severely alias the captured signal so that representations of the actual signal may be meaningless.

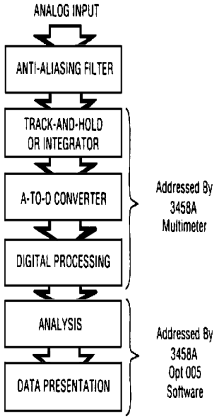

Figure E-1 In general, digital signal processing systems require a close look at various functions beginning with the analog signal and ending with results meaningful to the user.

Avoiding aliasing

To avoid signal distortion caused by aliasing, the effective sample interval must meet the Nyquist criterion of $1/(2f_0)$. In direct sampling, the effective sample interval is the actual time between measurements selected. Therefore, through the track-and-hold path or through the DCV path (explained in the next section), the maximum signal frequency is 25 kHz or 50 kHz for 20 µs or 10 µs sample intervals, respectively. If higher frequencies are present, then a low-pass filter of bandwidth f_0 or less should be inserted in the signal path.

For sequential sampling, the effective sample interval is the time between samples of the reconstructed wave form (refer to Figure E-2). If you select an effective sampling interval of less than 35 ns, the bandwidth of the track-and-hold path, 12 MHz, eliminates most distortion caused by aliasing. If the effective sample interval is greater than 35 ns and frequencies higher than 12 MHz are present, an external filter is necessary as well.

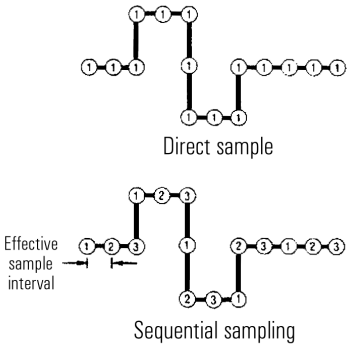

Figure E-2 Direct sampling acquires the wave form in one pass of the input. Sequential sampling requires a repetitive signal where the period is reconstructed in several passes. The numbers shown represent samples acquired in one period of the input.

Choice of Two Measurement Paths

The 3458A provides two different input measurement paths: the standard DCV path and the track-and-hold path (see Figure E-3). The track-and hold path is used for subsampling and direct sampling. The DCV path is used for direct sampling alone. At your discretion, you may use the standard DCV path for subsampling, but you have to program the algorithm for data capture.

Using the DCV path for direct sampling

The standard DCV path is selected for you when you program the command "PRESET DIG". This command establishes default parameters to directly digitize the input signal, assuming that you will want 256 samples at 50 kSamples/s with full scale set at 10 V peak. The trigger circuit assumes that you want to trigger on the input signal at 0 V level, positive slope, AC coupled. Hence, with these default conditions you can capture at least one cycle from 200 Hz up to 25 kHz.

The standard DCV path also offers speed and resolution tradeoffs from 18 bits (5 1/2 digits) at 6 kSamples/s to 16 bits (4 1/2 digits) at 100 kSamples/s. The noise floor on the 10 V range for the corresponding sample rates are 0.005%, and 0.05%, respectively.

As the resolution is increased in the DCV path there is a corresponding increase in the aperture time. Hence, the obvious trade-off for lower noise and more resolution is the loss of information because of the broadening of the sample aperture. To capture the peak value of a pulse, the aperture must be no wider than the pulse width. From a practical viewpoint, trigger uncertainty can make the task of capturing peak amplitudes nearly impossible for pulses near the width of the sampling aperture. The solution is to narrow the aperture to a point where the bandwidth of the input amplifier is the resolution limiting factor, not the sample aperture.

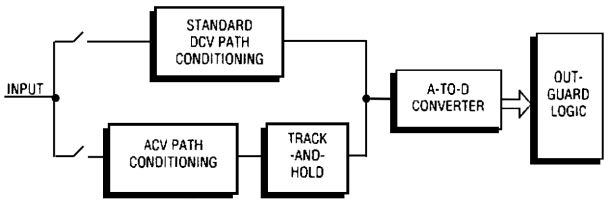

Figure E-3 The 3458A multimeter (RoHs Compliance) provides two different digitizing paths, the standard DCV path and a track-and-hold path.

Using the track-and-hold path for direct or sequential sampling

The track-and-hold path is the solution to capturing the amplitude of narrow pulses. This path has a bandwidth of 12 MHz and a fixed aperture of 2 ns. With trigger jitter of 2 ns, you can, with a little searching, capture the peak amplitude of a pulse as narrow as 40 ns without measurement degradation, as indicated in Figure E-4. Rise times of less than 10 ns will cause overshoot in a digitized measurement; hence, if it is likely that signals with these frequency components will be applied to the input of the 3458A, then bandlimit the signal by filtering. Direct digitizing with the track-and-hold path allows the capture of signals with frequency components up to 12 MHz. The same path is used to subsample repetitive signals up to 12 MHz.

Programming the 3458A for direct or subsampled (sequential) digitizing using the track-and-hold path is simple. Only one command is required. For example, DSAC provides direct sampling, AC coupled, or SSAC provides sequential sampling, AC coupled. These commands automatically use default parameters that can be changed.

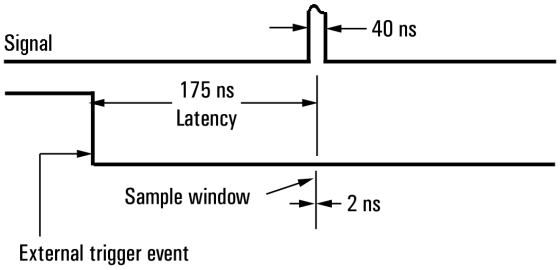

Figure E-4 Capturing the pulse amplitude of narrow pulses requires the use of the 12 MHz track-and-hold path. Note, the minimum time between sample acquisition and trigger event is 175 nanoseconds.

Capturing the Data

The 3458A can be triggered to commence the measurement cycle by the level and slope of the input signal, by a zero voltage level crossing of the power line, by the GET (group execute trigger) command on the GPIB, by an external TTL signal, by an internally generated trigger signal (for burst measurements, this can be paced), and by the computer asking for a reading.

The 3458A provides all the tools you need to catch the signal of interest by offering three levels of triggering and up to eight conditions to satisfy including the wave form's level and slope. The hierarchy of trigger levels is trigger arming (TARM), trigger (TRIG), and number of readings per trigger (NRDGS). Focused at digitizing, two additional commands are used for direct sampling and subsampling: SWEEP which is related to NRDGS, and SSRC which selects the trigger source (level or external) for subsampling. You can choose from a variety of events or conditions that must be satisfied before taking measurements, as shown is Figure E-5. The default condition for all three levels of triggering is AUTO; the 3458A will generate its own trigger as fast as the multimeter set-up allows.

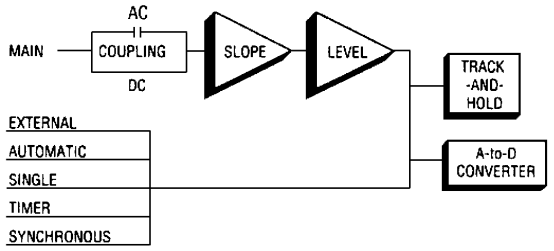

Figure E-5 The trigger event choices shown provide the versatility needed to match a wide variety of applications.

TARM is the first condition to be satisfied. Its function is to arm the trigger circuit prior to receiving the trigger signal. For example, if a synchronizing signal were available external to the signal of interest, then TARM EXT could be used to arm the 3458A to look for the trigger event. Also, TARM can be used to control multiple measurement sequences by adding the number of times you want a particular measurement cycle repeated. For example, TARM SGL,4, specifies that the trigger arming be applied four times and then stops. Refer to Figure E-6.

```
10 OUTPUT 722; “TARM HOLD” ! Places the 3458A in a measurement hold
condition.
20 OUTPUT 722,”TRIG EXT” ! Sets the trigger event to trigger.
30 OUTPUT 722, “NRDGS 5, TIMER” ! Sets up a burst of five readings for
every trigger.
40 OUTPUT 722; “TIMER 2E-3” ! The time between readings will correspond
to the TIMER setting(2E-3 or 2 ms)
          …
200 OUTPUT 722; “TARM SLG, 4” ! Four burst of measurements are allowed
to begin when the external triggers occur
```

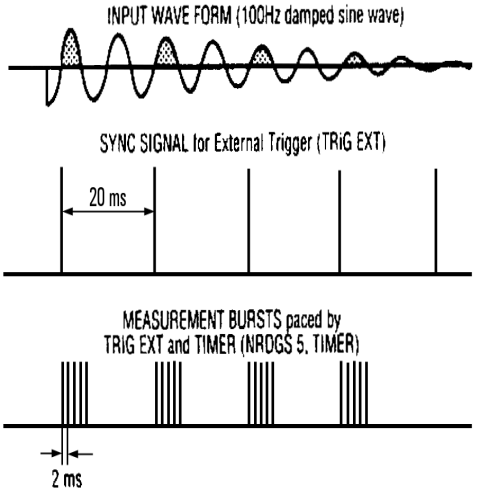

Figure E-6 Digitizing with the standard triggering command. Trigger Arming, TARM SGL, 4 allows a measurement cycle to occur only 4 times, reducing the amount of data necessary to determine the ratio of the shaded areas in the input wave form.

TRIG is the next condition to be satisfied. Only after both TARM and TRIG event conditions are satisfied can a burst measurement be made with NRDGS. Refer to Figure E-7.

```
NRDGS [# of readings] [,event]
```

lets you specify the number of readings to take, the trigger condition for each reading, and the number of readings saved in memory before or after the trigger event.

The SWEEP and SSRC commands are specifically designed to make the task of digitizing easier. The

```
SWEEP [effective interval between readings] [, number of readings]
```

command combines the NRDGS parameters with TIMER. SSRC selects the synchronizing source for subsampling, either external or level. Both the SWEEP and SSRC commands are used for SSAC (subsampled, AC coupled) and SSDC (subsampled, DC coupled), and the NRDGS and TRIG are ignored. For DSAC (direct sampled, AC coupled) and DSDC (direct sampled, DC coupled) all triggering commands are valid but the use of both in the same measurement is not recommended.

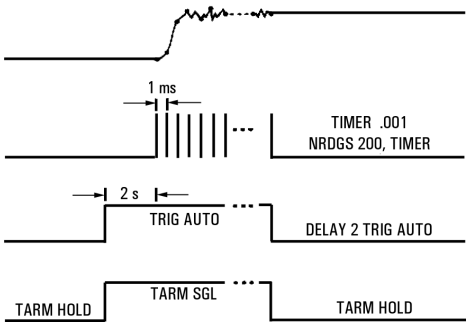

Figure E-7 Once the trigger arming and trigger event conditions are satisfied, a burst of measurements can digitize a wave form as shown in this example.

The SSRC command offers you either internal level triggering or synchronization with the external trigger. In the subsampling mode, the SSRC EXT calculates the number of external triggers it needs to accomplish the measurement you specify with the SWEEP command.

For example, if you want to capture a wave form with 100 ns time resolution for 4096 readings

```
[SWEEP 100E-9,4096]
```

the 3458A multiplies the number of readings by the time interval and divides by the minimum time between samples.

Delay can be used in conjunction with external trigger synchronization to window your measurement to examine the parts of the wave form you want to see in detail. For example, consider using the 3458A as a broadband phase/gain meter with a 3325A source to measure the transfer function of a passband filter over a frequency range of 0.5 to 5 MHz. Refer to Figure E-8. The highest frequency is 5 MHz so the minimum time between samples for entire band is 100 ns for two samples per cycle. Two methods suggest themselves for this analysis: (1) sweep the entire frequency spectrum at 100 ns interval or (2) divide the frequency spectrum into bands and sweep these bands at the $1/(2f_0)$ for the band. In the first case, the data acquisition time is minimized, in the second case the need for a fast computer is minimized.

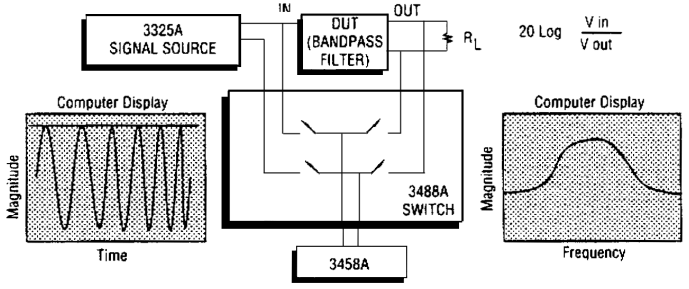

Figure E-8 Using the 3458A as a phase/gain meter with a swept frequency generator for magnitude only Bode plots. The DUT can be characterized over frequency with a phase synchronous trigger to time the measurement.

High Speed Data Transfers

The 3458A can transfer readings at its maximum reading rate to a 9000 Series 200/300 computer with a direct memory access card only the computer is set up to capture the data at this rate. The readings can be taken from the 3458A internal memory or as the dmm is making the measurements. Two conditions must occur: the dmm has to be devoted to high speed readings and the proper buffers must be set up in the computer.

PRESET DIG is exactly the command needed for the 3458A. It sets up the DMM for the highest speed possible.

As long as direct digitizing is the desired operation, there is no problem in reconstructing the wave form as it is presented to the computer. If you use the memory for data storage before transferring the captured signal, the 3458A orders the data for you.

Software help the wave form analysis library

The Wave Form Analysis Library, 3458A Option 005 (03458- 80005), not only lets you acquire the wave form without having to use even the simple commands to control the 3458A, but it also lets you analyze and present the data with a minimum of computer and instrument knowledge. A simple sequence of measurement setup, measurement acquisition, analysis, and presentation is all that you have to keep in mind while developing your master program that calls up both BASIC language and compiled subprograms. Refer to Figure E-9.

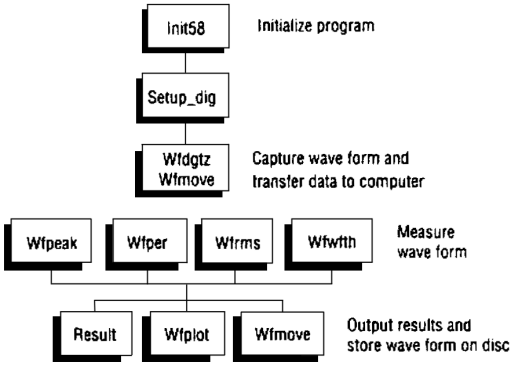

Figure E-9 Here is a typical way to structure your own automatic measurement program using the Library Subprograms (not necessarily a complete list).

In addition to time domain analysis like frequency, risetime, pulse width, and overshoot, the Wave Form Analysis Library offers frequency domain analysis with Fast Fourier Transform (FFT) and Inverse Fourier Transform (IFT), with the Hanning filter function. Further, the Wave Form Analysis Library gives you a “Fast Scope” program that lets your 3458A and a HP 9000 Series 200/300 computer take measurements up to 50,000 Samples/s and present the data to the computer display at a refresh rate up to 5/s. In effect, the combination gives you a very high resolution single channel oscilloscope of 12 MHz bandwidth.

The Wave Form Analysis Library also lets you compare a previously captured wave form with limits on the measurements to the input signal.

Several utility functions are also provided with the Wave Form Analysis Library: Format, which formats the output display in engineering units, Intrpo, which performs a linear interpolation between sample points, Sinc, which performs a sinc function interpolation between sample points for signals captured near the Nyquist limit, and Warn58, which prints error and warning messages on the computer CRT or printer.

As an example, consider how the Wave Form Analysis Library can be used to capture an AM modulated signal to extract the carrier, the modulation frequency, and the depth of modulation.

First, the main program must be written to call the library subprograms. The main program is a block of program code that controls and invokes the subprograms in the order necessary to solve the measurement problem. The main program can be short or long depending on the needs of the measurement task. Part of a main program is shown in below. This program captures a wave form using the 3458A, transfers the wave form to the computer, and plots the wave form on the computer's CRT. It uses four Library subprograms: Setup_dig, the dmm setup subprogram that determines the way you are going to digitize the wave form (DCV, DSAC, DSDC, SSAC, SSDC), the time interval between samples, and the number of samples (if you plan on using the FFT or IFT routines, the number of samples must be a power of two); Wfdgtz, the wave form capture subprogram; Wfmove, the transfer subprogram; and Wfplot, the plotting subprogram.

```
1280 CALL Setup_dig(1,1.e-5,1000)
1270 CALL Wfdgtz(1)
1280 CALL Wfmove("1","98",Scal(*),Wavf(*),Clip)
1290 CALL Wfplot(Scal(*),"Wave form 1",Wavf(*),1,1)
```

The subprogram is one of the most powerful elements available in any programming language. Each subprogram has its own context or state as distinct from the main program. This means that every subprogram has its own set of variables and its own line labels.

Starter main program

Every program using the library subprogram requires a main program. Many of the data arrays discussed in this part must be dimensioned in each main program. Additionally, the COM statements used by many of the library subprograms are needed in most main programs. Included with the Wave form Analysis Library is a starter main program that can form the beginning of all main programs as shown here.

```
 10  ! Main
 20  ! Core main program programming aid
 30  !** COMMON
 40  COM/Hp3458/@Recorder,Xist_plotter,Prt,Bus,Xist
 50  !** Real Arrays
 60  REAL Scal(0:4),Yamp(0:7)
 70  !** STRINGS
 80  DIM Source$[50],Destin$[50],Titles$[30]
 90  !** INTEGER ARRAYS
100  INTEGERWavf(1:16384),Redg(0:30),Fedg(0:30),Bandwf(0:163)
```

```
110  DISP               ! Clear display line
120  OUTPUT I USING "@" ! Clear CRT
130  !
140  CALL Init58        ! Wake up the bus
150  !
160  GINIT              ! Initialize graphics
170  !
180  ! Insert user main program here
250  ! to here
260  END
```

Returning to the original problem, the subprograms needed to analyze the AM modulated signal are:

Setup_dig, Wfdgtz, Wfmove, Fft, and Fft_plot.

In other words the following would be inserted as the main program:

```
190 CALL Setup_dig(2,20E-6,512)
200 CALL Wfdgtz (1)
210 CALL Wfmove("1","98",Scal(*),Wavf(*),Clip)
220 CALL Fft
(512,1,Hanning,Wavf(*),Real_dat(*),Imag_dat(*),Magn_dat(*))
240 CALL
Fft_plot(Magn_data(*),Smpl_intvl,Dyn_range,F_start,F_stop,Title$)
250 END
```

The results of this program are shown in Figure E-10.

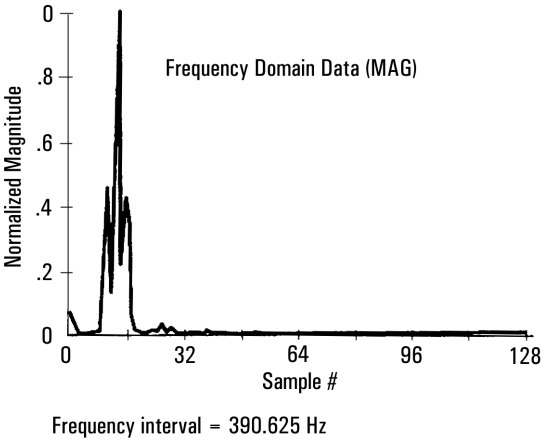

Figure E-10 Example of results generated using the Wave Form Analysis Library.

Errors in Measurements

The flexibility of the 3458A helps you avoid or compensate for many of the measurement errors that can occur in the digitizing process. Errors associated with digitizing can be grouped by their amplitude error and time error contributions to the total error in the measurement. For dynamic signals, time errors result in amplitude error. Fortunately, most time dependent measurements are differential and any absolute timing errors are calibrated out of the measurement. A close look at the block diagram of the 3458A reveals the sources of error in the measurement, summarized in Figure E-11.

Broadly speaking, errors that creep into digitizing measurements are evident in both the amplitude and time axes.

For amplitude, the errors are:

1. Quantization error
2. Missing code
3. Non-linearity
4. Noise
5. Bandwidth
6. Amplitude accuracy

On the time axes, the error factors are:

1. Timebase reference jitter
2. Trigger uncertainty
3. Trigger accuracy
4. Trigger latency
5. Aperture width
6. Aperture jitter

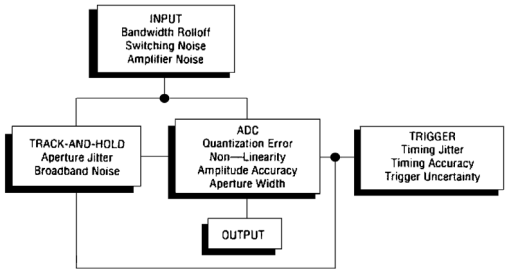

Figure E-11 These digitizing error sources should be considered in any measurement.

Amplitude errors

The input signal conditioning section of the 3458A has switches (relays), attenuators, and amplifiers associated with conditioning and routing the signal for either the Analog-to-Digital (ADC) or the track-and-hold. Auto zero eliminates input offset errors but the residual error does propagate. This section is the low frequency section of the 3458A. Hence, depending on the range, the signal is routed through a low pass filter (the input amplifier) before being presented to the ADC.

Quantization error is the fundamental, irreducible error associated with the perfect quantizing of a continuous (analog) signal into a finite number of digital bits. Hence, the resolution of the ADC has a direct impact on your ability to measure the input wave form in detail. Some limitations may be overcome by window amplifiers that will allow the signal's detailed examination in the presence of large offsets, but the introduction of the amplifier adds error to the measurement that is not necessary for high resolution ADCs.

Missing code may only manifest itself at high speed. The most common cause of missing code is dielectric absorption (DA), the polarization of dipoles in the insulating material surrounding the conductor. Careful design can eliminate this problem, but DA can cause measurements to have a “memory” of previous measurements. If sufficient settling time is given to the ADC, the problem falls below the quantization level.

Missing code coupled with quantization error results non-linearity of the ADC. This occurs in two forms: differential and integral non-linearity. Differential nonlinearity is the largest step that occurs between successive quantization

levels. Integral non-linearity is the maximum deviation of the linearity curve from a leastmean-square fit. In general, differential non-linearity may cause significant measurement error if a low level signal happens to fall on that part of the ADC transfer function with the differential non-linearity error. Integral non-linearity in an ADC is generally more detrimental when digitizing full scale signals.

Realize that the transfer function for an ADC is very dependent upon the slew rate (dV/dt). The transfer function for a static DC input level may appear close to the ideal. The transfer function under dynamic operating conditions may exhibit numerous errors as shown in Figure E-12.

An inescapable reality in any measurement is the attendant noise with increasing bandwidth. The effects of random measurement noise can be reduced by averaging the measurements. Caused by Johnson noise and other circuit related noise as well as noise on the input signal, the removal of this noise always costs measurement time. A measure of the quality of a digitizing instrument, called the “effective bits” of resolution, combines noise with ADC linearity to show the usable resolution of the digitizer:

$$\text{effective bits} = N - \log_2(\text{rms error (actual)}/\text{rms error (ideal)})$$

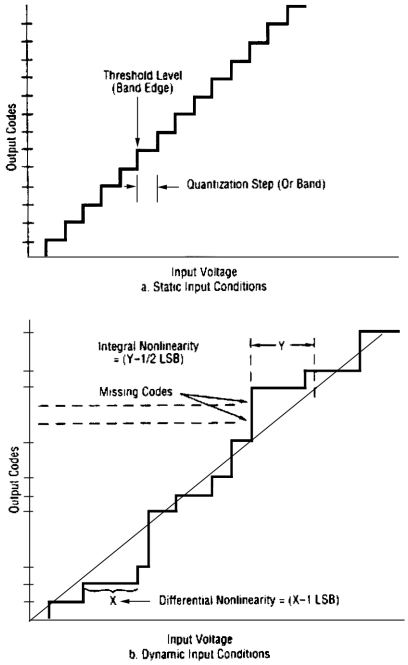

Figure E-12 With static DC input levels, the analog-to-digital converter may exhibit an ideal transfer function as shown in 12a. With a dynamic input, however, errors shown in 12b may appear.

The rms error (actual) is the error measured relative to the best-fit perfect sine wave. The rms error (ideal) is the theoretical error from a perfect N bit ADC. For low resolution instruments, the effective bits is a true measure quality; for high resolution instruments, the noise associated with any measurement swamps the actual performance of the ADC. If, however, a large number of samples is taken or, equivalently, the samples are averaged, the noise can be reduced to the point where actual quantization and non-linearity errors are evident in the Fourier transform of the sampled data. This effect is shown in Figure E-13. The third harmonic of the input signal is actually an integral non-linearity. Averaging ten samples does not remove its level, whereas the noise floor drops 10 dB.

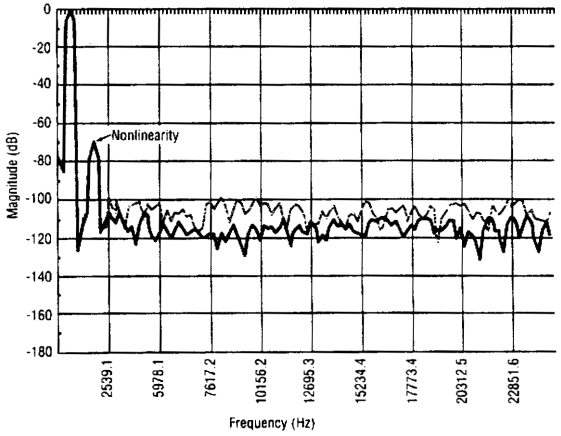

Figure E-13 Analog-to-digital converters that exhibit non-linearity errors cause spurious responses that averaging will not remove. The 3458A is linear to 16 bits at 100,000 readings/s.

The 3458A offers two input paths. The differences are that the direct ADC path (DCV) offers up to 160 kHz bandwidth up to a sampling rate of 100,000 samples per second; the track-and- hold path offers 12 MHz bandwidth at a sampling rate of 50,000 readings per second. Both paths exhibit single pole roll-off; both are nominally three dB down (half power) at the bandwidth point. Hence, two errors can creep into your measurements: aliasing and amplitude roll-off. In the track-and-hold path aliasing can be eliminated by increasing the effective sampling rate up to 100 MSamples/s and the track-and-hold circuit can be characterized for amplitude roll-off over the band of interest to compensate for the roll-off. In the case of the DCV path, the only real solution to aliasing is to supply a low pass analog filter. See Figure E-14.

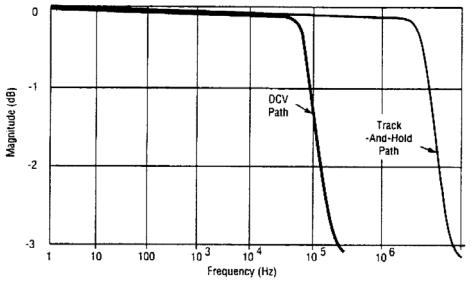

Figure E-14 Amplitude roll-off of the 3458A multimeter (RoHs Compliance) for its two different measurement paths.

Finally, the accuracy of the measurement itself, although not often discussed with digitizers, is related to the reference accuracy of the 3458A. For static and dynamic measurements, the absolute accuracy actually exceeds the dmm's resolution. And, in terms of long term drift, the absolute error is less than 7 ppm per year.

Trigger and timebase errors

The timebase, a precision temperature compensated quartz crystal, has its drift and jitter which will affect the amplitude measurement of the input signal. But, these tend to be very small - less than 50 ps. Hence, the clock accuracy and jitter do not really affect the measurement within the measurement bandwidth of the 3458A. The timebase jitter error is not cumulative; therefore each sample point has only its own jitter error and not the combined jitters of previous sample points. The effects of all the time axis errors are shown in Figure E-15.

The trigger error is orders of magnitude greater than timebase error and jitter. Two effects cause this. The 3458A has no delay line, so there is a trigger latency, a time delay between the trigger and the commencement of the measurement, that is fixed by the firmware, the clock, and the timing circuits. It is specified to be less than 175 ns for an external trigger. The accuracy of the trigger can also be affected by noise on the trigger signal and time interpolator variation between measurements. This is of the order of 50 ps as well except in very noisy cases, where it is advisable to use the 3458A's trigger filter which reduces the bandwidth of the trigger circuit to a nominal value of 70 kHz.

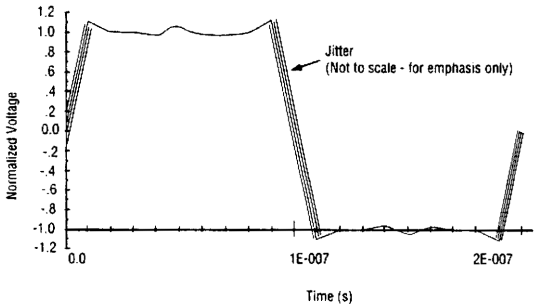

Figure E-15 The effects of timebase jitter is shown here. For the 3458A multimeter (RoHs Compliance), the jitter is 50 ps RMS. This jitter is repeatable so it can be characterized and corrected.

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