Model 2001 Multimeter

Operator's Manual

Contains Operating Information

KEITHLEY

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Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 3 years from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

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6/99

Model 2001 Multimeter
Operator's Manual

Cleveland, Ohio, U.S.A.
Sixth Printing July 1998
Document Number: 2001-900-01 Rev. F

Manual Print History

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

Revision A (Document Number 2001-900-01) ..... May 1992
Addendum A (Document Number 2001-900-02) ..... May 1992
Addendum A (Deviation Number 15315D) ..... May 1992
Addendum A (Document Number 2001-900-03) ..... June 1992
Addendum A (Document Number 2001-900-04) ..... June 1992
Revision B (Document Number 2001-900-01) ..... July 1992
Revision C (Document Number 2001-900-01) ..... December 1992
Addendum C (Document Number 2001-900-02) ..... June 1993
Addendum C (Document Number 2001-900-04) ..... September 1994
Addendum C (Document Number 2001-900-05) ..... January 1995
Addendum C (Document Number 2001-900-06) ..... July 1995
Revision D (Document Number 2001-900-02) ..... August 1995
Revision E (Document Number 2001-900-02) ..... April 1996
Revision F (Document Number 2001-900-01) ..... July 1998

Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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1

General Information

1.1 Introduction

This section contains general information about the Model 2001 Multimeter. It is arranged in the following manner:

1.2 **Features**
1.3 **Warranty information**
1.4 **Manual addenda**
1.5 **Safety symbols and terms**
1.6 **Specifications**
1.7 **Inspection**
1.8 **Options and accessories**

1.2 Features

Some important Model 2001 features include:

- Full range of functions — Among other functions, the multimeter can measure DC voltage (normal and peak spikes), AC voltage (RMS, average, and peak), DC current (normal and in-circuit), AC current (RMS and average), two and four-wire resistance (normal and offset-compensated), frequency, and temperature (resistance temperature devices or thermocouples).
- Two-line display — Readings and front panel messages are shown on an alphanumeric display having a 20-character top line and a 32-character bottom line.
- Multifunction measuring and display — From the front panel, you can configure the instrument to sequentially measure and simultaneously display readings of multiple functions.
- Reading and setup storage — Readings and setup data can be stored and recalled from the front panel or over the IEEE-488 bus. For example, the buffer can be programmed to store up to 850 readings at 4.5 digits, or up to 250 time-stamped readings at 6.5 digits. The Model 2001 can be configured with memory options that extend the storage capacity up to 30,000 readings and ten setups.
- High-speed measurements — The instrument is capable of acquiring, for example, 2000 readings/second at 4.5 digits of resolution, and 215 readings/second at 6.5 digits.
- Talk-only mode — From the front panel, you can set the instrument to send readings to an IEEE-488 printer or, with an optional adapter, to a Centronics printer.
- Digital calibration — The instrument may be digitally calibrated from either the front panel or over the bus.
- Standard IEEE-488 interface — Bus operation conforms to the IEEE-488.2 and SCPI standards.
- Trigger link — This is a new trigger concept that provides more versatile and precise external triggering. It is in addition to the standard Trigger In/Measurement Complete BNC external triggering techniques.
- Optional field-installable internal scanner — This is a 10-channel scanner card, which includes eight channels of 2-pole relay switching and two channels of 2-pole solid-state switching. All channels can be configured for 4-pole operation.

1.3 Warranty information

Warranty information is located on the inside front cover of this instruction manual. Should your Model 2001 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

1.4 Manual addenda

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into the manual.

1.5 Safety symbols and terms

The following symbols and terms may be found on an instrument or used in this manual.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The WARNING heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The CAUTION heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

1.6 Specifications

Full Model 2001 specifications are included in Appendix A.

1.7 Inspection

The Model 2001 was carefully inspected, both electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (Note: There may be a protective film over the display lens, which can be removed.) Report any damage to the shipping agent immediately. Save the original packing carton for possible future reshipment. The following items are included with every Model 2001 order:

- Model 2001 Multimeter (with MEM1 or MEM2 memory option, if ordered) with line cord.
- Model 8605 High Performance Modular Test Leads.
- Model 2001 Operator's Manual and Model 2001 Calibration Manual.
- Accessories as ordered.
- Full calibration data (conforming to MIL-STD 45662A).

If an additional manual is required, order the appropriate manual package:

- Keithley part number 2001-900-00 for the Operator's Manual.
- Keithley part number 2001-905-00 for the Calibration Manual.
- Keithley part number 2001-902-00 for the Repair Manual.

The manual packages include a manual and any pertinent addenda.

1.8 Options and accessories

The following options and accessories are available from Keithley for use with the Model 2001.

Model 1050 Padded Carrying Case — A carrying case for a Model 2001 or a Model 7001. Includes handles and shoulder strap.

Models 2001/MEM1 and 2001/MEM2 — These optional configurations of the Model 2001 extend its storage capacity. The MEM1 option has 32K-bytes for non-volatile storage of five setups, and 7000 readings in compact format or 1400 readings in full format. The MEM2 option has 128K-bytes for non-volatile storage of ten setups, and 30000 compact readings or 6000 full readings.

Model 2001-SCAN — This is a 10-channel scanner card that installs within the Model 2001. It has eight channels of 2-pole relay switching and two channels of 2-pole solid-state switching. All channels can be configured for 4-pole operation. Included are two pairs of leads for connection to Model 2001 rear panel inputs (Keithley part number CA-109).

Model 4288-1 Single Fixed Rack Mount Kit — Mounts a single Model 2001 in a standard 19-inch rack.

Model 4288-2 Side-by-side Rack Mount Kit — Mounts two instruments (Models 182, 428, 486, 487, 2001, 7001) side-by-side in a standard 19-inch rack.

Model 4288-3 Side-by-side Rack Mount Kit — Mounts a Model 2001 and a Model 199 side-by-side in a standard 19-inch rack.

Model 4288-4 Side-by-side Rack Mount Kit — Mounts a Model 2001 and a 5-inch instrument (Models 195A, 196, 220, 224, 230, 263, 595, 614, 617, 705, 740, 775, etc.) side-by-side in a standard 19-inch rack.

Models 7007-1 and 7007-2 Shielded IEEE-488 Cables — Connect the Model 2001 to the IEEE-488 bus using shielded cables and connectors to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter long; the Model 7007-2 is two meters long.

Models 8501-1 and 8501-2 Trigger Link Cables — Connect the Model 2001 to other instruments with Trigger Link connectors (e.g., Model 7001 Switch System). The Model 8501-1 is one meter long; the Model 8501-2 is two meters long.

Model 8502 Trigger Link Adapter — Allows you to connect the Trigger Link of the Model 2001 to instruments that use the standard BNC (In/Out) external triggering technique.

Model 8530 IEEE-488 to Centronics Printer Adapter Cable — Translates the IEEE-488 connector pinout and signal level to a Centronics termination. This permits a standard Centronics parallel printer to be connected to a Model 2001 in TALK-ONLY mode.

Model 8605 High Performance Modular Test Leads — Consists of two high voltage (1000V) test probes and leads. The test leads are terminated with a banana plug with retractable sheath on each end. (Each Model 2001 is shipped with one set of these test leads.)

Model 8606 High Performance Probe Tip Kit — Consists of two spade lugs, two alligator clips, and two spring hook test probes. (The spade lugs and alligator clips are rated at 30V RMS, 42.4V peak; the test probes are rated at 1000V.) These components are designed to be used with high performance test leads terminated with banana plugs, such as the Model 8605 High Performance Modular Test Leads.

The following test leads and probes are rated at 30V RMS, 42.4V peak:

Models 5805 and 5805-12 Kelvin Probes — Consists of two spring-loaded Kelvin test probes with banana plug termination. Designed to be used with instruments that measure 4-terminal resistance. The Model 5805 is 0.9m long; the Model 5805-12 is 3.6m long.

Model 5806 Kelvin Clip Lead Set — Includes two Kelvin clip test leads (0.9m) with banana plug termination. Designed for instruments that measure 4-terminal resistance. A set of eight replacement rubber bands for the Model 5806 is available as Keithley P/N GA-22.

Model 8604 SMD Probe Set — Consists of two test leads (3ft), each terminated with a surface mount device "grabber" clip on one end and a banana plug with retractable sheath on the other end.

Model 8610 Low Thermal Shorting Plug — Consists of four banana plugs mounted to a 1-inch square circuit board, interconnected to provide a short circuit among all plugs.

Model 8611 Low Thermal Patch Leads — Consists of two test leads (3ft), each with a banana plug with a retractable sheath at each end. These leads minimize the thermally-induced offsets that can be created by test leads.

Model 8612 Low Thermal Spade Leads — Consists of two test leads (3ft), each terminated with a spade lug on one end and a banana plug with a retractable sheath on the other end. These leads minimize the thermally-induced offsets that can be created by test leads.

Model 8680 RTD Probe Adapter — This adapts RTDs with terminated and unterminated cables to instruments with banana jacks for measuring 4-terminal resistance. It has a 4-pin "T"-style connector and a 4-pin screw terminal block.

Model 8681 Miniature RTD Surface Probe — This is a low cost platinum 4-wire-RTD with unterminated wires. It is designed to measure the temperature of flat surfaces or free space.

Model 8693 General Purpose/Immersion RTD Probe — This probe has a platinum RTD sensor. It is designed for immersion in liquids as well as other general purpose applications.

Model 8695 Surface RTD Probe — This probe has a platinum RTD sensor. It is designed to measure the temperature of flat surfaces of solids.

Model 8696 Air/Gas RTD Probe — This probe has a platinum RTD sensor. It has an exposed junction within a protective shroud for measuring the temperature of air or gases.

2

Getting Started

2.1 Introduction

This section contains introductory information on operating your Model 2001 Multimeter. For detailed front panel and IEEE-488 bus operation, refer to Sections 3 and 4 respectively.

The information in this section is arranged as follows:

2.2 **Front and rear panel summary:** Describes the controls and connectors on the front and rear panels, and the front panel display of the instrument.

2.3 **Overview of measurement process:** Provides a brief description of the measurement process.

2.4 **Initial configuration:** Reviews initial configuration information that should be considered before operation.

2.5 **Front panel operation:** Demonstrates basic front panel operation through the use of simple examples.

2.6 **IEEE-488.2 and SCPI basics:** Discusses fundamental information concerning operation over the IEEE-488 bus, including programming examples.

NOTE

The IEEE-488 bus is also referred to as GPIB, the general purpose interface bus. Both terms are used with the Model 2001 and in this manual.

The Keithley Applications Department is available at 1-800-348-3735 (U.S. only) to answer any questions about the Model 2001.

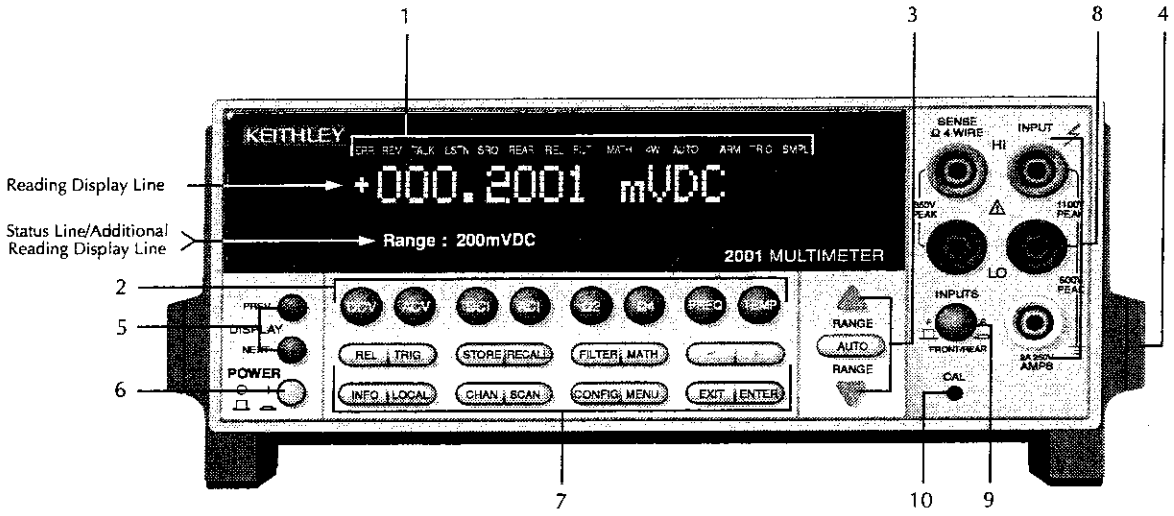
2.2 Front and rear panel summary

2.2.1 Front panel

The front panel controls and connections of the Model 2001 are shown in Figure 2-1. This figure includes important abbreviated information that should be reviewed before operating the instrument. Notice that some of the controls are dual-function, rocker-action type keys. These include REL/TRIG, STORE/RECALL, FILTER/MATH, ◄/►, INFO/LOCAL, CHAN/SCAN, CONFIG/MENU, and EXIT/ENTER.

2.2.2 Rear panel

The rear panel of the Model 2001 is shown in Figure 2-2. This figure also includes abbreviated information that should be reviewed before operating the instrument.



1 ANNUNCIATORS
ERR: Questionable reading (see paragraph 4.21)
REM: In remote
TALK: Addressed to talk
LSTN: Addressed to listen
SRQ: Service Request
REAR: Reading acquired from rear inputs
REL: Relative reading displayed
FILT: Digital filter enabled
MATH: Math calculation enabled
4W: 4-wire resistance reading displayed
AUTO: Autoranging enabled
ARM: Trigger armed; not in idle.
*(asterisk): Readings being stored

2 FUNCTION KEYS

DCV: DC voltage	Ω2: 2-wire resistance
ACV: AC voltage	Ω4: 4-wire resistance
DCI: DC current	FREQ: Frequency
ACI: AC current	TEMP: Temperature

3 RANGE KEYS
▲: Moves to higher range; increments digit
▼: Moves to lower range; increments digit
AUTO: Enables/disables autorange

4 HANDLE (not shown)
Pull out and rotate to desired position

5 DISPLAY KEYS
PREV: Moves to previous multiple display of a function
NEXT: Moves to next multiple display of a function

6 POWER
0 = OFF
1 = ON

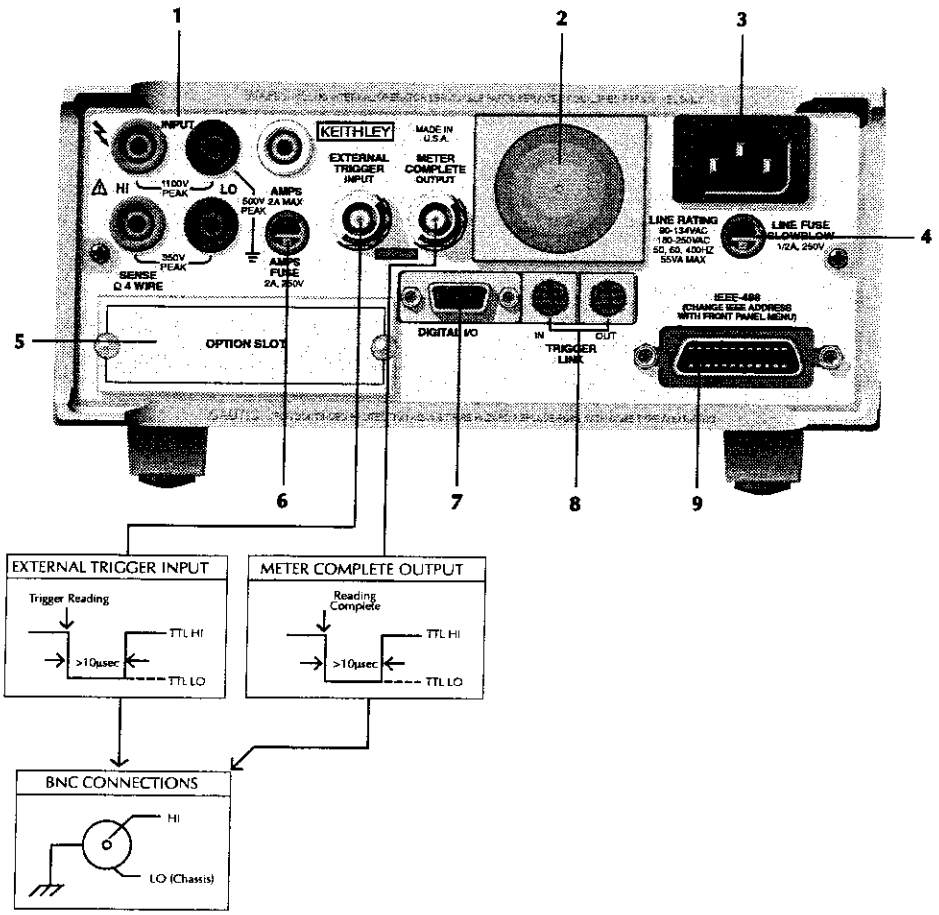
7 OPERATION KEYS
REL: Enables/disables relative reading
TRIG: Triggers unit
STORE: Enables data storage
RECALL: Displays reading data (reading, number, time). Use PREV/NEXT DISPLAY for maximum
FILTER: Displays digital filter status for present function and toggles filter on/off
MATH: Displays math calculation and toggles math on/off if configured
◀ and ▶ : Moves cursor among data entry digits, menu selections, and information displays
INFO: Shows context-sensitive information about the present display
LOCAL: Cancels IEEE-488 remote
CHAN: Selects internal scanner channel to measure (1-10)
SCAN: Performs scan of internal or external scanner channels, or ratio or delta
CONFIG: Configures functions and operations
MENU: Saves/restores instrument conditions; sets up GPIB; performs calibration and self-tests; defines limits, buffer, digital I/O, autozero
EXIT: Cancels selection, moves back within menu structure
ENTER: Holds reading, enters selection, moves down within menu structure

8 INPUT CONNECTIONS
INPUT HI and LO: Used for making DC volts, AC volts, and 2-wire resistance measurements
AMPS: Used in conjunction with INPUT LO to make DC current and AC current measurements. Also holds current input fuse (2A, 250V, fast blow, 5x20mm)
SENSE Ω4 WIRE HI and LO: Used with INPUT HI and LO to make 4-wire resistance measurements

9 INPUTS
Selects input connections on front or rear panels

10 CAL
Enables calibration functions

Figure 2-1
Model 2001 front panel



1 INPUT CONNECTIONS

INPUT HI and LO: Used for making DC volts, AC volts, and 2-wire resistance measurements.

AMPS: Used in conjunction with INPUT LO to make DC current and AC current measurements.

SENSE Ω4 WIRE HI and LO: Used with INPUT HI and LO to make 4-wire resistance measurements

2 FAN

Keep filter clean to ensure proper instrument cooling.

3 POWER LINE INPUT

90-134VAC and 180-250VAC (universal); 50, 60, or 400Hz (self-identifying)

WARNING: Connect to grounded outlet using 3-wire power cord.

4 LINE FUSE

Provides protection on the AC power line, Replace only with 0.5A, 250V, slow blow, 5x20mm

5 SCANNER

Optional Model 2001-SCAN Scanner Card installs in this slot

6 AMPS FUSE

Holds current input fuse (2A, 250V, fast blow, 5x20mm)

7 DIGITAL I/O

A DB-9 connector for the TTL-compatible digital I/O with on input and four outputs

8 TRIGGER LINK IN and OUT

Two 8-pin micro DIN connectors for sending and receiving trigger pulses among other instruments. (See paragraph 3.7.7)

9 IEEE-488 CONNECTOR

Connects the instrument to the IEEE-488 (GPIB) bus. NOTE: Use shielded IEEE-488 cables

Figure 2-2
Model 2001 rear panel

2.2.3 Front panel display

Normal displays

In the normal display mode, the front panel of the Model 2001 shows the following:

- Top line — Readings, units, and channel number if scanning. Where needed for clarification, the type of measurement.
- Bottom line — Range, if fixed; ACV and ACI coupling; frequency coupling and terminals; temperature sensor.

Most readings have from 3.5 to 7.5 digits of resolution. For example, an AC voltage measurement (RMS type), at 5.5 digits on the 200VAC range would be displayed as follows:

```
+000.000 VAC RMS
Range: 200 VAC   Coupling: AC
```

With a math operation enabled (percent or mX+b), the reading could be expressed in scientific notation, such as:

```
+5.0000e+03 VAC %
Range: 200 VAC   Coupling: AC
```

Multiple displays

The mode called multiple display is accessed from the normal display by pressing the NEXT or PREVious DISPLAY keys. Each measurement function has its own set of multiple displays.

In the multiple display mode, the Model 2001 can show the readings of up to three separate measurements. For example, in the DC voltage function, one of the multiple displays shows DC volts, AC ripple voltage, and ripple frequency:

```
+00.00000 VDC
+00.0000 VAC    +000.00 Hz
```

Or, a multiple display can show a bar graph, such as:

```
+12.00000 VDC
0|=====|=====|==   |    |+20V
```

The complete set of multiple displays is listed in Appendix H. They are described in detail in Section 3. The set for the DC voltage function is also shown in Table 2-1.

INFO displays

There are context-sensitive information message displays for most front panel operations. The explanatory information is toggled on and off with the INFO key. For example, the INFO message for one of the DCV multiple displays is:

```
INFO: VDC, VAC, Hz
Shows DC value, AC ripple, and ▶
◀ the ripple frequency.
```

where the blinking ◀ and ▶ characters signify that the front panel cursor keys must be used to view the complete bottom line.

INFO messages are listed in Appendix H.

Configuration menu displays

Each measurement function is individually configured by pressing CONFIG followed by the function key. In addition, operations that affect all measurement functions, such as triggers, data storage, and limits, are also configured by pressing CONFIG followed by the operation key.

The top level of the configuration menu for DC voltage is accessed by pressing the CONFIG key, and then the DCV key. The resulting display reads:

```
CONFIGURE DCV
SPEED  FILTER  RESOLUTION
```

In some cases, menu selections branch off to further define the options, such as the following for the SPEED option:

```
DCV MEASUREMENT SPEED
NORMAL  FAST  MEDIUM  HIACCURACY ▶
◀ SET-SPEED-EXACTLY  SET-BY-RSLN
```

Configuration menus for all functions and operations are shown in Appendix H. Guidelines for navigating the front panel menus are summarized in Table 2-2.

Table 2-1
DCV multiple displays

Display	Description
+00.00000 VDC Range: 20 VDC NEXT ↓ ↑ PREV	Normal display. (Range not shown if auto-range.)
+00.00000 VDC +00.0000 VAC +000.00 Hz NEXT ↓ ↑ PREV	AC ripple voltage and frequency.
+00.00000 VDC Pos-Pk=+00.00 V Highest=+00.00 V NEXT ↓ ↑ PREV	Positive peak spikes and highest value.
+00.00000 VDC Neg-Pk=+00.00 V Lowest=+00.00 V NEXT ↓ ↑ PREV	Negative peak spikes and lowest value.
+00.00000 VDC Pos-Pk=+00.00 V Neg-Pk=+00.00 V NEXT ↓ ↑ PREV	Positive and negative peak spikes.
+10.00000 VDC 0|=====|=====| | |+20V NEXT ↓ ↑ PREV	Bar graph to + or - full scale.
+10.00000 VDC -50% | | |====|====| +50% NEXT ↓ ↑ PREV	Zero-centered bar graph with adjustable limits.
+00.00000 VDC Max=+00.00000 Min=+00.00000 NEXT ↓ ↑ PREV	Maximum and minimum values.
+00.00000 VDC Actual=+00.00000 (without REL) NEXT ↓ ↑ PREV	Value with REL applied. Actual value.
+00.00000 VDC Reading=+00.00000 NEXT ↓ ↑ PREV	Result of math operation. Reading before math.
+00.00000 VDC PASS LLIM1| | |====| |HLIM1 NEXT ↓ ↑ PREV	HI/LO/PASS bar graph with adjustable limits.
+00.00000 VDC CH02 CH01=+00.0000 V CH03=+00.0000 V NEXT ↓ ↑ PREV	Readings of adjacent internal channels (with Model 2001-SCAN option).

Note: Press the NEXT and PREV DISPLAY keys to scroll through the multiple displays (with wraparound).

Table 2-2
Menu summary

Action	Description
CONFIG-DCV	Press the CONFIG key, then the DCV key, to view the top level of the DCV configuration menu. Access to other function and operation configurations are similar, e.g., CONFIG-ACV or CONFIG-TRIG.
MENU	Press the MENU key to view the top level of the main menu. The operations that have no corresponding key are included in the main menu.
◀ or ▶	Use the cursor keys to move the highlighted cursor among menu selections, or the digits of a parameter value, or change channels on the scanner.
RANGE ▲ RANGE ▼	Use the RANGE keys to increment and decrement digits of a parameter value.
ENTER	Accepts menu selection or data entry.
EXIT	Cancels changed menu selection. Also returns you to the previous menu level.
INFO	Displays context-sensitive information about the present menu level. Toggles information message on/off.

Buffered readings display

After readings have been stored in the buffer, they are displayed on the front panel by pressing the RECALL key. This action brings up the first reading in the buffer, such as:

+00.00000 VDC
Rdg#+00000 @Time=+000.000000 sec

where the top line shows the reading, and the bottom line shows the reading number and time-stamp. The RANGE ▲ and ▼ keys scroll through the readings and the ◀ and ▶ keys change the digit being scrolled. You can scroll through statistical data on the buffered readings by pressing the NEXT and PREVious DISPLAY keys. This also gives you the option of printing the data.

NOTE

Buffered readings are preserved across power transition when the memory options are installed.

Message displays

While operating the Model 2001, the front panel display is also used for showing status and error messages. These messages are shown to inform you of parameter conflicts, trigger overruns, etc. Refer to paragraph 3.3.4 for a complete list of these messages.

Section 4, IEEE-488 Reference, describes the programming of user messages to be shown on the front panel. (See the DISPlay subsystem.) Both lines of the display are available for this purpose.

2.3 Overview of measurement process

The following overview is intended to acquaint you with the basic measurement fundamentals without overwhelming you with the details of enhanced capabilities. This brief overview is sufficient to support the operation examples in paragraphs 2.5 (front panel) and 2.6 (IEEE-488 bus). For a complete explanation on all aspects of the measurement process, see paragraph 3.7.

The simplified model for a measurement operation is shown in Figure 2-3. As shown, the measurement operation consists of three layers: the arm layer, scan layer, and measure layer.

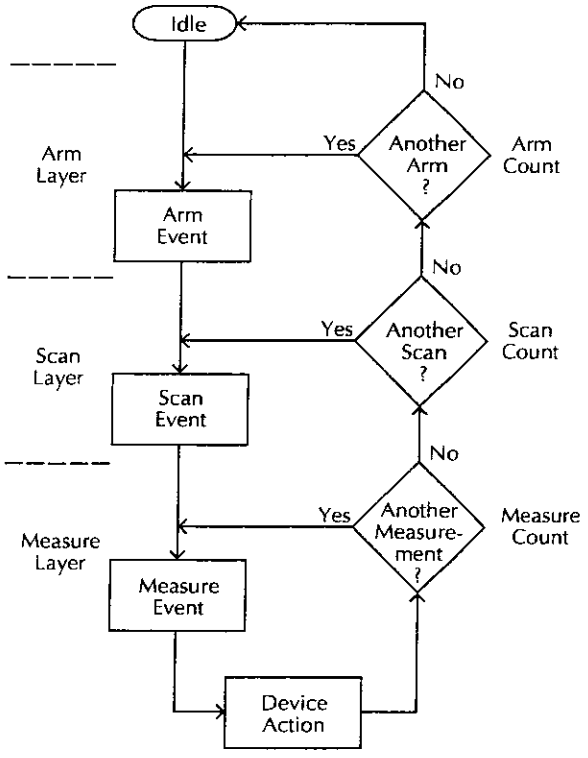


Figure 2-3
Simplified model of measurement operation

2.3.1 Idle

The instrument is considered to be in the idle state whenever it is not operating within one of the layers of the model. The front panel ARM indicator is off when the instrument is in the idle state.

When the Model 2001 is taken out of the idle state by pressing TRIG (or sending the :INIT or :INIT:CONT ON command over the IEEE-488 bus), the ARM indicator turns on and operation proceeds into the arm layer.

2.3.2 Arm layer

In general, the instrument requires an arm event to allow operation to proceed to the scan layer. With an arm source of Immediate (the factory default), operation immediately proceeds to the next layer when the instrument is taken out of the idle state. With one of the other arm sources selected, the instrument waits until the appropriate event occurs, as explained below:

- External — The instrument waits for an input trigger (via EXTERNAL TRIGGER connector on rear panel).
- Manual — The instrument waits until the front panel TRIG key is pressed.
- GPIB — The instrument waits until a bus trigger (GET or *TRG) is received.
- Trigger Link — The instrument waits until an input trigger is received (via TRIGGER LINK).
- Hold — The instrument waits in the arm layer until the arm source is changed. (Note: the signal and immediate layer commands, that is, :ARM:LAY1:SIGN and :ARM:LAY1:IMM, will satisfy the event detection logic.)

After all scan and measure operations are complete, the instrument can be returned to the arm layer by programming the instrument for additional arms. The arm count can be set to a finite value (1 to 99,999) or to infinity. The factory default value is one.

After the instrument leaves the arm layer, operation proceeds into the scan layer.

2.3.3 Scan layer

In general, the instrument requires a scan event to allow operation to proceed to the measure layer. With a scan source of Immediate (the factory default), operation immediately proceeds to the next layer. With one of the other scan sources selected (External, Manual, GPIB, Trigger Link, Timer, or Hold), the instrument waits until the appropriate event occurs.

With a scan source of Timer, the first pass through the scan layer occurs immediately. If programmed for additional scans, the instrument waits for an interval between 1msec and 999,999.999 seconds.

The scan count (number of scans) can be set to a finite value (1 to 99,999) or to infinity. The "bench" factory default value is infinity.

After the instrument leaves the scan layer, operation proceeds into the measure layer.

2.3.4 Measure layer

In general, measure events control the reading rate. With a measure source of Immediate (the factory default), a device action occurs immediately. The device action consists of taking a reading. If scanning is selected, the device action consists of taking a reading, opening a channel, configuring for next function in scan list, and closing a channel.

With one of the other measure sources selected (External, Manual, GPIB, Trigger Link, Timer, or Hold), the instrument waits until the appropriate event occurs before taking a reading and, optionally, scanning a channel.

With a measure source of Timer, the first reading is taken immediately. Each additional reading waits for the Timer to time out before it is taken.

The measure count (number of readings to take) is set to a finite value (1 to 99,999) or to infinity. The factory default value is infinity.

In factory default conditions, the arm layer and scan layer are transparent to the measurement operation.

2.4 Initial configuration

WARNING

Before turning on the Model 2001, make sure it is connected to a grounded power receptacle using the supplied power cord or the equivalent. Failure to properly ground the unit creates a shock hazard that could result in injury or death.

The Model 2001 can save from one to ten user setups in memory, depending on the installed memory option. You can select one of the user setups as the power-on default, or have the instrument power up to either of the two factory defaults (optimized for "BENCH" or "GPIB" operation). Since the examples in paragraph 2.5 assume BENCH defaults, reset the instrument to those settings by performing the following steps:

1. Press the MENU key to display the MAIN MENU options as shown below:

   MAIN MENU
   SAVESETUP GPIB CALIBRATION ▶
   ◀ TEST LIMITS STATUS-MSG GENERAL

   When the lower display line is longer than one line, the right-most character will be a ▶ symbol. Repeatedly press the ▶ key to view the second half of the lower line, and press the ◀ key to return to the first half display.

   NOTE

   Additional information is available for most front panel operations. Simply press the INFO key to toggle an INFO display. Use the ◀ and ▶ keys to see the complete lower line.

2. If the SAVESETUP option is not blinking, press the ◀ key until it is and then press ENTER to view the setup menu:

   SETUP MENU
   SAVE RESTORE POWERON RESET

3. Press the ▶ key until the RESET option of the SETUP MENU is blinking and then press ENTER to view the reset menu:

   RESET ORIGINAL DFLTS
   BENCH GPIB

4. Select the BENCH option by making it blink and pressing ENTER. The following confirmation message is displayed:

   RESETTING INSTRUMENT
   ENTER to confirm; EXIT to abort

5. Press ENTER to confirm. The parameters accessed by the front panel are now reset to factory defaults for bench operation. The display will show DC voltage readings with autorange enabled. The default settings for DC voltage are:

   - Measurement speed (integration time) — Normal, 1 power line cycle.
   - Digital filter — Advanced, 10 readings, 1% noise tolerance, moving average, enabled.
   - Display resolution — 6.5 digits.

2.5 Front panel operation

Basic front panel operation will be demonstrated by examples of measuring DC voltages. The first example shows readings at default settings and high accuracy readings. The second example shows storing high speed readings. These examples are only intended to teach basic operation.

Details for using the full capabilities of the Model 2001 from the front panel are contained in Section 3 of this manual. The manual for the Model 2001-SCAN Scanner Card has examples for closing and opening channels and scanning lists of channels.

NOTE

The front panel operation examples assume that the Model 2001 is initially set up for proper operation as explained in paragraph 2.4.

2.5.1 Measuring DC voltage example

Before starting this example, the front panel display should show triggered DC voltage measurements. If it does not, perform a bench reset following the procedure of paragraph 2.4.

Perform the following steps to make DC voltage measurements with the Model 2001 Multimeter.

Step 1 —Connect a DC voltage source

The Model 2001 can be used to make DC voltage measurements in the range of ±10nV to ±1100V. Low level measurement techniques need to be used at resolutions of 5.5 digits and more. See paragraph 3.4.1 for low level measurement considerations.

WARNING

The maximum input voltage between INPUT HI and INPUT LO is 1100V peak. The maximum common-mode voltage (voltage between INPUT LO and chassis ground) is 500V peak. Exceeding these values may create a shock hazard.

1. Select the front input jacks with the INPUTS button (outer position for front jacks, inner position for rear).
2. Using the set of supplied test leads, connect the Model 2001 to a DC voltage source (e.g., a battery) as shown in Figure 2-4.

Step 2 —Select a range and display a reading

Use the RANGE keys to select autoranging or a manual range:

1. As indicated by the AUTO annunciator, bench reset returns the instrument to autoranging. Pressing the AUTO range key toggles autoranging.
2. You can select a different range with the ▲ RANGE and ▼ RANGE keys. When using manual ranging, be sure to use a range high enough for the signal level. If the "Overflow" message is displayed on a manual range, select the next higher range until you obtain an on-range reading. Use the lowest possible range to obtain the best accuracy and resolution.
3. For the 200mV range, short the probe ends and allow the reading to settle. Press REL to null any offsets. Leave REL enabled while making measurements. Reconnect the probes to the voltage source.

NOTE

A reading can be held by pressing the ENTER key. This freezes the display until the EXIT key is pressed, returning the display to normal. If the ENTER key is pressed instead, the display is updated with another reading.

Step 3 —View the default configuration

The DCV function has the following defaults for speed, filter, and resolution:

- Measurement speed (integration time) — Normal (1 power line cycle; 16.7msec for 60Hz, 20msec for 50Hz and 400Hz).
- Digital filter — Advanced, 10 readings, 1% noise tolerance, moving average, enabled.
- Display resolution — 6.5 digits.

If these settings are not sufficient for your DCV measurement, they can be changed through the DCV configuration menu:

1. Press the CONFIG key and then the DCV or ENTER key. The instrument displays the following menu:

   CONFIGURE DCV
   SPEED FILTER RESOLUTION

NOTE

Pressing CONFIG, then ENTER displays the top level of the configuration menu for the present function.

2. You can view the present selections of each CONFIGURE DCV option by pressing the ◀ and ▶ keys to move to the desired option, then pressing ENTER. The present selection is shown blinking. (Remember that additional information is available by pressing the INFO key.)

This is the top level of the menu shown in Table 2-3.

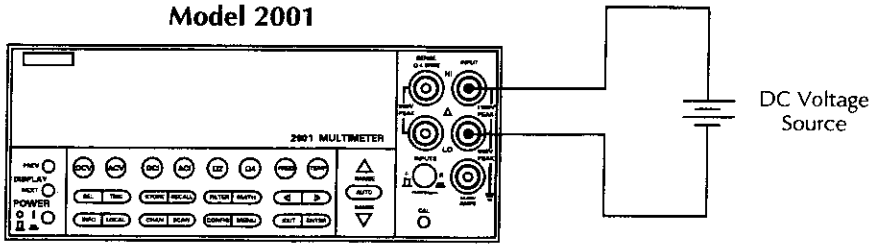


Figure 2-4
Typical DC voltage connections

Table 2-3
CONFIGURE DCV menu structure

Menu item	Description
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Program a simple average filter (1-100 readings).
ADVANCED	Program a simple average filter (1-100 readings) with a noise tolerance window (0-100% of range).
AVERAGING-MODE	Select moving average or repeating average mode.
RESOLUTION	Display resolution menu:
AUTO	Default to resolution appropriate for integration time.
3.5d, 4.5d, 5.5d, 6.5d, 7.5d	Select a specific resolution.

Step 4 — Configure for high accuracy

To make high accuracy readings of a voltage source, change the configuration of the DC voltage measurement, as follows:

1. Select SPEED from the CONFIGURE DCV menu, then press ENTER. The multimeter displays the following menu:

   DCV MEASUREMENT SPEED
   NORMAL FAST MEDIUM HIACCURACY ▶
   ◀ SET-SPEED-EXACTLY SET-BY-RSLN

2. Using the cursor keys, select the HIACCURACY option (integration time of 10 power line cycles), then press ENTER.

3. Select FILTER from the CONFIGURE DCV menu, then press ENTER. The following menu is displayed:

   DCV DIGITAL FILTER
   AUTO AVERAGING ADVANCED ▶
   ◀ AVERAGING-MODE

4. Using the cursor keys, select the AVERAGING option, then press ENTER. The instrument displays the following:

   AVG: 010 RDGS (1-100)
   Use ◀ , ▶ , ▲, ▼, ENTER,EXIT, or INFO

5. This is a simple moving average filter of 10 readings, which is the minimum recommended for high accuracy DC voltage measurements. If it is sufficient, just press ENTER or EXIT. If you want the instrument to average more readings, use the cursor keys and RANGE keys to increase the value (up to 100 readings). Press ENTER to make the change.

   NOTE

   This step does not enable the digital filter. That is done by pressing the FILTER key while outside the menu structure.

6. Select RESOLUTION from the CONFIGURE DCV menu. The following menu is displayed:

   SET DCV RESOLUTION
   AUTO 3.5d 4.5d 5.5d 6.5d 7.5d

7. Using the cursor keys, select 7.5 digits of resolution, then press ENTER.

8. Press EXIT to return to the normal display. The reading should reflect the speed and resolution changes. (Changes will affect only the DCV function.)

Step 5 —Enable the digital filter

If the filter is not on, press FILTER to enable the digital filter. The type of filter and number of readings selected is displayed momentarily, for example:

Filter Enabled
Digital = AVG(10)

The reading should now be less noisy. The digital filter can be disabled by pressing the FILTER key again.

Step 6 —View the multiple displays

Each measurement function has a series of front panel displays. The displays are accessed with the NEXT DISPLAY and PREV DISPLAY keys.

1. From the normal display of DC voltage, press the NEXT DISPLAY key once to also view AC voltage and frequency measurements of the signal, for example:

   +000.0000 mVDC
   +000.000 mVAC +000.00 Hz

2. Return to the normal DCV display by pressing PREV DISPLAY, or view the remaining DCV displays by pressing NEXT DISPLAY, which wraps around to the normal display. The DC voltage multiple displays were shown in Table 2-1.

NOTE

Pressing and holding either the NEXT DISPLAY or PREV DISPLAY key returns to the normal display.

2.5.2 Storing DC voltage readings example

This example assumes the Model 2001 is reset to its bench defaults, as outlined in paragraph 2.4. It also assumes the instrument is connected to a DC voltage source, and the front panel displays on-scale readings.

Step 1 —Configure for high speed measurements

To make high speed readings of a voltage source, change the configuration of DC voltage measurements, as follows:

1. Press CONFIG-DCV to view the DCV configuration menu:

   CONFIGURE DCV
   SPEED FILTER RESOLUTION

2. Select SPEED from the menu, then press ENTER. The multimeter displays the following menu:

   DCV MEASUREMENT SPEED
   NORMAL FAST MEDIUM HIACCURACY ▶
   ◀ SET-SPEED-EXACTLY SET-BY-RSLN

3. Using the cursor keys, select the FAST option, then press ENTER. Since the resolution is set to AUTO, where it defaults to a value appropriate for the speed, it will be set to 4.5d automatically.

4. Press EXIT to return to the normal display.

Step 2 —Store the readings

To store readings in the instrument's data storage buffer, perform the following:

1. Press the STORE key. The following message is displayed:

   STORE 00100 READINGS
   Use ◀ , ▶ , ▲, ▼, ENTER,EXIT, or INFO

2. The factory default number of readings to store is 100. Use the cursor and RANGE keys to make changes. The maximum possible number of readings depends on the following:
   - The data group selected for storage (full or compact). This is selected under the CONFIG DATA STORE menu.
   - The memory option (STD, MEM1, or MEM2).

3. Press ENTER to start storing readings. The asterisk annunciator lights to indicate a data storage operation. The bottom line of the display counts up the data storage points.

Step 3 —Recall the readings

To recall the stored readings, perform the following:

1. Press RECALL to view the readings. The following message is displayed with the cursor on the least significant digit of the reading number:

   +00.00000 VDC
   Rdg#+00000 @Time=+000.000000 sec

2. Use the RANGE ▲ and ▼ keys to increment and decrement the reading number and scroll through the buffer.

3. The NEXT and PREV DISPLAY keys can be used while recalling readings to access additional data, as shown in Table 2-4.

Table 2-4
Multiple displays for recalled readings

Display	Description
+00.00000 VDC Rdg#+00000 @Time=+000.000000 sec NEXT ↓ ↑ PREV	Normal stored reading. Reading number and time-stamp.
+00.00000 VDC MAX=+0.000000e+00 at RDG# +00000 NEXT ↓ ↑ PREV	Maximum value of stored readings.
+00.00000 VDC MIN=+0.000000e+00 at RDG# +00000 NEXT ↓ ↑ PREV	Minimum value of stored readings.
+00.00000 VDC AVG=+0.0000e+00 SDEV=+0.0000e+00 NEXT ↓ ↑ PREV	Average and standard deviation.
PRINT BUFFER DATA Press ENTER to start printing. NEXT ↓ ↑ PREV	Prompt to dump readings to a printer.

Note: Press the NEXT and PREV DISPLAY keys to scroll through the multiple displays (with wraparound.)

Step 4 —Configure for burst of high speed readings

There are two data acquisition modes, normal and burst. The burst reading rate is 2000 readings/sec into the buffer (plus post-processing time of the raw readings, typically 2msec/reading). To achieve this speed, certain tradeoffs are made with flexibility, as listed in Table 2-5.

1. To continue the reading storage example with burst mode selected, display the CONFIG DATA STORE menu by pressing the CONFIG key, then the STORE key:

   CONFIG DATA STORE
   BURST-MODE DATA-GROUP CONTROL ▶
   ◀ CLEAR-ALL COUNT FEED

2. Select BURST-MODE and press ENTER. After a momentary message about clearing the buffer, the display shows:

   BURST MODE
   OFF ON

3. Select ON and press ENTER. (Certain instrument parameters are saved when burst is enabled, and are restored when burst is disabled. See paragraph 3.8.1 for further details on burst mode.)

Table 2-5
Burst mode availability

Function/operation	Setting
DC voltage	Normal (no peak spikes)
AC voltage	Normal RMS or average
DC current	Normal (no in-circuit)
AC current	RMS or average
2-wire resistance	Normal (no offset compensation)
4-wire resistance	Not available
Frequency	Not available
Temperature	Not available
Range	Fixed
Autozero	Disabled
Speed	FAST (0.01 PLC)
Filter	Repeat acts like moving.
Resolution	4.5 digits
Multiple displays	Disabled
Data grouping	Compact (reading and reading number)
Delay	As set.

Notes:
1. The measurement display is not updated during burst.
2. A math operation slows post-processing time.

4. The next message sets the number of burst readings to store:

   BURST: 00100 READINGS
   Use ◄ , ► , ▲, ▼, ENTER,EXIT, or INFO

5. Use the cursor and RANGE ▲ and ▼ keys to change the buffer size. Then press ENTER for the change to take effect:

   00100 READING BURST
   Use TRIG to start; EXIT to abort

Step 5 —Acquire the burst readings

Initiate burst mode by pressing the TRIG key.

The ARM annunciator comes on when the raw readings are being acquired. The asterisk annunciator comes on when the readings are being post-processed. Both indicators go out when post-processing is complete.

Step 6 —Recall the burst readings

1. Examine the contents of the buffer by pressing RECALL:

   +00.000 VDC
   Rdg#+00000

2. Press the EXIT key once to leave the buffer contents display. Press it a second time to disable the burst mode.

2.6 IEEE-488.2 and SCPI basics

The following paragraphs discuss fundamental information concerning operation over the IEEE-488 bus. Detailed information on operating the instrument over the bus is contained in Section 4 of this manual.

2.6.1 SCPI overview

IEEE-488.2 defines a syntax and protocol for sending data to and from instruments. It also defines a set of common commands that are used to perform basic operations, such as reading status registers, providing triggers, and resetting the instrument to default conditions.

SCPI (Standard Commands for Programmable Instruments) defines a standard set of commands (and format) to control every aspect of instrument operation. Together, IEEE-488.2 and SCPI create a command structure for all programmable instruments.

2.6.2 Compatibility

An instrument that uses the IEEE-488.2 standard and SCPI does not have any special hardware requirements. The IEEE-488 interface that you used with the old standard (IEEE-488.1) will work with the new standard. Simply connect the Model 2001 to a computer that is equipped with an IEEE-488 interface.

NOTE

The term GPIB (General Purpose Interface Bus) is used in this manual and in the menu structure of the instrument. GPIB is simply another term for the IEEE-488 bus.

2.6.3 Bus connection

Before using the instrument over the bus, you must connect the IEEE-488 connector on the rear panel of the instrument to the IEEE-488 connector of your controller. Use a Keithley Model 7007 or similar IEEE-488 cable for this connection.

2.6.4 Primary address

The primary address of the Model 2001 must agree with the primary address you intend to specify in the controller's programming language. The factory setting for the primary address is 16, so if you intend to use that address, you need not change it. However, the primary address can be set to any value between 0 and 30 by using the GPIB setup menu (ADDRESSABLE selection) available with the MENU key.

2.6.5 Abbreviated common command summary

Table 2-6 provides an abbreviated list of common commands that are defined by the IEEE-488.2 standard. These are the common commands that are most used for bus operation. Note that each common command is preceded by an asterisk (*).

2.6.6 Abbreviated SCPI command summary

Most instrument operations are controlled using SCPI commands. Table 2-7 provides an abbreviated list of the SCPI commands necessary to perform some basic operations.

Not shown in the table are companion query commands for the :ARM and :TRIGger subsystem commands (:COUNt?, :DELay?, :SOURce?, and :TIMer?). For example, the :TRIGger:SOURce? query command is used to request the presently selected control source. After the query command is sent and the Model 2001 is addressed to talk, a message identifying the selected control source will be sent to the computer.

Table 2-6
Abbreviated common command summary

Mnemonic	Name	Description
*CLS	Clear status	Clears error queue, event registers, and IEEE-488 bus service request (SRQ) line.
*RCL <n>	Recall	Returns the instrument to the setup configuration stored in memory (n = 0 for STD, n = 0 to 4 for MEM1, or n = 0 to 9 for MEM2).
*RST	Reset	Returns the Model 2001 to *RST default conditions (see Appendix B).
*SAV <n>	Save	Saves the present setup configuration in memory (n = 0 for STD, n = 0 to 4 for MEM1, or n = 0 to 9 for MEM2).
*TRG	Trigger	Issues a bus trigger (same as group execute trigger command; GET).

Table 2-7
Abbreviated SCPI command summary

Command	Description
:SYSTem	Subsystem command path.
:PRESet	Set unit to a default configuration (see Appendix B).
[:SENSe[1]]	Subsystem command path.
:VOLTage[:DC]	Path to configure DC voltage.
:APERture <n>	Specify integration time in seconds (n = 166.67e-6 to 200e-3).
:AVERage	Path to control averaging filter:
:COUNt <n>	Specify number of points to average (n = 1 to 100).
:STATe ON|OFF	Enable/disable averaging filter.
:NPLCycles <n>	Specify integration time in number of line cycles (n = 0.01 to 10).
:RANGe	Path to configure measurement range:
[:UPPer] <n>	Select range (n = -1100 to +1100).
:AUTO <b>	Enable (1 or ON) or disable (0 or OFF) autorange.
:REFerence <n>	Specify REL value (n = -1100 to +1100).
:RESolution <n>	Specify measurement resolution (number of digits; n = 4 to 8).
:INITiate	Initiate one trigger (measure) cycle.
:ABORt	Reset trigger system and go to idle state.
:ARM	Subsystem command path to configure scan:
:LAYer2	Path to program scan layer:
:COUNt <n>|INF	Program number of scans (1 to 99999 or INFinite).
:DELay <num>	Program delay (0 to 999999.999sec).
:SOURce HOLD|IMMediate| TIMer| MANual|BUS|TLINk| EXTernal	Select event to control scan trigger.
:TIMer <num>	Set timer interval (0.001 to 999999.999sec).
:TRIGger	Subsystem command path to program measure layer:
:COUNt <n>|INF	Program number of measurements (1 to 99999, or INFinite).
:DELay <num>	Program delay (0 to 999999.999sec).
:SOURce HOLD|IMMediate|MANual| BUS| TLINK| EXTernal|TIMer	Select event to control measure trigger.
:TIMer <num>	Set timer interval (0.001 to 999999.999sec).
:ROUTe	Subsystem command path for scanning.
:CLOSe <list>	Path and command to close channel.
:STATe?	Request closed status of channel list.
:OPEN <list>|ALL	Open specified channels.
:SCAN <list>	Path and command to specify internal list.
:EXTernal <list>	Command to specify external list.

Notes:

1. Command short form is indicated by the uppercase characters. For example, instead of sending ":arm:layer2:source immediate", you can send ":arm:lay2:sour imm".
2. The brackets [ ] indicate optional names that need not be sent. For example: [:SENSe[1]]:VOLTage:DC:RANGe:[UPPer] 5 is the same as :VOLTage:DC:RANGe 5.

2.6.7 Syntax rules

The following information explains some of the programming syntax for the Model 2001. For more complete information, see Programming Syntax, which is located just after the tab labeled "SCPI Command Subsystems".

General form

The general form for SCPI commands is demonstrated in Table 2-7. Notice that they are hierarchical in nature and begin with a root command. For example, to set autoranging on the DC voltage function, you would send the following command:

```
:VOLT:DC:RANG:AUTO  ON
```

The root command for the above example is [:SENSe[1]]. This is an optional command word (as indicated by the brackets in the table) and need not be used.

Note that there must be a space between the command word and the parameter. In the above example, there is a space between the :AUTO command word and the ON parameter.

SCPI command words and common commands are not case sensitive. They can be sent in uppercase or lowercase. The commands in Table 2-7 show a combination of upper and lowercase characters. The uppercase characters identify the short-form version of the command. For example, all the following versions of the same program message are valid:

```
:ARM:LAYER2:SOURCE  MANUAL
:ARM:LAY2:SOURCE  MAN
:ARM:LAY2:SOUR  MAN
:arm:layer2:source  manual
:arm:lay2:sour  man
:Arm:Lay2:Sour  Man
:ArM:LaY2:SouR MaN
```

Parameters

As previously mentioned, a parameter is separated from the command word by a space character. The parameter can consist of one or more data types, such as integer, real, Boolean, string, name, or list. Some examples follow:

1. :voltage:dc:resolution 4
2. :trigger:delay 0.5
3. :display:window2:text:state on
4. :display:window2:text:data 'Model 2001'
5. :voltage:dc:average:tcontrol moving
6. :route:scan:internal (@1:3,5)

1. 4 — This integer parameter sets the DC voltage resolution to 3.5 digits.
2. 0.5 — This real number parameter sets the trigger delay period in seconds.
3. ON — This Boolean parameter enables the display of user text messages on the display, in this case, the bottom line. A "1" could have been used instead. "OFF" or "0" disables the function.
4. Model 2001 — This string parameter specifies the user text message. Single or double quotes delimit the message. Note that the previous command must be sent to enable the display of user text messages.
5. MOVing — This name parameter specifies the mode of the averaging or advanced digital filter.
6. (@1:3,5) — This list parameter specifies an internal scan list for the Model 2001-SCAN. Parentheses are used to enclose the list of channels. The @ symbol must precede the first channel in the list. A colon is used as a separator for the range limits (channels 1 through 3). Each channel or channel range in the list must be separated by a comma.

Multiple commands

Multiple commands can be sent in the same message as long as they are separated by semicolons. For example:

Instead of sending ...
```
:system:error?
:system:preset
```

You can send ...
```
:system:error?;preset
```

When the above message is sent, the first command word is recognized as the root command. When the command parser sees a colon after a semicolon, it resets the path pointer to the root before processing the next command.

Proper use of the path pointer allows commands in the same command level to be serviced without having to retype the entire command path. For example, the command :ARM:LAYer2:SOURce MANual moves the path pointer down to the last command level in the path. As a result, the :count, :delay, and :timer commands and their companion query commands can be included in the same program message without repeating the entire path. Some examples follow:

Instead of sending ...
```
:arm:lay2:sour  man;:arm:lay2:sour?
```

You can send ...
```
:arm:lay2:sour  man;sour?
```

Instead of sending ...
:trig:coun 1;:trig:del 1;:trig:tim 1

You can send ...
:trig:coun 1;del 1;tim 1

Notice that the colon for the additional commands is not included. Remember, when a colon (not preceded by a semicolon) is seen, the path pointer moves down to the next command level. For example:

:trig:del 1;tcon:prot asyn

When this message is sent, the path pointer moves down one command level for the DELAY and TCONFIGURE commands. The colon after the TCONFIGURE command then moves the pointer down to the next command level and enables PROTOCOL.

A few important points:

1. The path pointer can only move down. It cannot be moved up a level. (Note: It can be reset to the root mode by a preceding colon. For example, :ARM:LAY2: SOUR MAN; :TRIG:SOUR MAN.)
2. Each new message (line) must begin with the root command.
3. The colon at the beginning of a program message is optional.
4. The end of a program message moves the path pointer back to the root; so does a leading colon.
5. Any time one or more query commands are included in a program message, the Model 2001 must be addressed to talk to send the response message to the computer.

2.6.8 Programming examples

The following programming examples are written in the Hewlett-Packard BASIC 4.0 programming language. The programs assume that the Model 2001 is set to primary address 16.

Programming example #1 — Default DC voltage reading

The following code fragment resets the Model 2001 to a default configuration and gets a DC voltage reading:

```
100  OUTPUT 716;":syst:pres"
110  OUTPUT 716;":fetch?"
120  ENTER 716;A$
130  PRINT A$
```

Line 100 Return Model 2001 to :SYSTem:PRESet default configuration (DC volts, autorange, 1 PLC, filter enabled, 6.5 digits).
Line 110 Request new reading.
Line 120 Address to talk.
Line 130 Display reading, status, units, time-stamp, reading number, and channel.

Programming example #2 — High accuracy DC voltage reading

The following code fragment configures the Model 2001 for high accuracy DC voltage readings and gets one reading:

```
100  OUTPUT 716;":syst:pres"
110  OUTPUT 716;":volt:dc:nplc  10"
120  OUTPUT 716;":fetch?"
130  ENTER 716;A$
140  PRINT A$
```

Line 100 Return Model 2001 to default configuration.
Line 110 Change integration time to 10 PLC (and resolution to 7.5d).
Line 120 Request new reading.
Line 130 Address to talk.
Line 140 Display reading status, units, time-stamp, reading number, and channel.

Programming example #3 — High speed DC voltage readings

The following code fragment configures the Model 2001 for high speed DC voltage readings, stores 100 readings, and sends the readings over the bus:

```
100  OUTPUT 716;":syst:pres"
110  OUTPUT 716;":volt:dc:nplc  0.01"
120  OUTPUT 716;":trac:clear"
130  OUTPUT 716;":trac:feed  calc"
140  OUTPUT 716;":trac:egr  full"
150  OUTPUT 716;":trac:poin  100"
160  OUTPUT 716;":trac:feed:cont  next"
170  OUTPUT 716;":trac:data?"
180  ENTER 716;A$
190  PRINT A$
```

Line 100 Return Model 2001 to default configuration.
Line 110 Change integration time to 0.01 PLC.
Line 120 Clear all stored readings.
Line 130 Perform any math before storing readings.
Line 140 Store full data group (reading, reading number, units, timestamp, status, and channel).
Line 150 Set buffer count to 100 readings.
Line 160 Start storing, stop when done.

Line 170 Request readings (default is reading only, ASCII format).
Line 180 Address to talk.
Line 190 Display readings, status, units, time-stamps, reading numbers, and channels.

Programming example #4 — Burst speed DC voltage readings

The following code fragment configures the Model 2001 for burst speed DC voltage readings, stores 100 readings, and sends the readings over the bus:

```
100  OUTPUT 716;":syst:pres"
110  OUTPUT 716;":syst:amet burs"
120  OUTPUT 716; "form:elem read, rnum, unit,
stat"
130  OUTPUT 716;":trac:clear"
140  OUTPUT 716;":trac:feed calc"
150  OUTPUT 716;":trac:poin 100"
160  OUTPUT 716;":init"
170  WAIT 2
180  OUTPUT 716;":trac:data?"
190  ENTER 716;A$
200  PRINT A$
```

Line 100 Return Model 2001 to default configuration.
Line 110 Change acquisition method to burst; put unit in idle.
Line 120 Specify data elements (reading, reading number, units, and status).
Line 130 Clear all stored readings.
Line 140 Perform any math before storing readings.
Line 150 Set buffer count to 10 readings.
Line 160 Take unit out of idle; perform reading burst; return to idle.
Line 170 Wait for burst to complete.
Line 180 Request readings (default is readings only, ASCII format).
Line 190 Address to talk.
Line 200 Display readings.

3

Front Panel Operation

3.1 Introduction

This section contains detailed information on front panel operation of the Model 2001. It is organized as follows:

3.2 **Power-up procedure:** Covers information on connecting the instrument to line power, warm-up period, default conditions, and the power-up sequence.

3.3 **Display:** Covers display format and messages that may appear while using the instrument.

3.4 **Functions:** Describes the measurement functions of the instrument (DC and AC voltage, DC and AC current, 2-wire and 4-wire resistance, frequency, and temperature) and typical test connections.

3.5 **Range:** Covers both manual and autoranging operation.

3.6 **Relative:** Gives details on using the relative feature that can be used to null offsets or subtract a baseline value from present and future readings.

3.7 **Triggering:** Details types of trigger modes as well as trigger sources that can be used.

3.8 **Buffer:** Covers use of the reading buffer including programming buffer size and recalling data, time stamp, and statistics information.

3.9 **Filter:** Covers the use of the digital filter types that can be used to reduce reading noise.

3.10 **Math:** Describes the calculations that can be performed on readings in continuous operation.

3.11 **Scanning:** Discusses setting up internal and external scans, along with ratio and delta calculations.

3.12 **Menu:** Covers selections controlled from the main menu, such as saving instrument setups, GPIB (IEEE-488 bus) configuration, calibration, self-tests, limits, and the digital I/O port.

3.2 Power-up procedure

3.2.1 Line power connections

Follow the procedure below to connect the Model 2001 to line power and turn on the instrument.

1. The Model 2001 operates from a line voltage in the range of 90-134V or 180-250V at a frequency of 50, 60, or 400Hz. Check to see that the operating voltage in your area is compatible.

CAUTION

Operating the instrument on an incorrect line voltage may cause damage to the instrument, possibly voiding the warranty.

2. Before plugging in the power cord, make sure the front panel power switch is in the off (0) position.
3. Connect the female end of the supplied power cord to the AC receptacle on the rear panel. Connect the other end of the power cord to a grounded AC outlet.

WARNING

The power cord supplied with the Model 2001 contains a separate ground wire for use with grounded outlets. When

proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.

3.2.2 Line fuse replacement

A rear panel fuse located below the AC receptacle protects the power line input of the instrument. If the fuse needs to be replaced, perform the following steps:

WARNING

Make sure the instrument is disconnected from the power line and other equipment before replacing the line fuse.

1. With the power off, place the end of a flat-blade screwdriver into the rear panel LINE FUSE holder. Push in gently and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure on the holder and its internal spring will push the fuse carrier out of the holder.
2. Remove the fuse and replace it with the same type (0.5A, 250V, slow blow, 5 × 20mm). The Keithley part number is FU-71.

CAUTION

Do not use a fuse with a higher current rating than specified, or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse. See the optional Model 2001 Repair Manual for troubleshooting information.

3. Install the new fuse and fuse carrier into the holder by reversing the above procedure.

3.2.3 Power-up sequence

To turn on the power, simply push in the front panel POWER switch. Power is on when the switch is in the inner (1) position. To turn off power, press POWER a second time to release the switch.

On power-up, the Model 2001 performs self-tests on its EPROM and RAM, and checksum tests on data stored in non-volatile memory. (See Table 3-1.) If a failure is detected, the instrument momentarily displays an error message and the ERR annunciator turns on. (Messages are listed in Table 3-2.)

NOTE

If a problem develops while the instrument is under warranty, return it to Keithley Instruments, Inc. for repair. (See paragraph 1.3.)

If the instrument passes the self-tests, the firmware revision levels, memory option (if installed), and presently selected IEEE-488 primary address are displayed. An example of this display is shown as follows:

Model 2001
Rev. A01 A01 MEM1 IEEE Addr=16

The firmware revision levels (left to right) are for the main microcontroller and display microcontroller. The revision level number may be different in your particular unit. If the MEM1 or MEM2 memory options are not present, that portion of the bottom line is left blank. The IEEE-488 address is its default value of 16.

Next, if the unit is configured to display the calibration due date at power-up, the unit shows the following:

Model 2001
Calibration due: mmm/dd/yy

where "mmm" is the month abbreviation, "dd" is the day, and "yy" is the year. If no calibration date is set, the display shows that it is due now. (See the Model 2001 Calibration Manual to set the calibration due date and paragraph 3.12.3 of this manual to set the display option.)

After the power-up sequence, the instrument begins its normal display, for example:

000.0000 mVDC

Power-up error messages

Error messages that may be displayed during power-up are summarized in Table 3-2. These are shown when one of the checksum tests of Table 3-1 fails.

Table 3-1
Data checked on power-up

Data	Type of storage	Memory option
IEEE-488 address	Electrically-erasable PROM	STD, MEM1, MEM2
Power-on default	Electrically-erasable PROM	STD, MEM1, MEM2
Calibration constants	Electrically-erasable PROM	STD, MEM1, MEM2
Calibration dates	Electrically-erasable PROM	STD, MEM1, MEM2
Instrument setups	1 in electrically-erasable PROM	STD, MEM1, MEM2
	4 more in non-volatile RAM	MEM1
	9 more in non-volatile RAM	MEM2
Reading buffer	(Volatile RAM)	STD
	Non-volatile RAM	MEM1, MEM2

Note: STD is standard memory, MEM1 is memory option #1, MEM2 is memory option #2.

Table 3-2
Power-up error messages

Message	Action
Error +515, Calibration dates lost	The cal dates are set to factory default values, but they are not stored into EEPROM. To do this, perform a comprehensive calibration.
Error +514, DC calibration data lost	DC cal constants are set to factory default values, but they are not stored into EEPROM. To do this, perform a comprehensive calibration.
Error +513, AC calibration data lost	AC cal constants are set to factory default values, but they are not stored into EEPROM. To do this, perform a comprehensive calibration.
Error +512, Power-on state lost	Power-on defaults are reset to factory defaults (bench) and stored into EEPROM.
Error +511, GPIB address lost	GPIB address is reset to factory default (16) and stored into EEPROM.
Error +510, Reading buffer data lost	The reading buffer controls are reset to factory defaults, but they are not stored into NVRAM. To do this, store readings in the buffer.
Error -314, Save/recall memory lost	Instrument setup is reset to bench defaults and stored into EEPROM.

Notes:
1. Any of these error conditions may occur the first time a unit is turned on or after replacing the firmware.
2. Error +510, Reading buffer data lost, applies to units with optional memory.
3. Error +512, Power-on state lost, may occur the first time the unit is powered-up after replacing the MEM2 memory option with MEM1.

3.2.4 High energy circuit safety precautions

To optimize safety when measuring voltage in high energy distribution circuits, read and use the directions in the following warning.

WARNING

Dangerous arcs of an explosive nature in a high energy circuit can cause severe personal injury, or death. If the multimeter is connected to a high energy circuit when set to a current range, low resistance range, or any other low impedance range, the circuit is virtually shorted. Dangerous arcing can result even when the multimeter is set to a voltage range if the minimum voltage spacing is reduced.

When making measurements in high energy circuits, use test leads that meet the following requirements:

- Test leads should be fully insulated.
- Only use test leads that can be connected to the circuit (e.g., alligator clips, spade lugs, etc.) for hands-off measurements.
- Do not use test leads that decrease voltage spacing. This diminishes arc protection and creates a hazardous condition.

Use the following sequence when testing power circuits:

1. De-energize the circuit using the regular installed connect-disconnect device, such as a circuit breaker, main switch, etc.
2. Attach the test leads to the circuit under test. Use appropriate safety rated test leads for this application.
3. Set the multimeter to the proper function and range.
4. Energize the circuit using the installed connect-disconnect device and make measurements without disconnecting the multimeter.
5. De-energize the circuit using the installed connect-disconnect device.
6. Disconnect the test leads from the circuit under test.

WARNING

The maximum common-mode voltage (voltage between INPUT LO and chassis ground) is 500V peak. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.

3.2.5 Power-on default conditions

Power-on default conditions are those conditions the instrument assumes when it is first turned on. You can change these power-on default conditions (except the primary address) by using the save setup feature that is available with the MENU key, as described in paragraph 3.12.1. Depending on the installed memory option, either one, five, or ten user-defined setups can be stored, any one of which could be selected as the power-on default.

A table in paragraph 3.12.1 lists the default conditions that are set at the factory to optimize bench and GPIB (IEEE-488) operation.

3.2.6 Warm-up period

The Model 2001 can be used within one minute after it is turned on. However, the instrument should be turned on and allowed to warm up for at least one hour before use to achieve rated accuracy.

3.2.7 IEEE-488 primary address

The IEEE-488 primary address of the instrument must be the same as the primary address you specify in the controller's programming language. The default primary address of the instrument is 16, but you can set the address to any value from 0 to 30 by using the MENU key. Refer to paragraph 3.12.2 for step-by-step instructions on setting the primary address. Section 4 contains details on using the Model 2001 over the IEEE-488 bus.

3.3 Display

The display of the Model 2001 is primarily used to display readings along with the units and type of measurement. When not displaying readings, it is used for informational messages, such as menu headings and selections. At the top of the display are annunciators to indicate various states of operation.

3.3.1 Display format

As shown in Figure 3-1, the front panel has two lines of display information:

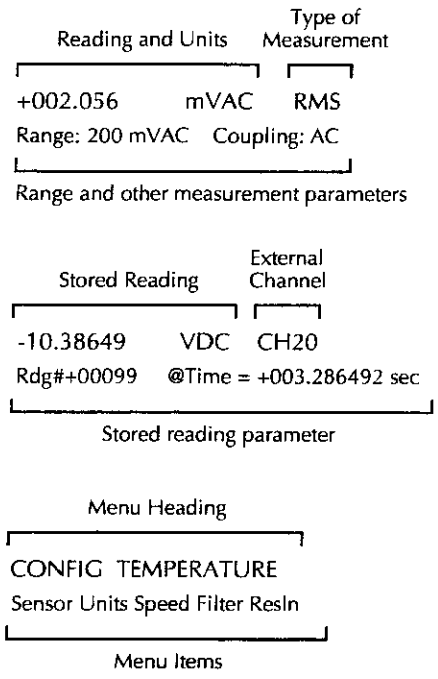


Figure 3-1
Model 2001 display formats

- The top line can display readings up to 7½ digits, along with units. It can also indicate the measurement type (e.g., RMS), display "hold", type of math operation, channel number, or limits pass/fail. It is also used for menu headings, values of stored readings, and messages.
- The bottom line displays the range and other measurement parameters (e.g., coupling or ratio), multiple displays, menu items, parameters of stored readings, and messages. For longer text strings, the bottom line is split in half. These are indicated by ◄ and ► characters at the left or right end of the bottom line. Press the cursor keys (◄ and ►) to view each half.

Scientific notation

Enabling a relative or math operation might cause the reading value to exceed the display resolution of the top line. In these cases, the instrument displays in 7½ digits of scientific notation. If the units have a multiplier prefix (milli-, micro-, etc.), the exponent of the value reflects that. Note that ratio measurements are always shown in 7½ digit scientific notation with no prefix or channel number.

The actual value of the reading, before the relative or math operation, can be viewed on the bottom line with the appropriate multiple display. (See Figure 3-2). The units and multiplier prefix on the bottom line are assumed to be the same as those on the top line reading.

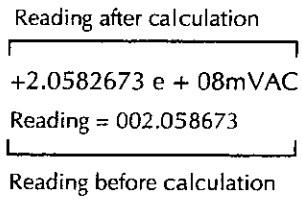


Figure 3-2
Scientific notation with calculate multiple display

Annunciators

The annunciators at the top of the display indicate the following conditions:

ERR: The displayed reading is questionable. See paragraph 4.21 for the conditions that define a questionable reading.

REM: Indicates the Model 2001 is in remote when used over the IEEE-488 bus. The Model 2001 can be placed in remote by addressing it to listen with the bus REN line true.

TALK: Shows that the Model 2001 is the active talker on the IEEE-488 bus. The unit can be placed in the talker active state by sending it the correct bus talk command, which is derived from the primary address.

LSTN: Turns on when the unit is an active IEEE-488 bus listener. The Model 2001 can be placed in the active listener state by addressing it to listen.

SRQ: Turns on when the unit requests service over the IEEE-488 bus. The SCPI STATus command allows you to control which conditions generate an SRQ (see paragraph 4.21).

REAR: Turns on when a reading has been acquired through the rear inputs.

REL: Turns on/off to indicate the present state of the relative reading feature.

FILT: When filtering has been selected for a particular function, this indicator turns on when the FILTER key is pressed. For those functions with auto-filtering, it turns on when AUTO is selected.

MATH: When a math operation (percent, mX+b, or none) has been selected from the CONFIGURE MATH menu, this indicator turns on when the MATH key is pressed.

4W: Turns on to indicate the 4-wire resistance function, in-circuit current, or temperature with a 4-wire RTD.

AUTO: Turns on when autoranging is selected for voltage, current (except in-circuit current, which has a fixed 12A range), or resistance measurements.

ARM: Turns on when the Model 2001 is taken out of the idle state (by the TRIG key or the :INIT or :INIT:CONT ON bus command). A measurement can only be performed with the Model 2001 out of the idle state.

*: Indicates when normal readings are being stored.

3.3.2 Multiple displays

Each measurement function has its own set of "multiple displays" shown on the bottom line of the front panel display. The PREVious and NEXT DISPLAY keys scroll through the selections for the present function.

Some of the multiple displays are for multiple functions, where different functions are measured sequentially from the same set of test leads. The readings are shown simultaneously, such as:

- Top line shows a DC voltage measurement; bottom line shows positive and negative peak spike measurements.
- Top line shows an AC RMS voltage reading; bottom line shows an AC frequency measurement and a crest factor calculation.

Also, the multiple displays can show a reading in a different form, or give additional information about the reading, for example:

- Top line shows a reading; bottom line shows a zero-centered bar graph with adjustable limits.
- Top line shows a frequency measurement; bottom line shows the adjustable trigger level.

To scroll through the multiple displays available for each measurement function, repeatedly press and release the NEXT DISPLAY key. The same action with the PREVious DISPLAY key does a reverse scroll through the displays. To return to the default reading display, just press and hold either key.

Multiple displays that are specific to a particular function or operation are discussed later in this section, such as the peak spikes displays in DC voltage, and the calculations display in math. (See Table 3-3 for paragraph references.) Displays that are common to most of the measurement functions are discussed here. Appendix H shows a complete listing of the multiple displays by function.

Table 3-3
Multiple displays by function

Function	Next display	Paragraph
All	Bar graph	3.3.2
	Zero-centered bar graph	3.3.2
	Maximum and minimum values	3.3.2
	Relative and actual values	3.6
	Calculated and actual values (see Note 1)	3.10
	Limits bar graph (see Note 1)	3.12.5
	Adjacent channel readings (see Note 2)	3.11
DC voltage	DC volts, AC ripple voltage and frequency	3.4.1
	Positive peak spikes and highest value	
	Negative peak spikes and lowest value	
	Positive and negative peak spikes	
AC voltage	AC RMS voltage, frequency, and crest factor	3.4.1
	AC RMS, average, and peak voltages	
DC current	(none specific to function)	3.4.2
AC current	AC RMS (or average) current and frequency	3.4.2
	AC RMS and average current	
2-wire resistance	Source current	3.4.3
	Voltage drop across DUT	
4-wire resistance	Source current	3.4.3
	Voltage drop across DUT	
	Lead resistance	
Frequency	Period calculation	3.4.4
	Trigger level	
Temperature	Celsius, Fahrenheit, and Kelvin units	3.4.5
	RTD resistance (or thermocouple voltage)	
	Reference junction (thermocouples only)	
Data storage buffer	Maximum and minimum values	3.8
	Average and standard deviation	

Notes:
1. Multiple displays for calculated values and limits bar graph are not available for the frequency function.
2. The multiple display for adjacent channel readings is not available for the DC and AC current functions.

Bar graph

The "normal" bar graph, with a zero at the left end, is a graphical representation of a reading as a portion of a range. (See Figure 3-3.) The vertical lines displayed along the bar designate 0%, 25%, 50%, 75%, and 100% of full scale. Each full segment of the bar represents approximately 4% of the range limit

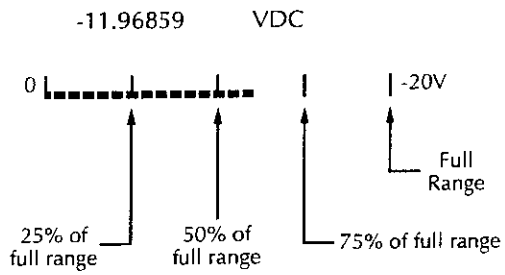


Figure 3-3
Bar graph (zero-at-left) multiple display

For measurement functions with a range (voltage, current, and resistance), the right endpoint of the bar graph is plus full scale of the present range for positive readings, and minus full scale for negative readings. When the 100% line changes to an arrow, the reading exceeds the present range.

Note that the normal bar graph is not available when the ACV units are dB or dBm.

For functions without a range (frequency and temperature), the right endpoint of the bar graph is user-programmable by pressing either CONFIG-NEXT DISPLAY or CONFIG-PREV DISPLAY. Note that these configuration menus are context-sensitive. If the unit is in any function except frequency or temperature, CONFIG-NEXT DISPLAY results in the zero bar graph configuration display.

Perform the following to view or change the range of the bar graph:

1. From the frequency or temperature function, press the CONFIG key and then the NEXT or PREV DISPLAY key. The following menu is displayed:

   BARGRAPH TYPE
   ZERO-AT-LEFT ZERO-CENTERED

2. Use the cursor keys (◄ and ►) to place the cursor on ZERO-AT-LEFT and press ENTER. You will access one of the following menus:

   For frequency:

   FREQ BARGRAPH RANGE
   2Hz 20Hz 200Hz 2kHz 20kHz ►
   ◄ 200kHz 2MHz 15MHz

   For temperature:

   BARGRAPH:0 to 0040°C

3. Change the frequency range by highlighting one of the selections and pressing ENTER. For the temperature range, use the cursor keys and the RANGE ▲ and ▼ keys to enter a numeric value (0 - 9999°C). Press ENTER when done.

Zero-centered bar graph

The zero-centered bar graph is a graphical representation of a reading with plus and minus limits. (See Figure 3-4.) The limits are expressed in a user-selectable percentage of range for voltage, current, and resistance, and a user-selectable value for frequency and temperature.

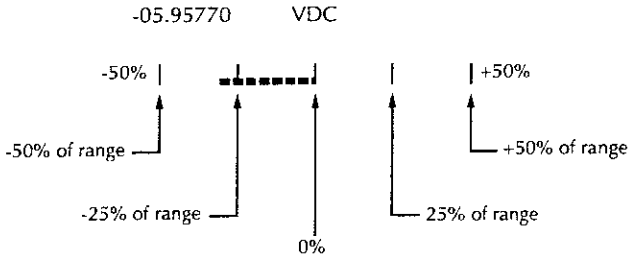


Figure 3-4
Zero-centered bar graph multiple display

The vertical lines displayed along the bar designate the plus and minus limits, zero, and halfway to either limit. There are ten full segments between zero and each end, so each full segment represents 10% of the limit. When a line at the limit changes to an arrow, the reading exceeds the programmed range.

The plus and minus percentage of range that is programmed (0.01 - 99.99%) applies to all voltage, current, and resistance functions. Because of rounding, values greater than 99.5% are shown as 100% and, likewise, values greater than 1% (such as 1.67%) are shown rounded to the nearest integer percent.

Note that the zero-centered bar graph is not available when the ACV units are dB or dBm.

Perform the following to view or change the plus and minus percentage of range:

1. From a voltage, current, or resistance function, press CONFIG and then NEXT or PREV DISPLAY. The following is displayed:

   ZERO-BARGRAPH±50.00%

2. Change the percentage by using the cursor keys and the RANGE ▲ and ▼ keys to enter a numeric value (0.01 - 99.99%). Press ENTER when done. The same percentage of range is used for voltage, current, and resistance measurements.

Perform the following to view or change the plus and minus value limit:

1. From the frequency or temperature function, press CONFIG and then NEXT or PREV DISPLAY. The following menu is displayed:

   BARGRAPH TYPE
   ZERO-AT-LEFT ZERO-CENTERED

2. Use the cursor keys (◄ and ►) to place the cursor on ZERO-CENTERED and press ENTER. You will access one of the following menus:

   For frequency:

   FREQ ZEROBARGRAPH(±)
   1Hz 10Hz 100Hz 1kHz 10kHz ►
   ◄ 100kHz 1MHz 10MHz 15MHz

   For temperature:

   ZERO-BARGRAPH±0002°C

3. Change the frequency limits by highlighting one of the selections and pressing ENTER. For the temperature, use the cursor keys and the RANGE ▲ and ▼ keys to enter a numeric value (0 - 9999°C). Press ENTER when done.

Maximum and minimum

The maximum and minimum multiple display shows the maximum and minimum readings since the display was entered. (See Figure 3-5.) The maximum and minimum values are reset by the following:

- Pressing the present function key.
- Leaving the display by changing function or entering a menu.

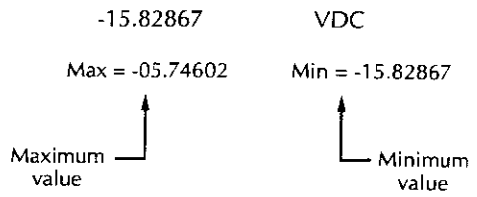


Figure 3-5
Maximum and minimum multiple display

The resolution, units, and prefix on the bottom line are the same as shown for top line reading. If necessary, the bottom line values automatically change to scientific notation, rounded to 4.5 digits.

3.3.3 Information messages

Press the INFO key to view context-sensitive information from most of the displays. An arrow (◄ or ►) on the bottom line indicates that there is more information. Use the cursor keys (◄ and ►) to view the complete line. To exit an INFO display, just press INFO, ENTER, EXIT, or a function key.

Information messages are included with the listing of menu structures in Appendix H.

3.3.4 Status and error messages

During Model 2001 operation and programming, you will encounter a number of front panel messages. Typical messages are either of status or error variety, as listed in Table 3-4.

For firmware revisions A02 and greater, the most recent status or error messages can be momentarily displayed. Just enter a configuration menu or the main menu, and press the AUTO range key. (The display is blank if no message is queued.)

Table 3-4
Status and error messages

Number	Description	Event
+900	"Internal System Error"	EE
+611	"Questionable Temperature"	SE
+610	"Questionable Calibration"	SE
+515	"Calibration dates lost"	EE
+514	"DC calibration data lost"	EE
+513	"AC calibration data lost"	EE
+512	"Power-on state lost"	EE
+511	"GPIB address lost"	EE
+510	"Reading buffer data lost"	EE
+444 to +350	Calibration Errors (see Calibration Manual)	EE
+312	"Buffer Pretriggered"	SE
+310	"Buffer full"	SE
+309	"Buffer half full"	SE
+308	"Buffer Available"	SE
+306	"Reading Available"	SE
+305	"High limit 2 event"	SE
+304	"Low limit 2 event"	SE
+303	"High limit 1 event"	SE
+302	"Low limit 1 event"	SE
+301	"Reading overflow"	SE
+174	"Re-entering the idle layer"	SE
+173	"Waiting in arm layer 2"	SE
+172	"Waiting in arm layer 1"	SE
+171	"Waiting in trigger layer"	SE
+161	"Program running"	SE
+126	"Device calculating"	SE
+125	"Device measuring"	SE
+124	"Device sweeping"	SE
+123	"Device ranging"	SE
+122	"Device settling"	SE
+121	"Device calibrating"	SE
+101	"Operation Complete"	SE
+000	"No Error"	SE
-100	"Command Error"	EE
-101	"Invalid Character"	EE
-102	"Syntax Error"	EE
-103	"Invalid Separator"	EE
-104	"Data Type Error"	EE
-105	"GET not allowed"	EE
-108	"Parameter not allowed"	EE
-109	"Missing Parameter"	EE
-110	"Command Header Error"	EE
-111	"Command Header Separator Error"	EE
-112	"Program mnemonic too long"	EE
-113	"Undefined header"	EE
-114	"Header suffix out of range"	EE

Table 3-4 (Continued)
Status and error messages

Number	Description	Event
-120	"Numeric data error"	EE
-121	"Invalid character in number"	EE
-123	"Exponent too large"	EE
-124	"Too many digits in number"	EE
-128	"Numeric data not allowed"	EE
-140	"Character data error"	EE
-141	"Invalid character data"	EE
-144	"Character data too long"	EE
-148	"Character data not allowed"	EE
-150	"String data error"	EE
-151	"Invalid string data"	EE
-154	"String too long"	EE
-158	"String data not allowed"	EE
-160	"Block data error"	EE
-161	"Invalid block data"	EE
-168	"Block data not allowed"	EE
-170	"Expression error"	EE
-171	"Invalid expression"	EE
-178	"Expression data not allowed"	EE
-200	"Execution error"	EE
-201	"Invalid while in local"	EE
-202	"Settings lost due to rtl" (return to local)	EE
-210	"Trigger error"	EE
-211	"Trigger ignored"	EE
-212	"Arm ignored"	EE
-213	"Init ignored"	EE
-214	"Trigger deadlock"	EE
-215	"Arm deadlock"	EE
-220	"Parameter Error"	EE
-221	"Settings conflict"	EE
-222	"Parameter data out of range"	EE
-223	"Too much data"	EE
-224	"Illegal parameter value"	EE
-230	"Data corrupt or stale"	EE
-241	"Hardware missing"	EE
-260	"Expression Error"	EE
-314	"Save/recall memory lost"	EE
-330	"Self Test failed"	EE
-350	"Queue overflow"	EE
-410	"Query interrupted"	EE
-420	"Query unterminated"	EE
-430	"Query deadlocked"	EE
-440	"Query unterminated after indefinite response"	EE

SE = Status event
EE = Error event

3.3.5 Menu structures

From the front panel of the Model 2001, you configure measurements through the use of menus. A complete listing of the menus is given in Appendix H. The menus are grouped into three areas:

- Measurement functions: DC voltage, AC voltage, DC current, AC current, 2-wire resistance, 4-wire resistance, frequency, and temperature.
- Measurement operations: Multiple displays, relative readings, triggers, reading storage, digital filter, math, channels, and scanning.
- Other menu operations: Setup storage, IEEE-488 (GPIB) setup, calibration, self-tests, limits, status messages, and general operations.

The first two groups have specific keys on the front panel. The third group does not. The desired menu is displayed by pressing the appropriate key or key sequence:

- CONFIG and then DCV (or ACV, DCI, ACI, Ω2, Ω4, FREQ, TEMP): Shows the configuration menu for each measurement function.
- CONFIG and then NEXT DISPLAY (or PREV DISPLAY, REL, TRIG, STORE, FILTER, MATH, CHAN, SCAN): Shows the configuration menu for the multiple displays and each measurement operation.
- MENU: The main menu accesses items for which there are no dedicated keys.

Navigating menus

1. From the instrument's normal state of displaying readings, you can:
   - View a configuration menu by pressing CONFIG and then the desired function or operation key (DCV, TRIG, etc.).
   - View the top level of the main menu by pressing the MENU key.
2. The unit is returned to the normal reading display by:
   - Pressing EXIT or MENU from the top level of the main menu.
   - Pressing EXIT from the top level of a configuration menu.
   - Pressing a measurement function key from within a menu.
3. Pressing the ENTER key selects an item and, if further definition is needed, moves down within the menu structure. Pressing the EXIT key backs up within a menu structure.
4. The cursor position is denoted by a blinking menu item or parameter. The cursor is moved from one item to the next using the cursor keys (◄ and ►). To select an item, highlight it with the cursor, then press ENTER.
5. A displayed arrow (◄ or ►) on the bottom line indicates there is more information or additional menu items to select from. When " ► " is displayed, use the ► cursor key to display the additional message(s), and conversely, when " ◄ " is displayed, use the ◄ cursor key. The cursor keys have an auto-repeat feature.
6. A numeric parameter is keyed in by placing the cursor on the digit to be changed, and pressing the RANGE ▲ or ▼ keys to increment or decrement the digit.
7. A change is only executed when the ENTER key is pressed. Entering an invalid parameter generates an error, and the entry is ignored. Changes are also ignored if an EXIT is performed.
8. The INFO key can be used anywhere in a menu to display helpful information messages concerning operation. To cancel an information message and remain in the menu, press INFO a second time, EXIT, or ENTER. Pressing a function key cancels INFO and a menu, and returns the instrument to a reading display.

3.3.6 EXIT key

The EXIT key has more actions than those mentioned in paragraph 3.3.5. Table 3-5 lists the action for single conditions.

When more than one of the conditions of Table 3-5 is present, the hierarchy for the action taken by each press of the EXIT key is as follows:

1. Cancels any temporary or error messages that are displayed.
2. Cancels INFO message and shows the normal reading display.
3. Cancels reading display hold and returns to normal reading display.
4. Disables scanning and returns to normal operation. Also interrupts data storage if enabled.
5. Interrupts data storage and returns to normal operation.

Table 3-5
EXIT key actions

Condition	EXIT key action
Temporary message displayed (e.g., TRIGGERS HALTED)	Cancels display of temporary message.
INFO message displayed	Cancels INFO message, returns to menu or normal reading display.
Reading display hold	Cancels reading display hold, resumes normal reading display.
Scanning	Disables scanning. Also stops data storage if enabled.
Data storage	Stops data storage. Temporary message STORAGE INTERRUPTED is displayed.

Some examples of when multiple conditions are cancelled by pressing the EXIT key follow.

Example 1: After pressing ENTER to hold the reading display, press INFO to view the message. The first press of EXIT returns you to the held reading; a second press cancels reading display hold.

Example 2: Configure a scan list and start scanning. Press ENTER to hold the display, then press INFO to view the message. The first press of EXIT returns you to the held reading; the second press returns you to the normal reading display. A third press of EXIT stops the scan and returns to normal operation.

Example 3: Configure a scan list and start scanning readings into a buffer. Press EXIT once. Scanning and storing are terminated; normal operation is resumed. Note that the trigger model is restored to its pre-scanning configuration.

Example 4: Configure a scan list and start scanning readings into a buffer. Press ENTER to hold the reading display. Press INFO to view the message. The first press of EXIT returns you to the held reading display. A second press of EXIT cancels the held reading and shows normal storage. A third press of EXIT stops scanning and storing; normal operation is resumed.

3.4 Functions

The Model 2001 has much flexibility when configuring the measurement functions. This flexibility must be used sensibly in order to balance the various settings for a particular application. For example, you can configure DC volts with an integration time of 0.01 PLC (power line cycle) at 7.5 digits of resolution and no filter, but the reading will be extremely noisy. As another example, DCV peak spikes can be configured for 7.5 digits of resolution, yet the measurement is specified at 3.5 digits. When in doubt, use the default settings and the auto selections until you become more familiar with the effects of other settings.

The instrument can be configured to display multiple functions, where different functions are measured sequentially from the same leads. These are referred to as "multiple displays" and they are shown on the bottom line of the display. The displays for multiple functions are discussed in the following paragraphs.

NOTE

All measurements in the multiple display mode will be within specifications. However, for optimum measurement integrity, the primary display mode should be used.

To minimize the need to reprogram setup conditions every time you switch from one function to another, each function "remembers" its own unique setup configuration. Setup configuration parameters that are remembered include:

- Range
- Relative
- Integration time
- Filtering
- Display resolution
- Multiple displays

To access the configuration menus for the measurement functions, press the CONFIG key and then a function key (DCV, ACV, DCI, ACI, Ω2, Ω4, FREQ, TEMP). Rules for navigating the menu structures are covered in paragraph 3.3.5.

3.4.1 DC and AC voltage

DC voltage measurements

The Model 2001 can make DC voltage measurements between 10nV and 1100V. Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure is as follows:

1. Connect the test leads to the INPUT HI and LO terminals of the Model 2001. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the DCV function.
3. Select a range consistent with the expected voltage. For automatic range selection, press the AUTO key. The AUTO annunciator denotes whether auto-ranging is enabled.
4. Connect the test leads to the source as shown in Figure 3-6.

CAUTION

Do not exceed 1100V peak between INPUT HI and LO, or instrument damage may occur.

5. Observe the display. If the "Overflow" message is shown, select a higher range until a normal reading is displayed. Always use the lowest possible range for the best resolution.
6. Take a reading from the display.

Zeroing

The term "when properly zeroed" means that you must establish a baseline for subsequent measurements on that range. The 200mV DC range requires zero to be set to achieve rated accuracy. This procedure should be performed whenever the ambient temperature changes. To zero (rel) the Model 2001, use the following procedure:

1. Disable rel, if presently enabled, by pressing the REL key. The REL annunciator will turn off.
2. Select the 200mVDC range.
3. Connect the test leads to INPUT HI and LO of the Model 2001 and short them together. Noise and thermal offsets may require a few moments to stabilize.
4. Press the REL key. The display will read zero.
5. Remove the short and connect the test leads to the signal to be measured.

Also, use shielded, low-thermal connections for the 200mV range to avoid errors caused by noise or thermal offsets. Connect the shield to the negative source terminal.

AC voltage measurements

The Model 2001 can make true RMS AC voltage measurements between 100nV and 775V. Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure is as follows:

1. Connect the test leads to the INPUT HI and LO terminals of the Model 2001.
2. Select the ACV function.
3. Select a range consistent with the expected voltage. For automatic range selection, press the AUTO key. The AUTO annunciator denotes whether autoranging is enabled.
4. Connect the test leads to the source as shown in Figure 3-7.

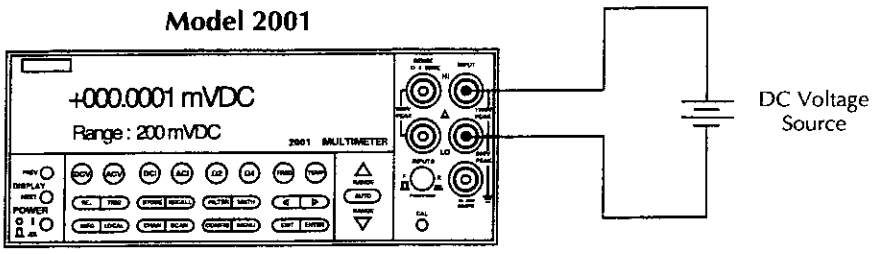
CAUTION

Do not apply more than 1100V peak between INPUT HI and LO, or 2×10^7V•Hz input, or instrument damage may occur.

5. Observe the display. If the "Overflow" message is shown, select a higher range until a normal reading is displayed. Always use the lowest possible range for the best resolution.
6. Take a reading from the display.

Voltage configuration

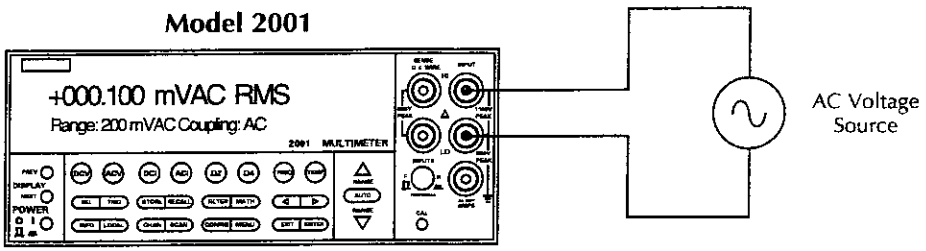
The following paragraphs detail how to change the Model 2001 from its bench reset conditions for DC and AC voltage measurements. The configuration menus are summarized in Tables 3-6 and 3-7. Note that a function does not have to be selected in order to be configured. When the function is selected, it will assume the programmed status.



Input Resistance = 10MΩ on 1000V and 200V ranges ;
> 10GΩ on 20V, 2V and 200mV ranges.
= 1MΩ on DCV peak spikes measurement.

Caution: Maximum Input = 1100V peak

Figure 3-6
DC voltage measurements



Input Impedance = 1MΩ shunted by <140pF

Caution: Maximum Input = 1100V peak, 2 x 10^7 V•Hz

Figure 3-7
AC voltage measurements

Table 3-6
CONFIGURE DCV menu structure

Menu item	Description
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
ANALOG-FILTER	Enable (ON) or disable (OFF) analog filter.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Program a simple average filter (1-100 readings).
ADVANCED	Program a simple average filter (1-100 readings) with a noise tolerance window (0-100% of range).
AVERAGING-MODE	Select moving average or repeating average mode.
RESOLUTION	Display resolution menu:
AUTO	Default to resolution appropriate for integration time.
3.5d, 4.5d, 5.5d, 6.5d, 7.5d	Select a specific resolution.

Table 3-7
CONFIGURE ACV menu structure

Menu item	Description
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Program a simple average filter (1-100 readings).
ADVANCED	Program a simple average filter (1-100 readings) with a noise tolerance window (0-100% of range).
AVERAGING-MODE	Select moving average or repeating average mode.
RESOLUTION	Display resolution menu:
AUTO	Default to resolution appropriate for integration time.
3.5d, 4.5d, 5.5d, 6.5d, 7.5d	Select a specific resolution.
UNITS	Display units menu:
VOLTS	Select volts.
dB	Select dB and set voltage reference level.
dBm	Select dBm and set reference impedance.
COUPLING	Coupling menu:
AC	Select AC coupled measurements.
AC+DC	Select DC coupled measurements.
AC-TYPE	Type of ACV measurement menu:
RMS	Select true RMS ACV.
AVERAGE	Select average ACV.
PEAK	Select peak ACV.
LOW-FREQ-RMS	Select low frequency (typically <50Hz) true RMS ACV.
POSITIVE-PEAK	Select positive DCV peak spikes measurements.
NEGATIVE-PEAK	Select negative DCV peak spikes measurements.

SPEED

The SPEED parameter sets the integration time of the A/D converter, the period of time the input signal is measured (also known as aperture). The integration time affects the usable resolution, the amount of reading noise, as well as the ultimate reading rate of the instrument. Any triggers received while the instrument is processing a reading are ignored. From the front panel, the integration time is specified in parameters based on a number of power line cycles (NPLC), where 1 PLC for 60Hz is 16.67msec and 1 PLC for 50Hz and 400Hz is 20msec.

The optimum integration time setting for a given application depends on your measurement requirements. If speed is of primary importance, use the FAST (0.01 PLC) integration time at the expense of increased reading noise and less usable resolution. For maximum common-mode and normal-mode rejection, use the HIACCURACY (10 PLC) integration time. The NORMAL (1 PLC) and MEDIUM (0.1 PLC) can be used when a compromise between noise performance and speed is acceptable. The additional parameters for integration time, SET-SPEED-EXACTLY and SET-BY-RSLN, are discussed below.

You can program the integration time parameter as follows:

1. From the normal reading display, press the CONFIG key and then the appropriate function key to access the top level of a function configuration menu. For example, the CONFIGURE DCV menu is displayed as follows:

   CONFIGURE DCV
   SPEED FILTER RESOLUTION

2. Use the cursor keys (◄ and ►) to highlight SPEED and press ENTER. The following typical menu is shown:

   DCV MEASUREMENT SPEED
   NORMAL FAST MEDIUM HIACCURACY ►
   ◄ SET-SPEED-EXACTLY SET-BY-RSLN

3. Highlight the desired integration time and press ENTER. For all functions (except frequency), the parameters are as follows:

   NORMAL = 1 PLC
   FAST = 0.01 PLC
   MEDIUM = 0.1 PLC
   HIACCURACY = 10 PLC

There are two additional parameters, SET-SPEED-EXACTLY and SET-BY-RSLN. If the SET-SPEED-EXACTLY parameter is chosen, the following message is displayed:

NPLC=01.00 (.01-10)

By using the cursor keys (◄ and ►) and the RANGE ▲ and ▼ keys, you can enter the integration time expressed in power line cycles. Note that integer integrations time will increase noise rejection.

The SET-BY-RSLN parameter optimizes the integration time for the present resolution setting. See Table 3-8 for the default integration times of the DCV and ACV functions. The default set-by-resolution integration times of other functions are listed in paragraphs 3.4.2, 3.4.3, and 3.4.5.

ANALOG FILTER

The ANALOG-FILTER menu item is used to check and/or change the state of the analog filter for the DCV function. It is described in paragraph 3.9.

After selecting this menu item, cursor position indicates the present state (ON or OFF) of the analog filter. To change the state, place the cursor (using the ◄ and ► keys) on the alternate selection and press ENTER.

FILTER

The FILTER parameter lets you set the digital filter response and control its on/off operation. It is described in paragraph 3.9. Only the specifics for DC and AC voltage are covered here.

The AUTO parameter for a digital filter optimizes its use for the present measurement function. The defaults for automatic filtering of DCV and ACV are listed in Table 3-9.

Table 3-8
DCV and ACV integration times set-by-resolution

Measurement function and type	Resolution	Integration time
DCV	3.5d, 4.5d	0.01 PLC
	5.5d	0.02 PLC
	6.5d	0.20 PLC
	7.5d	2.00 PLC
DCV peak spikes	3.5d (to 7.5d)	Not used
RMS, average	3.5d, 4.5d	0.01 PLC
	5.5d	0.02 PLC
	6.5d, 7.5d	10.00 PLC
Low frequency RMS	3.5d to 7.5d	Not used
ACV peak	4d (to 8d)	Not used

Notes:
1. For DCV measurements, if the integration time is SET-BY-RSLN and the resolution AUTO, the integration time will be 1.0 PLC and the resolution 6.5 digits.
2. For RMS and average measurements, if the integration time is SET-BY-RSLN and the resolution is AUTO, the integration will be 1.0 PLC and the resolution 5.5 digits.
3. For DCV peak spikes, low frequency RMS, and ACV peak measurements, the integration time setting is ignored.
4. The resolution of DCV peak spikes can be from 3.5d to 7.5d, but the accuracy is specified at 3.5d. The resolution of ACV peak can be from 4d to 8d, but the accuracy is specified at 4d.

Table 3-9
DCV and ACV auto filter

Measurement function and type	Units	State	Type	Readings	Noise tolerance	Averaging Mode
DCV	-	On	Advanced	10	1.0%	Moving
DCV peak spikes	-	On	Advanced	10	5.0%	Moving
RMS, average, low frequency RMS	Any	Off	Advanced	10	5.0%	Moving
ACV peak	Volts	On	Advanced	10	5.0%	Moving
	dB, dBm	On	Averaging	10	-	Moving

RESOLUTION

Except for frequency, temperature, and some special cases of AC voltage, all functions can operate with 3.5, 4.5, 5.5, 6.5, or 7.5-digit resolution, or they can default to a setting appropriate for the selected integration time. You can program the resolution parameter as follows:

1. From the normal reading display, press the CONFIG key and then the appropriate function key to access the top level of a function configuration menu. For example, the CONFIGURE DCV menu is displayed as follows:

   CONFIGURE DCV
   SPEED FILTER RESOLUTION

2. Use the cursor keys (◄ and ►) to highlight RESOLUTION and press ENTER. The following typical menu is shown:

   SET DCV RESOLUTION
   AUTO 3.5d 4.5d 5.5d 6.5d 7.5d

3. Highlight the desired resolution and press ENTER.

The AUTO selection optimizes the resolution for the present integration time setting. See Table 3-10 for the default resolutions of the DCV and ACV functions. The default resolutions of other functions are listed in paragraphs 3.4.2, 3.4.3, and 3.4.5.

Table 3-10
DCV and ACV auto resolution

Measurement function and type	Integration time	Resolution
DCV	0.01 to <0.02 PLC	4.5d
	0.02 to <0.20 PLC	5.5d
	0.20 to <2.00 PLC	6.5d
	2.00 to 10.00 PLC	7.5d
DCV peak spikes	Not used	3.5d
RMS, average	0.01 to <0.02 PLC	4.5d
	0.02 to <10.00 PLC	5.5d
	10.00 PLC	6.5d
Low frequency RMS	Not used	5.5d
ACV peak	Not used	4d

Notes:
1. If the DCV resolution is AUTO and the integration time SET-BY-RSLN, the resolution will be 6.5 digits and the integration time 1.0 PLC.
2. For DCV peak spikes, low frequency RMS, and ACV peak measurements, the integration time setting is ignored.
3. For RMS and average measurements, if the resolution is AUTO and the integration time is SET-BY-RSLN, the resolution will be 5.5 digits and the integration time 1.0 PLC.

UNITS

This parameter selects the displayed units for AC voltage measurements. You can program the ACV units parameter as follows:

1. From the CONFIGURE ACV menu, select UNITS and press ENTER. The following menu is displayed:

   SET ACV DISP UNITS
   VOLTS dB dBm

2. Highlight the desired units and press ENTER.

VOLTS: With volts selected as the units, AC voltage measurements are expressed in volts.

dB: Expressing AC voltage in dB makes it possible to compress a large range of measurements into a much smaller scope. The relationship between dB and voltage is defined by the following equation:

$$dB = 20 \log \frac{V_{IN}}{V_{REF}}$$

where: V_{IN} is the AC input signal.
V_{REF} is the specified voltage reference level.

The instrument will read 0dB when the reference voltage level is applied to the input. dB measurements are possible on all ACV measurement types except positive peak spikes and negative peak spikes, as these may be negative, and the log of a negative number is not defined. Note that dB measurements are specified only for the low frequency RMS measurement type.

If a relative value is in effect when dB is selected, the value is converted to dB. If a relative value is stored after dB units are selected, the units of the relative value are dB.

To set the reference voltage level, perform the following steps:

1. From the SET ACV DISP UNITS menu, select the dB option. The following typical message is shown:

   dB REF LEV:001.000 V

2. By using the cursor keys (◀ and ▶) and the RANGE ▲ and ▼ keys, you can enter the desired voltage reference level (0.001V to 750V).
3. Press ENTER to complete the change. If positive peak spikes or negative peak spikes is the selected AC type, the change is not allowed.

dBm: dBm is defined as decibels above or below a 1mW reference. With a user-programmable reference impedance, the Model 2001 reads 0dBm when the voltage needed to dissipate 1mW through the reference impedance is applied. The relationship between dBm, a reference impedance, and the voltage is defined by the following equation:

$$dBm = 10 \log \frac{(V_{IN}^2/Z_{REF})}{1mW}$$

where: V_{IN} is the AC input signal.
Z_{REF} is the specified reference impedance.

NOTE

Do not confuse reference impedance with input impedance. The input impedance of the instrument is not modified by the dBm parameter.

If a relative value is in effect when dBm is selected, the value is converted to dBm. If a relative value is stored after dB units are selected, the units of the relative value is dBm.

To set the reference impedance, perform the following steps:

1. From the SET ACV DISP UNITS menu, select the dBm option. The following menu is shown:

   SET dBm REFERENCE
   50Ω 75Ω 93Ω 132Ω 300Ω 600Ω

2. Highlight the desired reference impedance and press ENTER to complete the change. If positive peak spikes or negative peak spikes is the selected AC type, the change is not allowed.

dB/dBm notes:

1. dB and dBm units are not allowed with positive or negative peak spike measurements.
2. dB and dBm units are not allowed with an advanced filter.
3. With dB or dBm units selected, there is no bar graph on zero-centered bar graph multiple display.
4. When units are changed from volts to dB or dBm with A02 and greater firmware, all values less than zero that depend on the new units are made equal to zero. This includes, for example, relative values and stored readings. This avoids the overflow condition of a log of a negative number.

COUPLING

This parameter selects the input coupling for the ACV function. When AC coupling is selected, a DC blocking capacitor is placed in series with the input. This removes the DC component from the RMS, average, or peak ACV measurement.

When AC+DC coupling is selected, the blocking capacitor is removed. Subsequent RMS, average, or peak ACV measurements will reflect both the AC and DC components of the signal.

While displaying readings, the present coupling setting is shown on the bottom line, if not showing a multiple display.

You can set the ACV coupling as follows:

1. From the CONFIGURE ACV menu, select COUPLING and press ENTER. The following menu is displayed:

   SET AC COUPLING
   AC AC+DC

2. Highlight the desired coupling and press ENTER.

Note that the coupling settings for ACV and ACI are discrete. Thus, setting the coupling of ACV has no effect on the coupling of ACI.

AC-TYPE

This parameter selects the measurement type for the ACV function. The Model 2001 directly measures RMS, average, and peak AC voltages. For a 330V peak-to-peak sine wave, which is line voltage in the U.S., the measurements would be:

- RMS = 117V
- Average = 105V (full wave rectified)
- Peak AC = 165V

The peak detector is also used to measure positive and negative peak spikes riding on a DC signal and they are, therefore, also configured from the AC-TYPE menu.

You can program the ACV type parameter as follows:

1. From the CONFIGURE ACV menu, select AC-TYPE and press ENTER. The following menu is displayed:

   SET ACV MEASUREMENT
   RMS AVERAGE PEAK LOW-FREQ-RMS ►
   ◄ POSITIVE-PEAK NEGATIVE-PEAK

2. Highlight the desired measurement type and press ENTER.

RMS and LOW-FREQ-RMS: Selecting between normal RMS mode and low frequency RMS mode depends on the desired accuracy and speed. Low frequency RMS mode is more accurate, but slower.

Both modes are specified between 20Hz and 2MHz, with low frequency RMS specified additionally down to 1Hz. Some guidelines for choosing between the two modes follow:

- Below 50Hz, use low frequency RMS mode for its greater accuracy.
- Between 50 and 100Hz, use either mode.
- Above 100Hz, use normal RMS mode for its greater speed.

AVERAGE: When this item is selected, the signal path in the instrument bypasses the RMS converter, so the average ACV measurement is just the filtered output of a full wave rectifier.

PEAK: For AC peak measurements, the instrument displays the largest peak (positive or negative) of the input signal. The measurement window is fixed at 100msec.

Note that you can configure the resolution of ACV peak measurements from 4 digits (3.5d from SET ACV RESOLUTION menu) to 8 digits (7.5d), but the accuracy is specified at 4 digits. In addition, the accuracy specifications for AC peak measurements assume AC+DC coupling below 200Hz.

POSITIVE-PEAK and NEGATIVE-PEAK: Peak spike measurements are available as an ACV primary display (top line). They are also available as a DCV multiple display (bottom line). The menu items POSITIVE-PEAK and NEGATIVE-PEAK enable the measurement as a primary display. See Figure 3-8 for a description of the primary display.

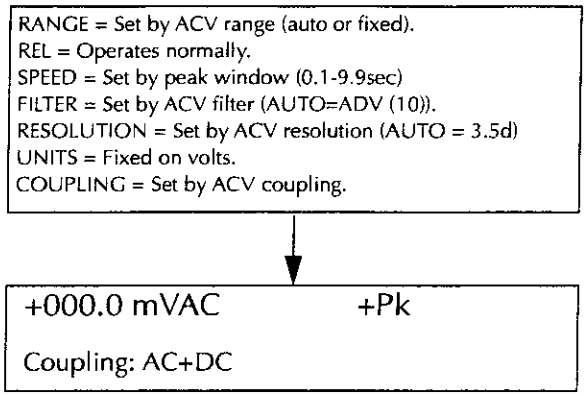
After selecting a positive or negative peak spikes measurement from the SET ACV MEASUREMENT menu, you are asked to enter a value for the measurement window. A typical message follows:

PEAK WINDOW = 0.1 s

This sets the time the signal is sampled before the display is updated with a new reading. It can range from 0.1sec to 9.9sec.

As a primary display, the resolution of peak spikes can be set from 3.5d to 7.5d, but the accuracy is specified at 3.5d. (As a multiple display, the resolution is fixed at 3.5d.)

Note that dB and dBm are not allowed as valid units for peak spikes. Positive-going spikes on a negative DC level could still read as a negative value, and the log of a negative number is not defined.

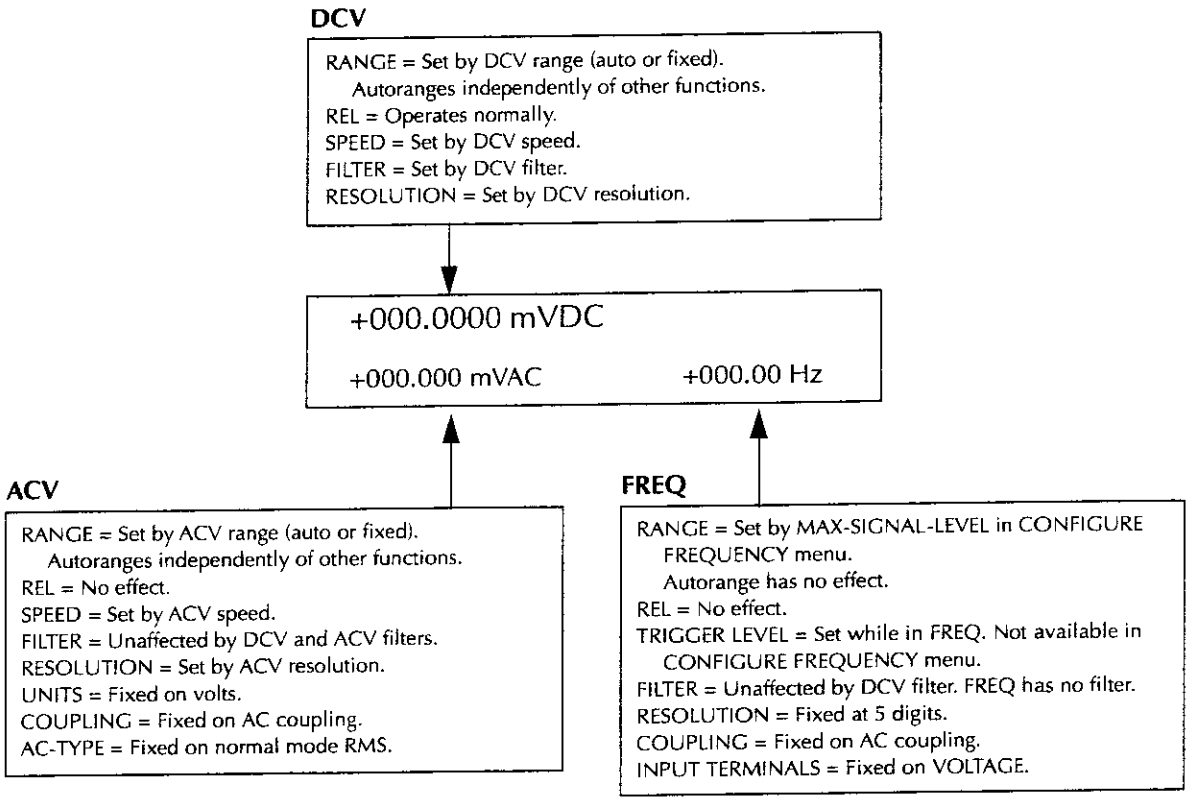


NOTES:
1. Positive peak spikes and negative peak spikes are selected in the CONFIGURE-ACV menu.
2. Peak spikes measurement is specified for volts at 3.5 digits.
3. "Peak window" is the time a signal is sampled before a reading is displayed.

Figure 3-8
Positive and negative peak spikes

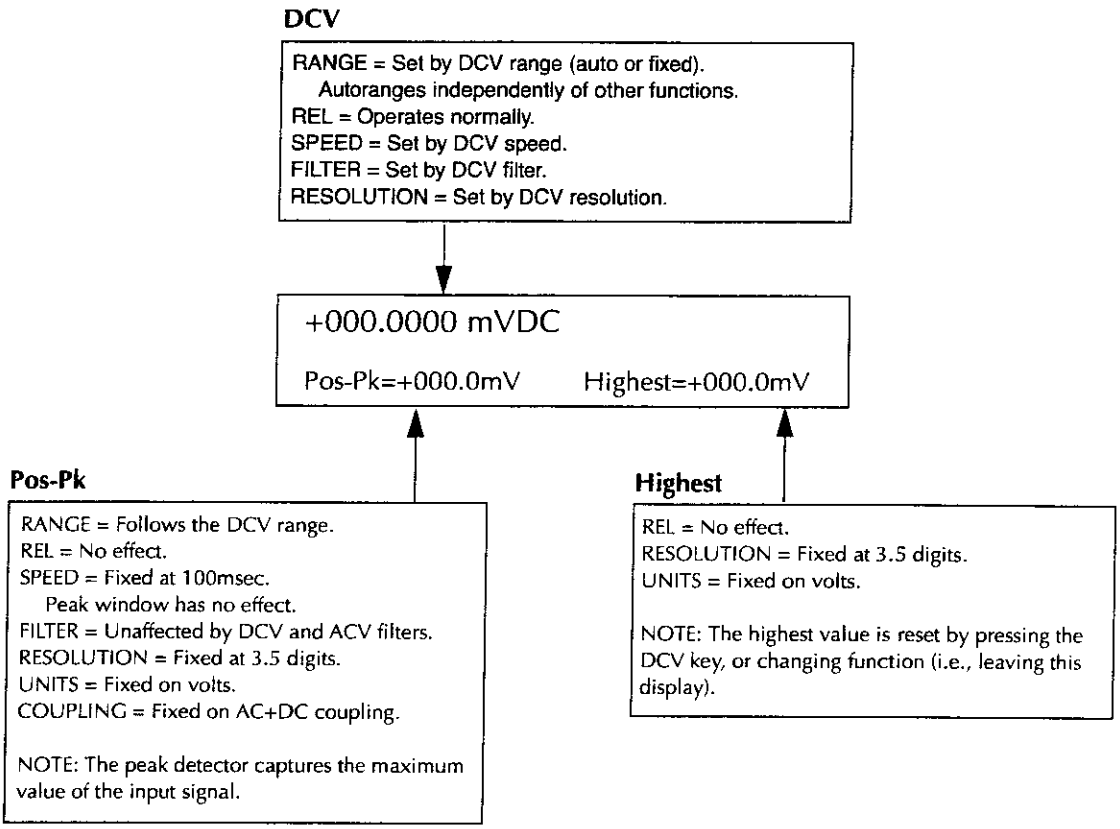
Multiple displays

The displays for DC and AC voltage that show multiple functions are shown in Figures 3-9 and 3-10. The multiple display for crest factor, which is calculated from the peak and RMS values, is described here.



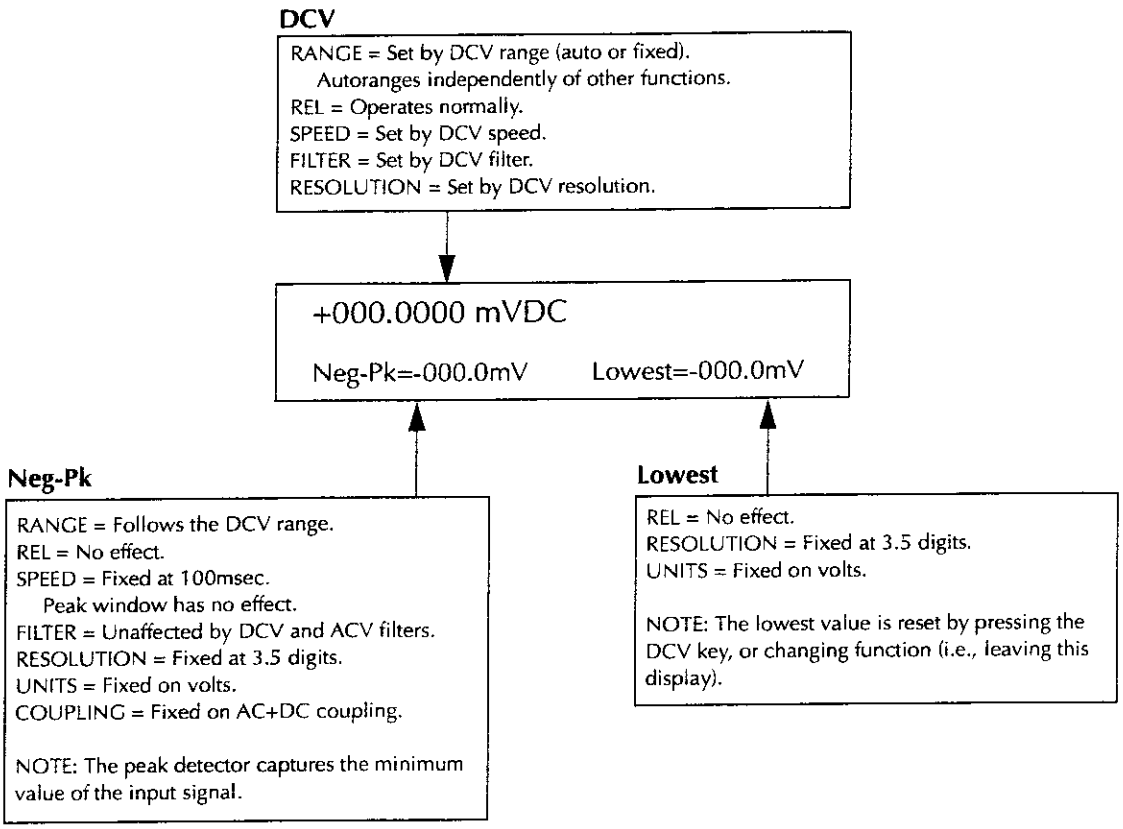
A. DC voltage, AC voltage, and frequency functions

Figure 3-9
DC voltage multifunction multiple displays



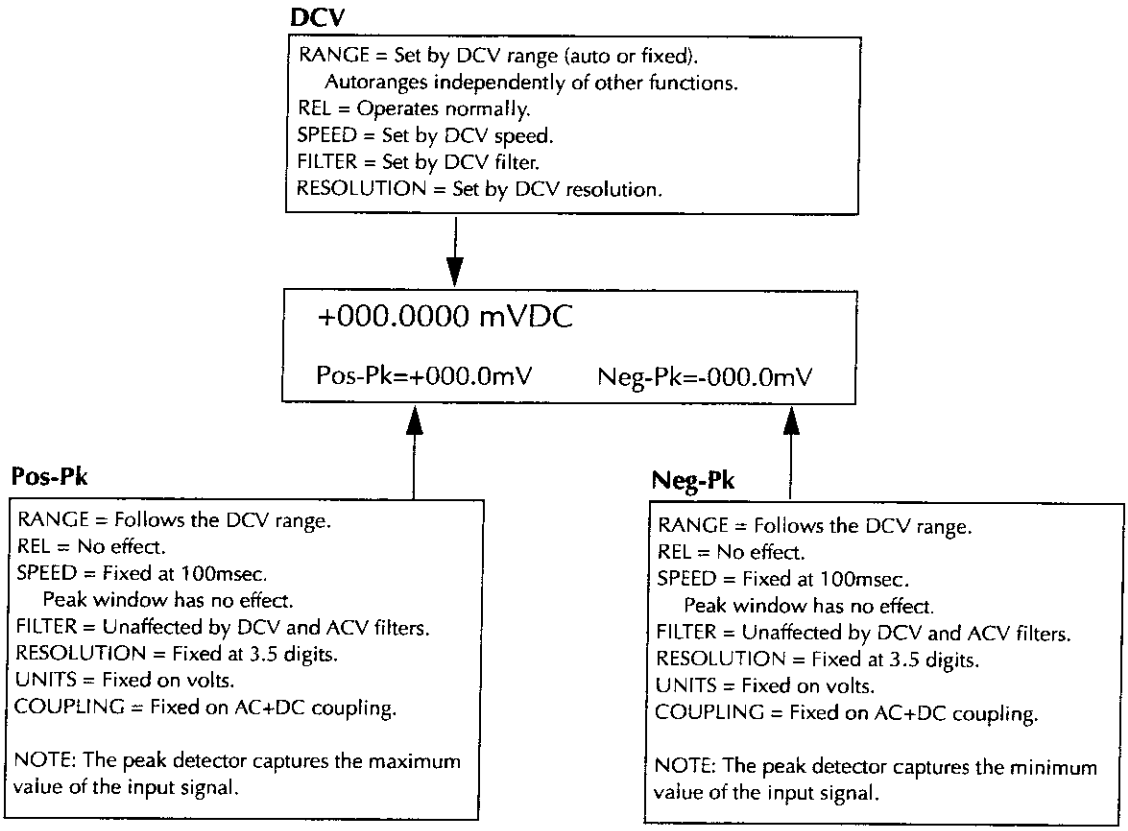
B. DC voltage and positive peak spikes functions

Figure 3-9 (continued)
DC voltage multifunction multiple displays



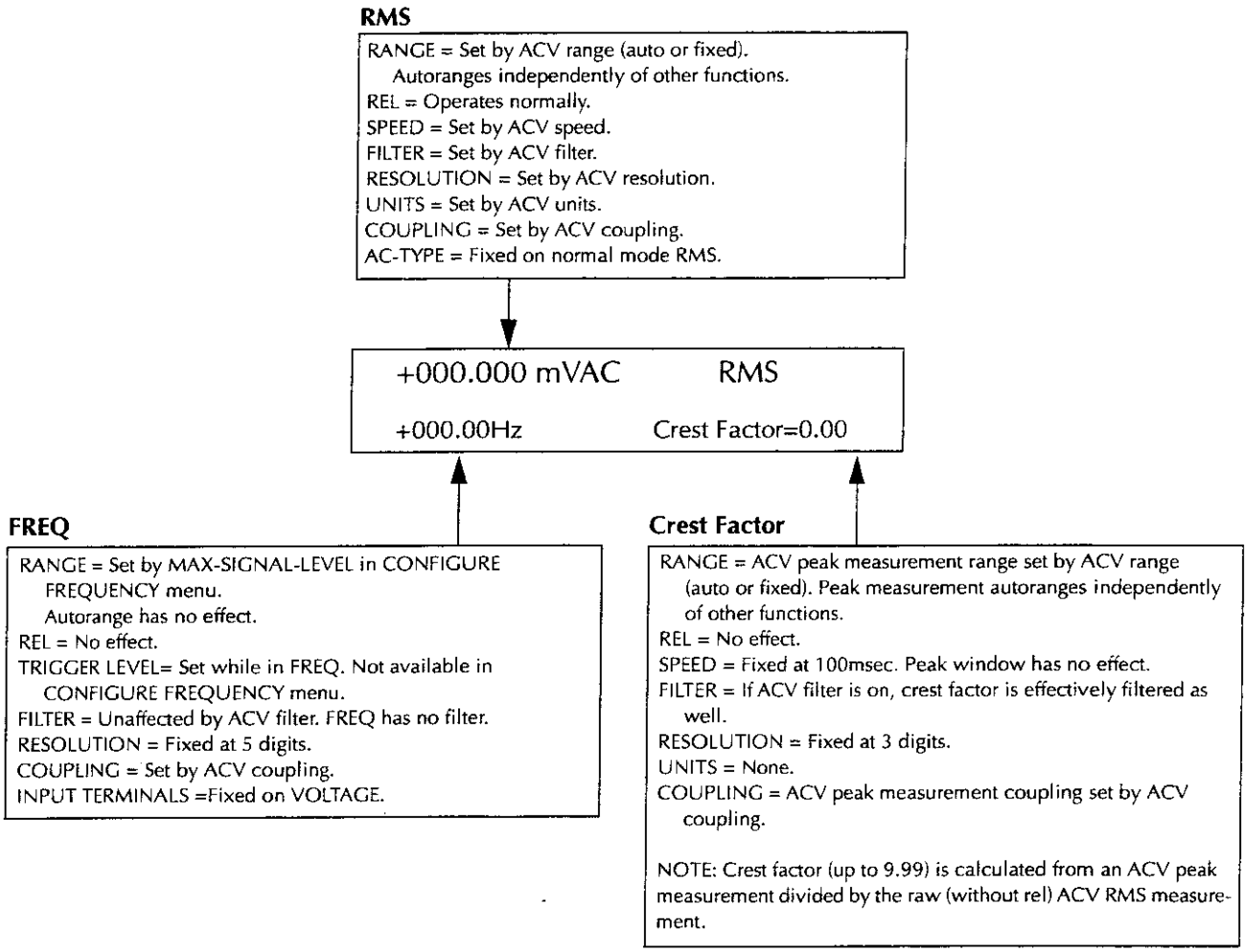
C. DC voltage and negative peak spikes functions

Figure 3-9 (continued)
DC voltage multifunction multiple displays



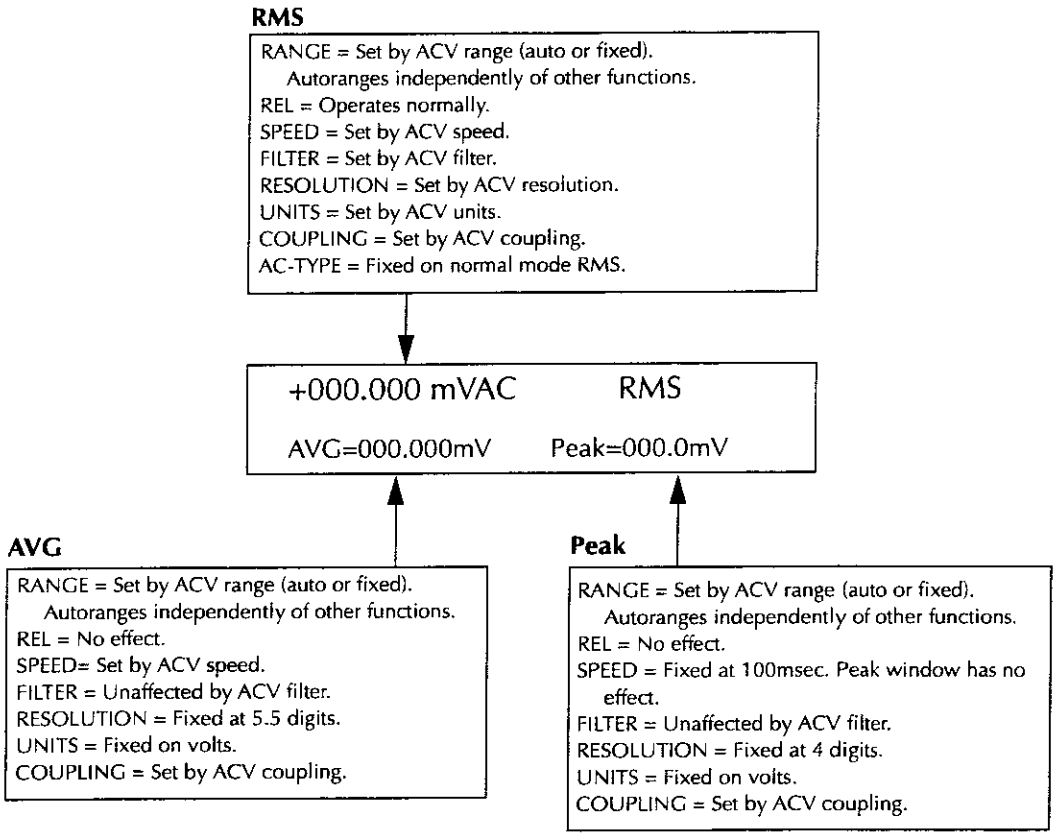
D. DC voltage, positive and negative peak spikes functions

Figure 3-9 (continued)
DC voltage multifunction multiple displays



A. AC RMS voltage, frequency, and crest factor

Figure 3-10
AC voltage multifunction multiple displays



B. AC RMS, average, and peak voltages

Figure 3-10 (continued)
AC voltage multifunction multiple displays

Crest factor: The crest factor of a waveform is the ratio of its peak value to its RMS value. Thus, the crest factor specifies the dynamic range of a true RMS instrument. For sinusoidal waveforms, the crest factor is 1.414. For a symmetrical square wave, the crest factor is unity. The crest factor of a rectangular pulse is related to its duty cycle; as the duty cycle decreases, the crest factor increases.

For the Model 2001, the additional error term for RMS measurements caused by a high crest factor is specified up to a value of five. The maximum displayable value is 9.99, or else it shows "over".

Note that the crest factor is not calculated if dB or dBm is the presently selected units.

Low level considerations

For sensitive measurements, external considerations besides the Model 2001 affect the accuracy. Effects not noticeable when working with higher voltages are significant in microvolt signals. The Model 2001 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors that affect accuracy, including thermal offsets and stray pick-up.

Shielding: AC voltages that are extremely large compared with the DC signal to be measured may produce an erroneous output. Therefore, to minimize AC interference, the circuit should be shielded with the shield connected to the Model 2001 INPUT LO (particularly for low-level sources). Improper shielding can cause the Model 2001 to behave in one or more of the following ways:

- Unexpected offset voltages.
- Inconsistent readings between ranges.
- Sudden shifts in reading.

To minimize pick-up, keep the voltage source and the Model 2001 away from strong AC magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each signal at only one point.

Thermal EMFs: Thermal emfs (thermoelectric potentials) are generated by thermal differences between the junctions of dissimilar metals. These can be large compared to the signal that the Model 2001 can measure. Thermal emfs can cause the following conditions:

- Instability or zero offset is much higher than expected.
- The reading is sensitive to (and responds to) temperature changes. This effect can be demonstrated by touching the circuit, by placing a heat source near the circuit, or by a regular pattern of instability (corresponding to heating and air conditioning systems, or changes in sunlight).

To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the Model 2001. A banana plug generates a few microvolts. A clean copper conductor such as #10 bus wire is ideal for this application. The leads to the input may be shielded or unshielded, as necessary. Refer to Shielding.

Widely varying temperatures within the circuit can also create thermal emfs. Therefore, maintain constant offset temperatures to minimize these thermal emfs. A cardboard box around the circuit under test also helps by minimizing air currents.

The REL control can be used to null out constant offset voltages.

Note that additional thermals may be generated by the optional Model 2001-SCAN scanner card.

AC voltage offset: The Model 2001, at 5½d resolution, will typically display 150 counts of offset on AC volts with the input shorted. This offset is caused by the offset of the TRMS converter. This offset will not affect reading accuracy and should not be zeroed out using the rel feature. The following equation expresses how this offset (V_{OFFSET}) is added to the signal input (V_{IN}):

$$\text{Displayed reading} = \sqrt{(V_{IN})^2 + (V_{OFFSET})^2}$$

Example: Range = 2VAC
Offset = 150 counts (1.5mV)
Input = 200mV RMS

$$\text{Display reading} = \sqrt{(200\text{mV})^2 + (1.5\text{mV})^2}$$

$$= \sqrt{0.04\text{V} + (2.25 \times 10^{-6} V)}$$

$$= .200005\text{V}$$

The offset is seen as the last digit which is not displayed. Therefore, the offset is negligible. If the rel feature were used to zero the display, the 150 counts of offset would be subtracted from V_{IN} resulting in an error of 150 counts in the displayed reading.

3.4.2 DC and AC current

DC current measurements

The Model 2001 can make normal DC current measurements between 10pA and 2.1A. Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure is as follows:

1. Connect the test leads to the AMPS and INPUT LO terminals of the Model 2001. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the DCI function.
3. Select a range consistent with the expected current. For automatic range selection, press the AUTO key. The AUTO annunciator denotes whether auto-ranging is enabled.
4. Connect the test leads to the source as shown in Figure 3-11.

CAUTION

Do not apply more than 2.1A, 250V to the AMPS input, or the amps protection fuse will blow.

5. Observe the display. If the "Overflow" message is shown, select a higher range until a normal reading is displayed. Always use the lowest possible range for the best resolution.
6. Take a reading from the display.

AC current measurements

The Model 2001 can make AC current measurements between 100pA and 2.1A. Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure is as follows:

1. Connect the test leads to the AMPS and INPUT LO terminals of the Model 2001. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the ACI function.
3. Select a range consistent with the expected current. For automatic range selection, press the AUTO key. The AUTO annunciator denotes whether auto-ranging is enabled.
4. Connect the test leads to the source as shown in Figure 3-11.

CAUTION

Do not apply more than 2.1A, 250V to the AMPS input, or the amps protection fuse will blow.

5. Observe the display. If the "Overflow" message is shown, select a higher range until a normal reading is displayed. Always use the lowest possible range for the best resolution.
6. Take a reading from the display.

AMPS fuse replacement

There are two protection fuses for the current ranges, one for the front terminals, another for the rear. This procedure describes how to change an AMPS fuse.

WARNING

Make sure the instrument is disconnected from the power line and other equipment before replacing an AMPS fuse.

1. Turn off the power and disconnect the power line and test leads.
2. Perform one of the following steps:
   A. For the front panel AMPS fuse, gently push in the AMPS jack with your thumb and rotate the fuse carrier one-quarter turn counter-clockwise. Release pressure on the jack and its internal spring will push the jack out of the socket.
   B. For the rear panel AMPS fuse, place the end of a flat-blade screwdriver into the rear panel AMPS holder. Push in gently and rotate the fuse carrier one-quarter turn counter-clockwise. Release pressure on the holder and its internal spring will push the fuse carrier out of the holder.
3. Remove the fuse and replace it with the same type (2A, 250V, fast blow, 5 × 20mm). The Keithley part number is FU-48.

CAUTION

Do not use a fuse with a higher current rating than specified, or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse. See the optional Model 2001 Repair Manual for troubleshooting information.

4. Install the new fuse by reversing the above procedure.

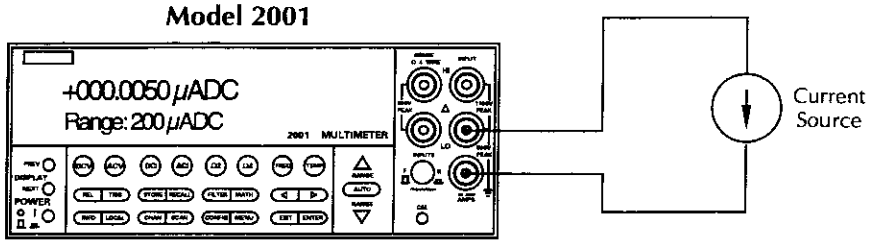


Figure 3-11
DC and AC current measurements

Current configuration

The following paragraphs detail how to change the Model 2001 from its bench reset conditions for DC and AC current measurements. The configuration menus are summarized in Tables 3-11 and 3-12. Note that a function does not have to be selected in order to be configured. When the function is selected, it will assume the programmed status.

Table 3-11
CONFIGURE DCI menu structure

Menu item	Description
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Program a simple average filter (1-100 readings).
ADVANCED	Program a simple average filter (1-100 readings) with a noise tolerance window (0-100% of range).
AVERAGING-MODE	Select moving average or repeating average mode.
RESOLUTION	Display resolution menu:
AUTO	Default to resolution appropriate for integration time.
3.5d, 4.5d, 5.5d, 6.5d, 7.5d	Select a specific resolution.
MEASUREMENT-MODE	Measurement mode menu:
NORMAL	Select normal current measurement (use AMPS terminals).
IN-CIRCUIT	Select in-circuit current measurement (use INPUT and SENSE terminals).

Table 3-12
CONFIGURE ACI menu structure

Menu item	Description
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Program a simple average filter (1-100 readings).
ADVANCED	Program a simple average filter (1-100 readings) with a noise tolerance window (0-100% of range).
AVERAGING-MODE	Select moving average or repeating average mode.
RESOLUTION	Display resolution menu:
AUTO	Default to resolution appropriate for integration time.
3.5d, 4.5d, 5.5d, 6.5d, 7.5d	Select a specific resolution.
COUPLING	Coupling menu:
AC	Select AC coupled measurements.
AC+DC	Select DC coupled measurements.
AC-TYPE	Type of ACI measurement menu:
RMS	Select true RMS ACI.
AVERAGE	Select average ACI.

SPEED

The SPEED parameter sets the integration time of the A/D converter, the period of time the input signal is measured (also known as aperture). It is discussed in paragraph 3.4.1, DC and AC voltage. Only the differences for DC and AC current are noted here.

The SET-BY-RSLN parameter optimizes the integration time for the present resolution setting. The defaults for set-by-resolution integration times of DCI and ACI are listed in Table 3-13.

Table 3-13
DCI and ACI integration time set-by-resolution

Measurement function and type	Resolution	Integration time
DC current	3.5d, 4.5d	0.01 PLC
	5.5d	0.02 PLC
	6.5d	0.20 PLC
	7.5d	2.00 PLC
DC in-circuit current	3.5d to 7.5d	Not used
RMS, average	3.5d, 4.5d	0.01 PLC
	5.5d	0.02 PLC
	6.5d, 7.5d	10.00 PLC

Notes:
1. For normal DC current, if the integration time is SET-BY-RSLN and the resolution is AUTO, the integration time will be 1.0 PLC and the resolution 6.5 digits.
2. For DC in-circuit current, the integration time setting is ignored.
3. For AC current, if the integration time is SET-BY-RSLN and the resolution is AUTO, the integration time will be 1.0 PLC and the resolution 5.5 digits.

FILTER

The FILTER parameter lets you set the digital filter response and control its on/off operation. It is described in paragraph 3.9. Only the specifics for DC and AC current are covered here.

The AUTO parameter for a digital filter optimizes its use for the present measurement function. The defaults for automatic filtering of DCI and ACI are listed in Table 3-14.

RESOLUTION

The RESOLUTION parameter sets the display resolution. It is discussed in paragraph 3.4.1, DC and AC voltage. Only the differences for DC and AC current are noted here.

The available resolution on all current functions and types is 3.5 digits to 7.5 digits. If the DCI or ACI resolution is AUTO, refer to Table 3-15 for the resolution associated with the integration time.

Table 3-14
DCI and ACI auto filter

Measurement function and type	State	Type	Readings	Noise tolerance	Mode
DC current	On	Advanced	10	1.0%	Moving
DC in-circuit current	On	Advanced	10	1.0%	Moving
AC current	Off	Advanced	10	5.0%	Moving

Table 3-15
DCI and ACI auto resolution

Measurement function and type	Integration time	Resolution
DC current	0.01 to <0.02 PLC	4.5d
	0.02 to <0.20 PLC	5.5d
	0.20 to <2.00 PLC	6.5d
	2.00 to 10.00 PLC	7.5d
DC in-circuit current	Not used	5.5d
RMS, average	0.01 to <0.02 PLC	4.5d
	0.02 to <10.00 PLC	5.5d
	10.00 PLC	6.5d

Notes:
1. For normal DC current, if the resolution is AUTO and the integration time is SET-BY-RSLN, the resolution will be 6.5 digits and the integration time 1.0 PLC.
2. For DC in-circuit current, the integration time setting is ignored.
3. For AC current, if the resolution is AUTO and the integration time is SET-BY-RSLN, the resolution will be 5.5 digits and the integration time 1.0 PLC.

MEASUREMENT-MODE

This option selects the DC current measurement mode, either normal or in-circuit measurements. It is programmed as follows:

1. From the CONFIGURE DCI menu, select MEASUREMENT-MODE and press ENTER. The following menu is shown:

   DCI MEASUREMENT MODE
   NORMAL IN-CIRCUIT

2. Highlight the desired mode and press ENTER.

NORMAL: This option is for normal current measuring, where the meter is placed in series with the current path and the voltage across an internal shunt resistor is measured. The specifications are derated by 50ppm for currents over 0.5A because of the self-heating effects on the shunt resistor.

IN-CIRCUIT: In-circuit current is a calculation based on a 4-wire resistance measurement and a voltage measurement. It is similar to an offset-compensated ohms reading.

A measurement overflow occurs for any of the following conditions:

- The measured voltage exceeds |±200mV|.
- The trace resistance is less than 1mΩ or greater than 10Ω.
- The in-circuit current is greater than 12A.

The current in a low resistance conductor (e.g., a printed circuit trace) can be measured without breaking the current path. The Model 2001 can do this with a pair of Kelvin test probes across the conductor. See Figure 3-12. The method follows:

1. Using one set of the Kelvin probe tips, the instrument sources a known current (I_{SOURCE}) through the conductor and simultaneously measures the resulting voltage (V_{MEAS1}) with the other set of probe tips:

$$V_{MEAS1} = (I_{IN\text{-}CKT} + I_{SOURCE})R_{TRACE}$$

or

$$R_{TRACE} = \frac{V_{MEAS1}}{(I_{IN\text{-}CKT} + I_{SOURCE})}$$

2. The instrument then measures the voltage (V_{MEAS2}) across the conductor without sourcing an additional current:

$$V_{MEAS2} = (I_{IN\text{-}CKT})R_{TRACE}$$

or

$$R_{TRACE} = \frac{V_{MEAS2}}{(I_{IN\text{-}CKT})}$$

3. It then calculates the in-circuit current by combining the equations and solving for $I_{IN\text{-}CKT}$:

$$\frac{V_{MEAS1}}{(I_{IN\text{-}CKT} + I_{SOURCE})} = \frac{V_{MEAS2}}{(I_{IN\text{-}CKT})}$$

$$V_{MEAS1}(I_{IN\text{-}CKT}) = V_{MEAS2}(I_{IN\text{-}CKT} + I_{SOURCE})$$

$$V_{MEAS1}(I_{IN\text{-}CKT}) - V_{MEAS2}(I_{IN\text{-}CKT}) = V_{MEAS2}(I_{SOURCE})$$

$$I_{IN\text{-}CKT}(V_{MEAS1} - V_{MEAS2}) = V_{MEAS2}(I_{SOURCE})$$

$$I_{IN\text{-}CKT} = \frac{V_{MEAS2}(I_{SOURCE})}{(V_{MEAS1} - V_{MEAS2})}$$

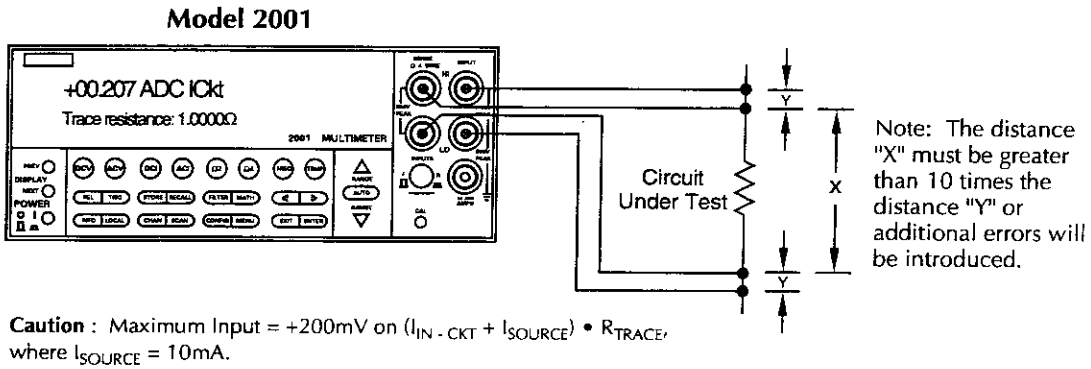


Figure 3-12
DC in-circuit current measurements

Because of accuracy considerations, in-circuit current readings are limited to traces with a resistance of 1mΩ to 10Ω. If either of these limits is exceeded in the resistance calculation, the in-circuit current cannot be calculated. The bottom line of the front panel display will show and update the trace resistance.

A procedure to measure in-circuit current follows:

1. Select the in-circuit current measurement mode from the CONFIGURE DCI menu and place the instrument in the DCI function. Note that the 4W annunciator lights to indicate this is a 4-wire measurement.
2. Connect a set of Kelvin test probes, such as Keithley Model 5805 or 5806, to the Model 2001 INPUT HI and LO terminals and SENSE HI and LO terminals.
3. For R_{TRACE} <50mΩ, or where the conductors are physically hot, rel out (zero correct) any thermal offsets that are present before measuring in-circuit current. With power to the test circuit removed, place the probes on the desired trace and enable rel from the DCI function.
4. Turn on the power to the test circuit and read the in-circuit current calculation. The speed of this measurement is four readings per second at 1PLC. Its range is fixed at 12A. The default filter for in-circuit current is a moving average of ten readings. Additional filtering may be needed at low voltage levels.

COUPLING

This parameter selects the input coupling for the ACI function. When AC coupling is selected, a DC blocking capacitor is placed in series with the AC measurement circuit. (Note that the current shunt resistors are always DC coupled to the inputs.) This removes the DC component from the RMS and average ACI measurement.

When AC+DC coupling is selected, the blocking capacitor is removed. Subsequent RMS or average ACI measurements will reflect both the AC and DC components of the signal.

You can set the ACI coupling as follows:

1. From the CONFIGURE ACI menu, select COUPLING and press ENTER. The following menu is displayed:

   SET AC COUPLING
   AC AC+DC

2. Highlight the desired coupling and press ENTER.

Note that the coupling settings for ACI and ACV are discrete. Thus, setting the coupling of ACI has no effect on the coupling of ACV.

AC-TYPE

This parameter selects the measurement type for the ACI function. The Model 2001 directly measures RMS and average AC current. You can program the ACI type parameter as follows:

1. From the CONFIGURE ACI menu, select AC-TYPE and press ENTER. The following menu is displayed:

   SET ACI MEASUREMENT
   RMS AVERAGE

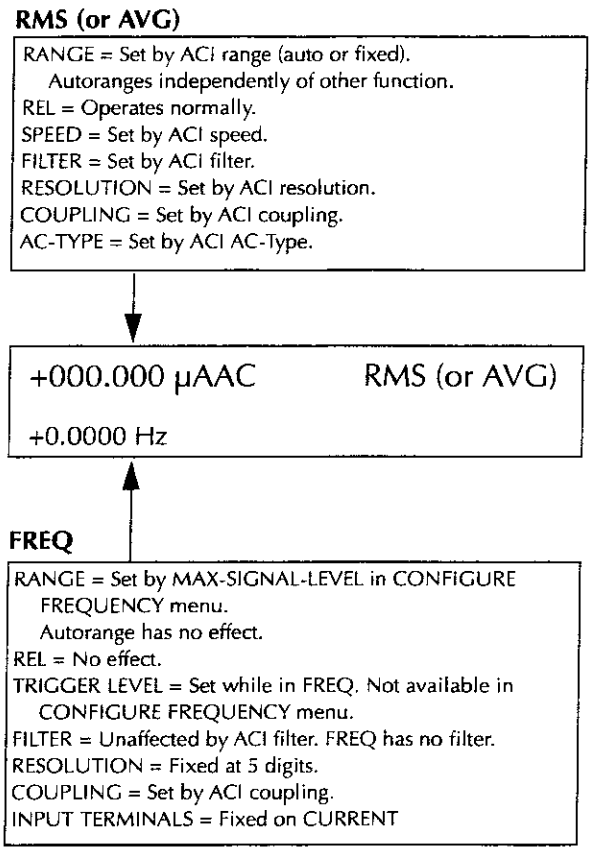
2. Highlight the desired measurement type and press ENTER.

RMS: With this parameter selected, the instrument performs RMS AC current measurements.

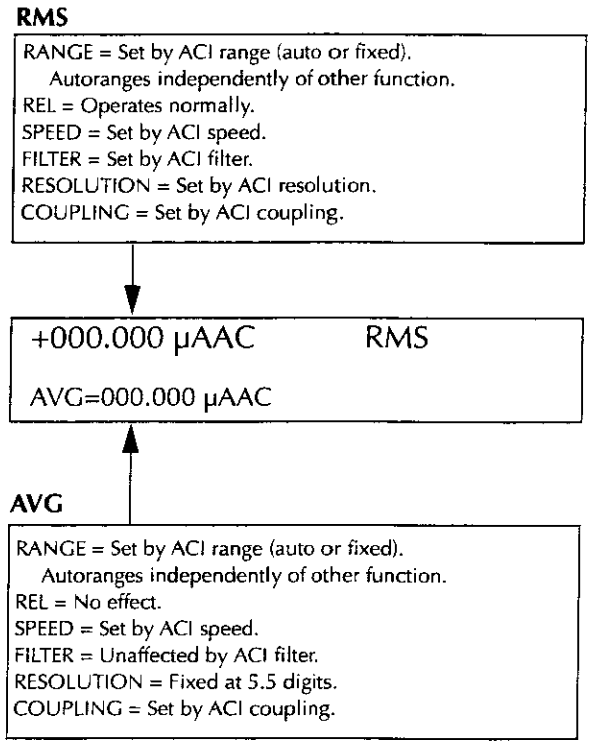
AVERAGE: When this item is selected, the signal path in the instrument bypasses the RMS converter, so the average ACI measurement is just the filtered output of a full wave rectifier.

Multiple displays

The multiple displays for AC current that show multiple functions are shown in Figure 3-13. There are no multifunction displays for DC current.



A. AC RMS (or average) current and frequency functions



B. AC RMS and average current functions

Figure 3-13
AC current multifuncton multiple displays

3.4.3 Two and four-wire resistance

2-wire resistance measurements

The Model 2001 can make 2-wire resistance measurements between 1µΩ and 1.05GΩ. Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure is as follows:

1. Connect test leads to the INPUT HI and LO terminals of the Model 2001. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the Ω2 function.
3. Select a range consistent with the expected resistance. For automatic range selection, press the AUTO key. The AUTO annunciator denotes whether auto-ranging is enabled.
4. Enable offset compensation if needed (refer to the procedure later in this paragraph).

NOTE

Whether or not offset compensation is being used, the 20Ω, 200Ω, 2kΩ, 20kΩ, and 200kΩ ranges require zero correction in order to achieve the best accuracy. The zero correction procedure is located in a following paragraph.

5. Connect the test leads to the resistance as shown in Figure 3-14.

CAUTION

Do not exceed 1100V peak between INPUT HI and LO, or instrument damage may occur.

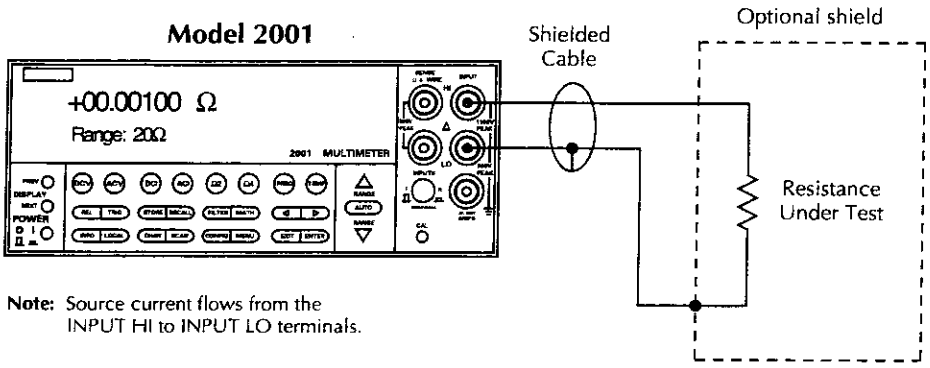


Figure 3-14
Two-wire resistance measurements

6. Observe the display. If the "Overflow" message is shown, select a higher range until a normal reading is displayed. Always use the lowest possible range for the best resolution.
7. Take a reading from the display.

4-wire resistance measurements

The Model 2001 can make 4-wire resistance measurements between 1μΩ and 210kΩ. Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure is as follows:

1. Connect test leads to the INPUT HI and LO and SENSE Ω4 WIRE HI and LO terminals of the Model 2001. Recommended Kelvin test probes include the Keithley Models 5805 and 5806. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.
2. Select the Ω4 function.
3. Select a range consistent with the expected resistance. For automatic range selection, press the AUTO key. The AUTO annunciator denotes whether auto-ranging is enabled.
4. Enable offset compensation if needed (refer to the procedure later in this paragraph).

NOTE

If offset compensation is not being used, the 20Ω and 200Ω ranges require zero correction in order to achieve the best accuracy. The zero correction procedure is located in a following paragraph.

5. Connect the test leads to the resistance as shown in Figure 3-15.

CAUTION

Do not exceed 1100V peak between INPUT HI and LO, or instrument damage may occur.

6. Observe the display. If the "Overflow" message is shown, select a higher range until a normal reading is displayed. Always use the lowest possible range for the best resolution.
7. Take a reading from the display.

Zeroing

The term "when properly zeroed" means that you must establish a baseline for subsequent measurements on that range. The 20Ω and 200Ω resistance ranges require zero correction to correct for thermal offsets. This procedure should be performed whenever the ambient temperature changes. To zero (rel) the Model 2001, use the following procedure:

1. Disable rel, if presently enabled, by pressing the REL key. The REL annunciator will turn off.
2. Select the desired function (Ω2 or Ω4) and range.
3. Connect the test leads to INPUT HI and LO (and SENSE Ω4 WIRE if the Ω4 function is selected) of the Model 2001 and short them together. Noise and thermal offsets may require a few moments to stabilize.
4. Press the REL key. The display will read zero.
5. Remove the short and connect the test leads to the resistance to be measured.

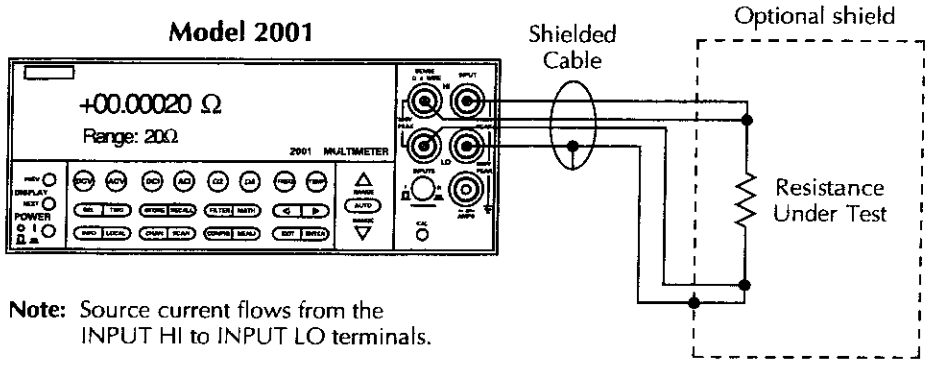


Figure 3-15
Four-wire resistance measurements

Shielding

It helps to shield resistance greater than 100kΩ to achieve a stable reading. Place the resistance in a shielded enclosure and electrically connect the shield to the INPUT LO terminal of the instrument.

Resistance configuration

The following paragraphs detail how to change the Model 2001 from its bench reset conditions for 2-wire and 4-wire resistance measurements. The configuration menus are summarized in Tables 3-16 and 3-17. Note that a function does not have to be selected in order to be configured. When the function is selected, it will assume the programmed status.

Table 3-16
CONFIGURE OHMS-2W menu structure

Menu item	Description
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Program a simple average filter (1-100 readings).
ADVANCED	Program a simple average filter (1-100 readings) with a noise tolerance window (0-100% of range).
AVERAGING-MODE	Select moving average or repeating average mode.
RESOLUTION	Display resolution menu:
AUTO	Default to resolution appropriate for integration time.
3.5d, 4.5d, 5.5d, 6.5d, 7.5d	Select a specific resolution.
OFFSETCOMP	Enable/disable offset compensation (20Ω-20kΩ ranges).
MAXAUTORANGE	Set upper limit for autoranging of 2-wire resistance.
1GΩ, 200MΩ, 20MΩ, 2MΩ, 200kΩ, 20kΩ	Select a specific range.

Table 3-17
CONFIGURE OHMS-4W menu structure

Menu item	Description
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Program a simple average filter (1-100 readings).
ADVANCED	Program a simple average filter (1-100 readings) with a noise tolerance window (0-100% of range).
AVERAGING-MODE	Select moving average or repeating average mode.
RESOLUTION	Display resolution menu:
AUTO	Default to resolution appropriate for integration time.
3.5d, 4.5d, 5.5d, 6.5d, 7.5d	Select a specific resolution.
OFFSETCOMP	Enable/disable offset compensation (20Ω-20kΩ ranges).
MAXAUTORANGE	Set upper limit for autoranging of 4-wire resistance.
200kΩ, 20kΩ, 2kΩ	Select a specific range.

SPEED

The SPEED parameter sets the integration time of the A/D converter, the period of time the input signal is measured (also known as aperture). It is discussed in paragraph 3.4.1, DC and AC voltage. Only the differences for 2-wire and 4-wire resistance are noted here.

The SET-BY-RSLN parameter optimizes the integration time for the present resolution setting. The defaults for set-by-resolution integration times of Ω2 and Ω4 are listed in Table 3-18.

Table 3-18
Ω2 and Ω4 integration time set-by-resolution

Resolution	Integration time
3.5d, 4.5d	0.01 PLC
5.5d	0.02 PLC
6.5d	0.20 PLC
7.5d	2.00 PLC

Note: If the integration time is SET-BY-RSLN and the resolution AUTO, the integration time will be 1.0 PLC and the resolution 6.5 digits.

FILTER

The FILTER parameter lets you set the digital filter response and control its on/off operation. It is described in paragraph 3.9. Only the specifics for 2- and 4-wire resistance are covered here.

The AUTO parameter for a digital filter optimizes its use for the present measurement function. The defaults for automatic filtering of Ω2 and Ω4 are listed in Table 3-19.

Table 3-19
Ω2 and Ω4 auto filter

Measurement function	State	Type	Reading	Noise tolerance	Averaging Mode
2-wire resistance	On	Advanced	10	1.0%	Moving
4-wire resistance	On	Advanced	10	1.0%	Moving

RESOLUTION

The RESOLUTION parameter sets the display resolution. It is discussed in paragraph 3.4.1, DC and AC voltage. Only the differences for Ω2 and Ω4 are noted here.

The available resolution on all resistance functions and types is 3.5 digits to 7.5 digits. If the Ω2 or Ω4 resolution is AUTO, refer to Table 3-20 for the resolution associated with the integration time.

Table 3-20
Ω2 and Ω4 auto resolution

Integration time	Resolution
0.01 to <0.02 PLC	4.5d
0.02 to <0.20 PLC	5.5d
0.20 to <2.00 PLC	6.5d
2.00 to 10.00 PLC	7.5d

Note: If the resolution is AUTO and the integration time SET-BY-RSLN, the resolution will be 6.5 digits and the integration time 1.0 PLC.

OFFSETCOMP

Offset compensation is used to compensate for voltage potentials, such as thermal offsets, across the device under test. This feature eliminates errors due to a low level external voltage source configured in series with the unknown resistor. Offsets up to ±0.2V on the 20Ω and 200Ω ranges, and from -0.2V to +2V on the 2kΩ and 20kΩ ranges can be corrected with offset compensation. Offset compensation is available for 2- and 4-wire resistance measurements.

During offset compensated resistance measurements, the Model 2001 performs the following steps for each A/D conversion:

1. Makes a normal resistance measurement of the device. In general, this consists of sourcing a current through the device, and measuring the voltage drop across the device.
2. Turns off the internal current source and again measures the voltage drop across the device. This is the voltage caused by an external device.
3. Calculates and displays the corrected resistance value.

Offset compensation not only corrects for small error voltages in the measurement circuit, but it also compensates for thermal voltages generated within the Model 2001. In normal mode ohms, these thermal EMF offsets are accounted for during calibration.

You can enable/disable offset compensation as follows:

1. From the CONFIGURE OHMS-2W or CONFIGURE OHMS-4W menu, select OFFSETCOMP and press ENTER. The following menu is displayed:

   SET OFFSET COMP
   ON OFF

2. Highlight the desired selection and press ENTER.

Offset compensated readings are indicated by "OCmp" to the right of the reading.

Note that the offset compensation settings of the ohms functions are discrete. Thus, enabling offset compensation in 2-wire ohms has no effect on 4-wire ohms.

MAXAUTORANGE

By setting an upper limit on autoranging, you can prevent changes to ranges that you do not want to use. This speeds up the reading rate while still using auto-ranging. You can program the MAXAUTORANGE as follows:

1. From the CONFIGURE OHMS-2W or CONFIGURE OHMS-4W menu, select MAXAUTORANGE and press ENTER. One of the following menus is displayed:

   SET Ω2 MAX AUTORANGE
   1GΩ 200MΩ 20MΩ 2MΩ 200kΩ 20kΩ

or

SET Ω4 MAX AUTORANGE
200kΩ 20kΩ 2kΩ

2. Highlight the desired maximum range for autoranging and press ENTER.

Multiple displays

There are three multiple displays available just for the resistance functions:

- Source current
- Voltage drop
- Lead resistance (Ω4 only)

Source current: This is the value of the current being sourced for the present resistance range. It is based on the calibration constants and is shown as follows:

Source Current = 0.0000 mA

Voltage drop: This display shows the voltage drop across the resistance under test. It is shown as follows:

Voltage Drop = 0.0000 mV

This voltage drop is determined by multiplying the source current by the resistance and does not include voltage contributions from other current that may be flowing through the resistance.

Lead Resistance: This display, available only for 4-wire ohms, shows the value of the lead resistance that is being nulled by using the Ω4 function. You can use the information to decide if a 4-wire measurement is necessary. The display is as follows:

Lead Resistance = 0.0000 Ω

If the lead resistance exceeds 1kΩ, the display is:

Lead Resistance > 1000Ω

3.4.4 Frequency

The Model 2001 can make frequency measurements from 1Hz to 15MHz through its INPUT HI and INPUT LO terminals, and from 1Hz to 1MHz through its AMPS and INPUT LO terminals. Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure is as follows:

1. Connect the test leads to the INPUT HI and LO terminals of the Model 2001. Either the front or rear inputs can be used; place the INPUTS button in the appropriate position.

NOTE

A bench reset defaults the frequency input terminals to INPUT HI and LO.

2. Select the FREQ function.
3. Connect the test leads to the source as shown in Figure 3-16A.

CAUTION

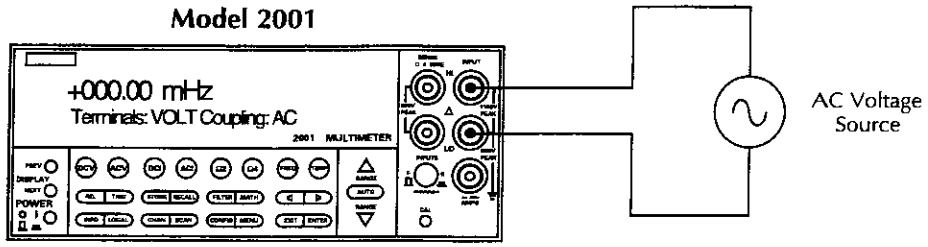
Do not exceed 1100V peak between INPUT HI and INPUT LO, or instrument damage may occur.

4. Take a reading from the display.

The procedure for measuring frequency with the AMPS and INPUT LO terminals is similar. (See Figure 3-16B for a connection diagram.) Be sure the frequency function is configured to use the current terminals.

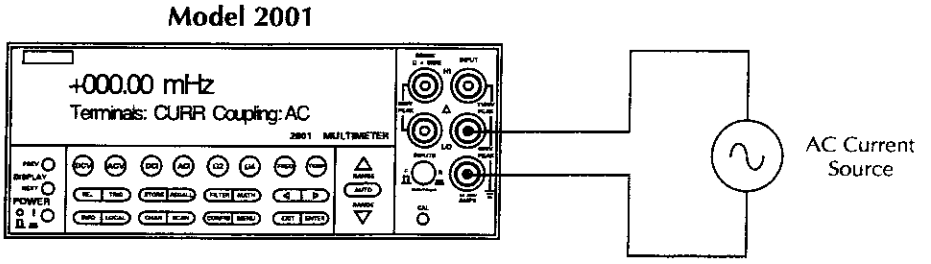
CAUTION

Do not apply more than 2.1A, 250V to the AMPS input, or the amps protection fuse will blow. (Refer to paragraph 3.4.2 for the AMPS fuse replacement procedure.)



Caution : Maximum Input = 1100V peak, 2 x 10^7 V•Hz

A. AC Voltage Input



Caution : Maximum Input = 1A peak

B. AC Current Input

Figure 3-16
Frequency measurements

Trigger level

The frequency function has an adjustable trigger level. An appropriate trigger level is needed for the frequency counter to operate properly. The instrument only counts cycles with peak amplitudes that reach the trigger level. For example, if the trigger level is set for 5V, cycles with peak amplitudes less than 5V are not counted.

If using AC+DC coupling, make sure the trigger level accounts for the DC bias level. For example, if a 1V peak-to-peak input signal is riding on a 5V DC bias level, a trigger level of 5.5V is appropriate.

While the display is showing frequency measurements, the RANGE ▲ and ▼ keys can be used to change the trigger level of the measurement.

Each press of a RANGE ▲ or ▼ key adjusts the trigger level by 0.5% of the presently selected maximum signal level to a maximum of 60% of the range. The AUTO RANGE key returns the trigger level to 0V or 0mA. After pressing one of the range keys, the present trigger level is momentarily displayed. The trigger level is also available as a multiple display.

See Table 3-21 for the trigger level ranges and increments.

Table 3-21
Trigger level range and increments

Maximum signal level	Trigger level	
	Range	Increment
1V	-0.600 to +0.600V	0.005V
10V	-6.00 to +6.00V	0.05V
100V	-60.0 to +60.0V	0.5V
1000V	-600 to +600V	5V
1mA	-0.600mA to +0.600mA	0.005mA
10mA	-6.00mA to +6.00mA	0.05mA
100mA	-60.0mA to +60.0mA	0.5mA
1A	-600mA to +600mA	5mA

Note: The trigger level for TTL triggering defaults to +0.80V.

Frequency configuration

The following paragraphs detail how to change the Model 2001 from its bench reset conditions for frequency measurements. The configuration menu is summarized in Table 3-22. Note that a function does not have to be selected in order to be configured. When the function is selected, it will assume the programmed status.

Table 3-22
CONFIGURE FREQUENCY menu structure

Menu item	Description
MAX-SIGNAL-LEVEL 1V, 10V, 100V, 1000V, TTL 1mA, 10mA, 100mA, 1A	Display maximum signal level menu: Select maximum voltage level for voltage inputs. Select maximum current level for current inputs.
RESOLUTION 4-DIGITS, 5-DIGITS	Display resolution menu: Select a specific resolution.
INPUT-TERMINALS VOLTAGE CURRENT	Input terminals for frequency measurements menu: Select INPUT HI and INPUT LO terminals. Select AMPS and INPUT LO terminals.
COUPLING AC AC+DC	Coupling menu: Select AC coupled measurements. Select DC coupled measurements.

Note: The maximum signal level menu is coupled to the input terminals menu, i.e., voltage levels are shown if voltage is the selected input.

MAX-SIGNAL-LEVEL

The maximum signal level is used to specify the maximum expected input voltage or current level for frequency measurements. The maximum signal level is set as follows:

1. From the CONFIGURE FREQUENCY menu, select MAX-SIGNAL-LEVEL and press ENTER. Depending on the presently selected input terminals (VOLTAGE or CURRENT), one of the following menus is displayed:

   MAXIMUM SIGNAL LEVEL
   1V 10V 100V 1000V TTL

   or

   MAXIMUM SIGNAL LEVEL
   1mA 10mA 100mA 1A

2. Highlight the desired maximum signal level and press ENTER. Selecting the TTL parameter configures the maximum signal level to 10V and the trigger level to +0.80V.

RESOLUTION

The available display resolutions are 4 digits and 5 digits. There is no auto resolution parameter on the frequency function.

You can set the resolution as follows:

1. From the CONFIGURE FREQUENCY menu, select RESOLUTION and press ENTER. The following menu is displayed:

   SET FREQ RESOLUTION
   4-DIGITS 5-DIGITS

2. Highlight the desired resolution and press ENTER.

INPUT-TERMINALS

Both the volts and amps input terminals can be used to measure frequency. The upper limit on the voltage terminals is 15MHz; on the amps terminals it is 1MHz. The voltage limit is subject to the 2×10^7V•Hz product.

The input terminals for frequency measuring are set as follows:

1. From the CONFIGURE FREQUENCY menu, select INPUT-TERMINALS and press ENTER. The following menu is shown:

   FREQ INPUT SOURCE
   VOLTAGE CURRENT

2. Highlight the desired input source and press ENTER.

COUPLING

This parameter selects the input coupling for the frequency function. When AC coupling is selected, a DC blocking capacitor is placed in series with the input. This removes the DC component of the input signal.

When AC+DC coupling is selected, the blocking capacitor is removed. Subsequent frequency measurements will reflect both the AC and DC components of the signal.

You can set the frequency coupling as follows:

1. From the CONFIGURE FREQUENCY menu, select COUPLING and press ENTER. The following menu is displayed:

   SET FREQ COUPLING
   AC AC+DC

2. Highlight the desired coupling and press ENTER.

Multiple displays

There are two multiple displays just for the frequency function:

- Period calculation
- Trigger level

The multiple display showing the period of the waveform is calculated from the frequency measurement and, as such, is only available when the frequency does not equal 0Hz. It is also unavailable when math is enabled.

The trigger level multiple display is the same message that is displayed when the trigger level is changed, but it is a permanent display.

3.4.5 Temperature

The Model 2001 measures temperature with two different sensor types: RTDs and thermocouples. With RTDs, the Model 2001 can measure temperature between -200°C and +630°C. RTDs can be connected to the input terminals or the optional Model 2001-SCAN scanner card.

With thermocouples connected to an external thermocouple card, such as a Model 7057A or 7402 in a Model 7001 Switch System, the instrument measures temperature over a range that is dependent on the thermocouple type. (Refer to the specifications in Appendix A.)

Temperature measurements

Assuming "bench reset" conditions (see paragraph 3.12.1), the basic procedure to measure temperature with a type PT385 4-wire RTD (the default sensor) is as follows:

1. Connect the RTD sensor to the Model 2001 as shown in Figure 3-17. You can use banana plugs (with the front or rear inputs), or the optional Model 8680 RTD Probe Adapter (with the front inputs). Place the INPUTS button in the appropriate position. RTDs can also be connected to the optional Model 2001-SCAN scanner card. (See the Model 2001-SCAN manual.)
2. Select the TEMP function.

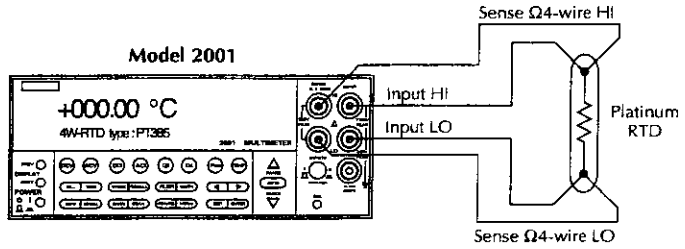
   CAUTION

   Do not exceed 1100V peak between INPUT HI and LO, or 350V peak between SENSE Ω4 WIRE HI and LO, or instrument damage may occur.

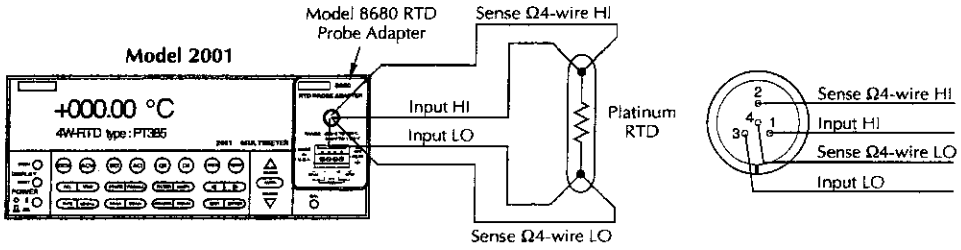
3. Observe the display. If the "Overflow" message is shown, the RTD might not be connected properly.
4. Take a reading from the display.

The procedure for measuring temperature with 3-wire and 2-wire RTDs is similar. (See Figures 3-18 and 3-19 for connection diagrams.) Be sure that the temperature function is configured for the correct sensor type. (Use the 4-WIRE-RTD selection for a 3-wire RTD sensor.)

To measure temperature with thermocouples, you need to connect the thermocouples to a suitable external scanner card, such as the Keithley Model 7057A or 7402. These cards must be inserted into a Model 705 or 706 Scanner or the Model 7001 Switch System, as shown in Figure 3-20. The thermocouple cards use Channel 1 as the reference junction, and must be configured on the Model 2001 for voltage reference and offset.

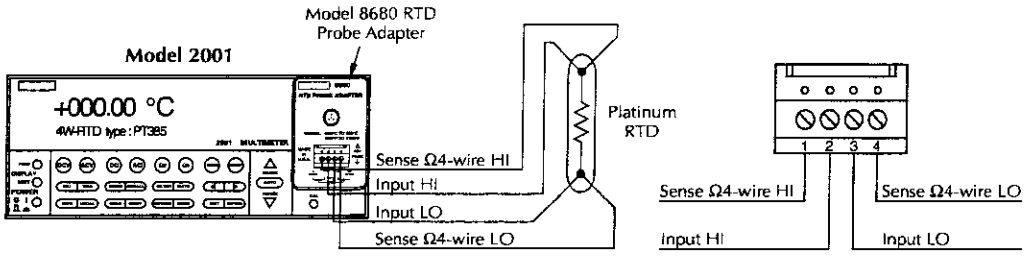


A. Connections to Banana Jacks



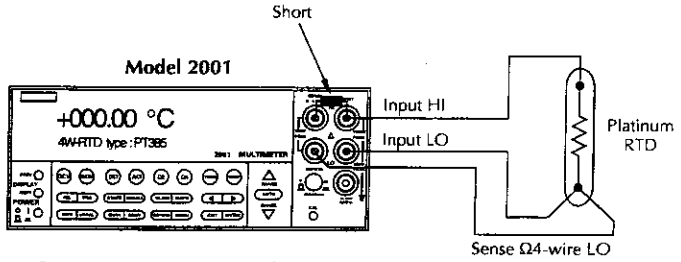
WARNING : To avoid a shock hazard and possible instrument damage, do not use the Model 8680 RTD Probe Adapter to measure voltages exceeding 30V RMS, 42.4V peak.

B. Connections to Circular Jack

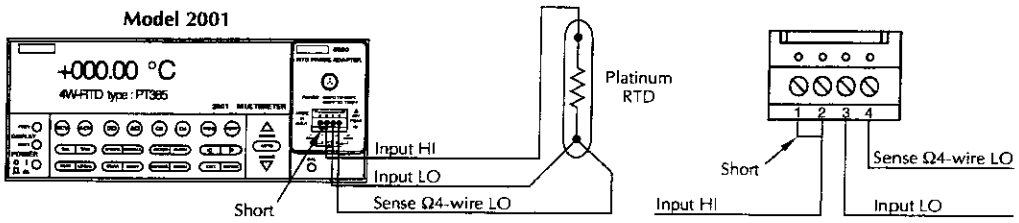


C. Connections to Terminal Block

Figure 3-17
4-wire RTD temperature measurements



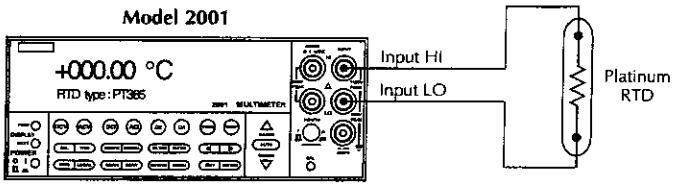
A. Connections to Banana Jacks



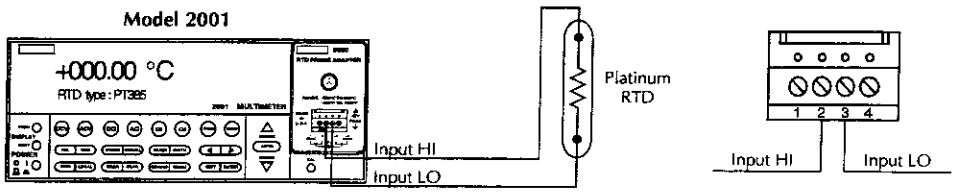
B. Connections to Terminal Block

WARNING : To avoid a shock hazard and possible instrument damage, do not use the Model 8680 RTD Probe Adapter to measure voltages exceeding 30V RMS, 42.4V peak.

Figure 3-18
3-wire RTD temperature measurements



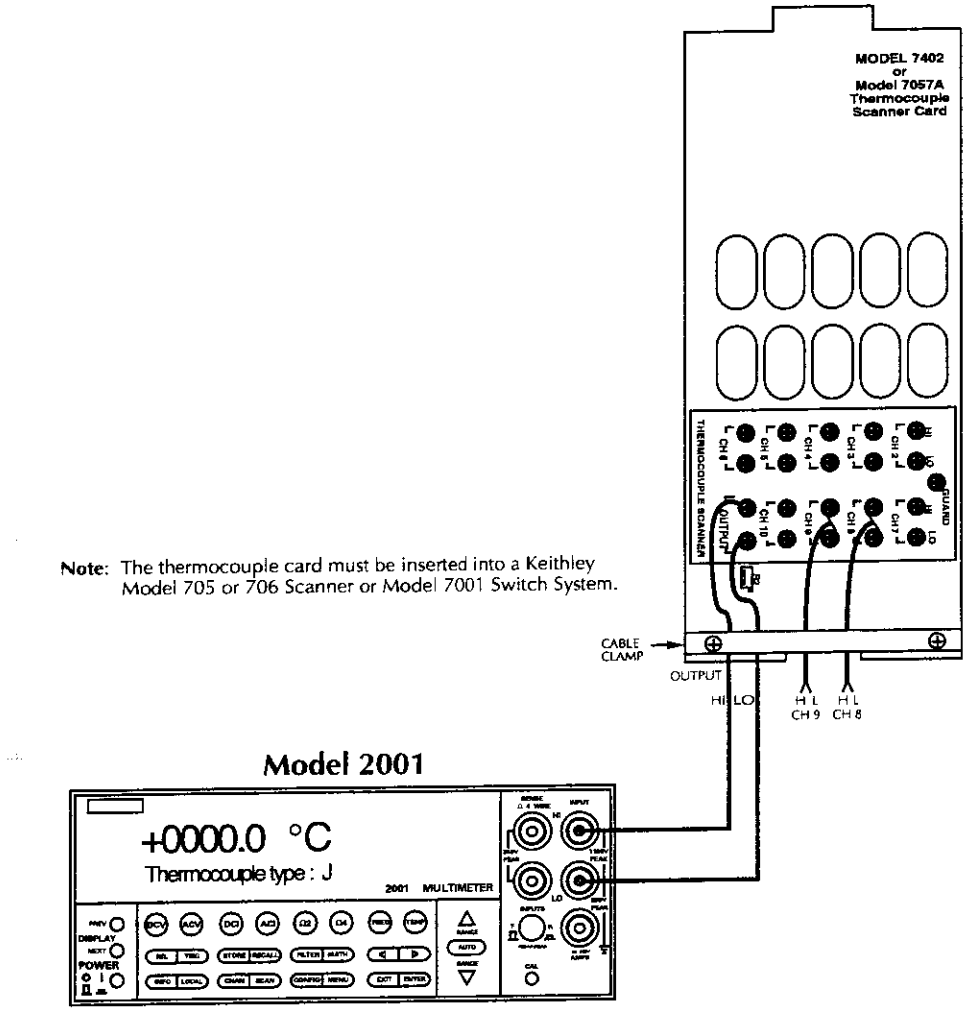
A. Connections to Banana Jacks



B. Connections to Terminal Block

WARNING : To avoid a shock hazard and possible instrument damage, do not use the Model 8680 RTD Probe Adapter to measure voltages exceeding 30V RMS, 42.4V peak.

Figure 3-19
2-wire RTD temperature measurements



Note: The thermocouple card must be inserted into a Keithley Model 705 or 706 Scanner or Model 7001 Switch System.

Figure 3-20
Thermocouple configuration

Temperature configuration

The following paragraphs detail how to change the Model 2001 from its bench reset conditions for temperature measurements. The configuration menu is summarized in Table 3-23. Note that a function does not have to be selected in order to be configured. When the function is selected, it will assume the programmed status.

Table 3-23
CONFIG TEMPERATURE menu structure

Menu item	Description
SENSOR	Sensor type menu:
4-WIRE-RTD	4-wire RTD type menu:
PT385	Select a PT385 type.
PT3916	Select a PT3916 type.
USER-RTD	Select desired R-zero, alpha, beta, and delta.
SPRTD	Select SPRTD type.
RTD	2-wire RTD type menu:
PT385	Select a PT385 type.
PT3916	Select a PT3916 type.
USER-RTD	Select desired R-zero, alpha, beta, and delta.
SPRTD	Select SPRTD type.
THERMOCOUPLE	Thermocouple setup menu:
THERMOCOUPLE-TYPE	Select desired thermocouple type (J, K, T, E, R, S, B, N).
REF-JUNCTIONS	Configure reference junction menu (JN1 thru JN5):
CONFIGURE	Configure simulated or real junction.
ACQUIRE-REF-TEMP	Acquire reference temperature.
UNITS	Temperature units menu:
DEG-C, DEG-F, K	Select desired temperature units.
SPEED	Measurement speed (integration time) menu:
NORMAL	Select 1 PLC (power line cycle, 16.67msec for 60Hz, 20msec for 50Hz and 400Hz).
FAST	Select 0.01 PLC.
MEDIUM	Select 0.1 PLC.
HIACCURACY	Select 10 PLC.
SET-SPEED-EXACTLY	Set integration time in PLC (0.01-10).
SET-BY-RSLN	Default to setting appropriate for resolution.
FILTER	Digital filter menu:
AUTO	Default to filter appropriate for integration time.
AVERAGING	Select simple average filter (1-100 readings).
AVERAGING-MODE	Select moving average or repeating average mode.
RESLN	Display resolution menu:
AUTO	Default to resolution appropriate for sensor.
1°, 0.1°, 0.01°, 0.001°	Select a specific resolution.

SENSOR

This parameter is used to select the temperature sensor. If using a 4- or 3-wire RTD sensor, choose 4-WIRE-RTD. If using a 2-wire RTD, choose RTD. Select THERMOCOUPLE when using an external thermocouple scanner card (Model 7057A or Model 7402).

You can select the temperature sensor as follows:

1. From the CONFIG TEMPERATURE menu, highlight SENSOR and press ENTER. The following menu is displayed:

   TEMP SENSOR TYPE
   4-WIRE-RTD RTD THERMOCOUPLE

2. Use the cursor keys to highlight the desired sensor and press ENTER. For the 4-WIRE-RTD and RTD parameters, the following menu is displayed:

   SET RTD TYPE
   PT385 PT3916 USER-RTD SPRTD

Choosing THERMOCOUPLE displays the following menu:

THERMOCOUPLE SETUP
THERMOCOUPLE-TYPE REF-JUNCTIONS

RTD type: This menu has three options for RTD standards. Two are configured for common RTDs, the third allows you to enter your own RTD factors:

- PT385–Selects default parameters for 0.00385 standard.
- PT3916–Selects default parameters for 0.003916 standard.
- USER-RTD–Selects user-defined parameters.

When a PT385 or PT3916 is selected, the instrument uses the following defaults:

Type	Alpha	Beta	Delta	Ω at 0°C
PT385	0.003850	0.111	1.50700	100Ω
PT3916	0.003916	0.116	1.50594	100Ω

If you want to change one or more of these factors, select USER-RTD, and enter the desired values. The equations using the factors are shown in Figure 3-21.

For T < 0°C:

$$R_T = R_0[1 + AT + BT^2 + CT^3(T\text{-}100)]$$

For 0°C < T < 630°C:

$$R_T = R_0(1 + AT + BT^2)$$

Where:

$$A = \alpha\left(1 + \frac{\delta}{100}\right)$$

$$B = -\alpha\delta \bullet 10^{-4}$$

$$C = -\alpha\beta \bullet 10^{-8}$$

Above 0°C, the equation solves faster by applying:

$$T = \frac{-A + \sqrt{A^2 - 4B\left(1 - \frac{R_T}{R_0}\right)}}{2B}$$

Below 0°C, it is an iterative solution and it runs slower.

Figure 3-21
Temperature equations

SPRTD: Choosing type SPRTD takes you to the SPRTD COEFFICIENTS menu, which allows you to program the following parameters:

R-ZERO: RTD 0°C resistance value
A4: set A4 coefficient
B4: set B4 coefficient
A7: set A7 coefficient
B7: set B7 coefficient
C7: set C7 coefficient

The ITS-90 standard provides two reference equations for Standard Platinum Resistance Thermometers covering the temperature range 18.8033K to 1234.93K. A single SPRTD, however, usually cannot be used to cover the entire range.The temperature range is therefore broken up into several subranges. These subranges depend on the calibration points of the temperature scale and are based on the melting or triple points of various pure substances. For an exact list

Table 3-24
Translating SPRTD coefficients

Coefficients	RTD coefficients to Model 2001 coefficients
Subrange #1: 13.8033K - 273.16K	Not applicable
Subrange #2: 24.5561K - 273.16K	A2 to A4, B2 to B4
Subrange #3: 54.3584K - 273.16K	A3 to A4, B3 to B4
Subrange #4: 83.8058K - 273.16K	No substitution needed
Subrange #5: 234.3156K - 302.9146K	A5 to A4, A5 to A7, B5 to B4 B5 to B7, Set C7 = 0. A5 value entered for both A4 and A7; B5 value entered for both B4 and B7
Subrange #6: 273.15K - 1234.93K	Not applicable
Subrange #7: 273.15K - 933.473K	No substitution needed
Subrange #8: 273.15K - 692.677K	A8 to A7, B8 to B7, Set C7 = 0
Subrange #9: 273.15K - 505.078K	A9 to A7, B9 to B7, Set C7 = 0
Subrange #10: 273.15K - 429.7485K	A10 to A7, B10 to B7, Set C7 = 0
Subrange #11: 273.15K - 302.9146K	A11 to A7, Set B7 = 0, C7 = 0

of the elements needed and details on RTD calibration, refer to NIST Technical Note 1265 "Guidelines For Realizing the International Temperature Scale of 1990". In each subrange, the calibration constants required for that range are listed.

An SPRTD as supplied from the manufacturer will come with a certificate of calibration that lists the calibration constants and the temperature range supported. In all cases except subranges #4 and #7, translation of the supplied coefficients to Model 2001 values will be required. In most cases, this translation is done simply entering the A value (for example) supplied with the SPRTD into the A4 position (temperatures less than 0°C) or A7 value (temperatures above 0°C) required by the Model 2001. The same procedure is used for translating the B and, where applicable, C constants.

Table 3-24 should be helpful in translating SPRTD coefficients to Model 2001 SPRTD coefficients. The Model 2001 supports SPRTD temperatures between 83.805K and 933.473K. For any of the subranges below, only temperatures within the range from 83.805K to 933.47K will be measured.

Measurement Example: Suppose you are using an SPRTD that has been calibrated for subrange #2 above, in which case the RTD is calibrated for measurements between 24.5561 and 273.16K. The Model 2001, however, supports only SPRTD temperatures down to 83.805K, so temperatures below this value will be reported as an overflow even though the SPRTD is capable of measuring lower. The calibration certificate lists A2, B2, C1, C2, and C3 as the calibration coefficients. You can set up the Model 2001 for this measurement as follows:

1. Set the temperature sensor type to be FRTD (4-wire measurement) from the CONFIG/TEMP/SENSOR/TYPE menu.
2. Choose the SPRTD RTD type using the CONFIG/TEMP/SENSOR/TYPE/FRTD/SPRTD menu.
3. From the SPRTD COEFFICIENTS menu, set the RTD 0°C resistance value and the following coefficients:
   - Set the Model 2001 A4 coefficient to the RTD certificate A2 value.
   - Set the Model 2001 B4 coefficient to the RTD certificate B2 value.

Note that the A7, B7, and C7 values will not be used for this sensor.

4. Switch to the temperature function, and begin taking readings.

THERMOCOUPLE TYPE: This option of the THERMOCOUPLE SETUP menu brings up a menu of thermocouple types:

```
THERMOCOUPLE TYPE
J  K  T  E  R  S  B  N
```

To select a type, highlight it and press ENTER.

REF-JUNCTIONS: This item of the THERMOCOUPLE SETUP menu allows you to select one of five reference junctions for further configuration. Typically, each thermocouple card uses a single reference junction. The menu is displayed as follows:

```
CONFIGURE REFJCNS
JCN1  JCN2  JCN3  JCN4  JCN5
```

After choosing one of the reference junctions, you can configure it further or acquire a reference temperature (to update the stored reference temperature), as shown in the typical following menu:

```
REFERENCE JUNCTION#1
CONFIGURE  ACQUIRE-REF-TEMP
```

Choosing the ACQUIRE-REF-TEMP option updates the stored reference temperature used for generating a temperature measurement. If the junction type (JCN) is simulated, the defined simulated junction temperature is used. If the junction type is real, you must manually close that channel from the scanner before acquiring the temperature.

Selecting the CONFIGURE option displays a configuration menu for a particular reference junction (#1 through #5):

```
CONFIGURE REFJCN#1
SIMULATED-TEMP  REAL-JUNCTION
```

The SIMULATED-TEMP option allows you to enter a default temperature. Typical reference junction temperatures are 0°C and 23°C. (Note the reference junction temperature is shown in the units selected by the SET TEMP UNITS menu.) The REAL-JUNCTION option lets you enter values for a temperature coefficient for the selected reference junction (in mV/°C) and an offset voltage (in mV at 0°C). Consult the Model 7057A or 7402 manual for correct configuration.

UNITS

This parameter selects the displayed units for temperature measurements. You can program the temperature units parameter as follows:

1. From the CONFIG TEMPERATURE menu, select UNITS and press ENTER. The following menu is displayed:

```
SET TEMP UNITS
DEG-C  DEG-F  K
```

2. Highlight the desired units and press ENTER.

There is a multiple display for the temperature function that shows the reading expressed in all three temperature units.

SPEED

The SPEED parameter sets the integration time of the A/D converter, the period of time the input signal is measured (also known as aperture). It is discussed in paragraph 3.4.1, DC and AC voltage. Only the differences for temperature are noted here.

The SET-BY-RSLN parameter optimizes the integration time for the present resolution setting. The defaults for set-by-resolution integration times of temperature are listed in Table 3-25.

Table 3-25
Temperature integration time set-by-resolution

Resolution degrees	Resolution digits	Integration time
1 degree	3.5d	1.0 PLC
0.1 degree	4.5d	1.0 PLC
0.01 degree	5.5d	1.0 PLC
0.001 degree	6.5d	1.0 PLC

Note: If the integration time is SET-BY-RSLN and the resolution AUTO, the integration time will be 1.0 PLC and the resolution set by sensor.

FILTER

The FILTER parameter lets you set the digital filter response and control its on/off operation. It is described in paragraph 3.9. Only the specifics for temperature are covered here.

The advanced filter is not available for the temperature function.

The AUTO parameter for a digital filter optimizes its use for the present measurement function. The defaults for automatic filtering of temperature are as follows:

State	Type	Readings	Averaging Mode
On	Averaging	10	Moving

RESLN

The RESLN parameter sets the display resolution. It is discussed in paragraph 3.4.1, DC and AC voltage. Only the differences for temperature are noted here.

Resolution for temperature is not expressed in number of digits, but in fractions of a degree, ranging from 1° to 0.001°. The accuracy of RTD and thermocouple measurements are rated at different resolutions; refer to the specifications in Appendix A for details.

If the temperature resolution is AUTO, the resolution is forced to match the sensor type. Refer to Table 3-26 for the resolution associated with the various sensors.

Table 3-26
Temperature auto resolution

Sensor	Resolution	
	Degree	Digits
RTDs 2-, 3-, or 4-wire	0.01	5.5d
Thermocouples J, K, T, E	0.1	4.5d
Thermocouples R, S, B, N	1	3.5d

Note: If the resolution is AUTO and the integration time SET-BY-RSLN, the integration time will be 1.0 PLC.

Multiple displays

The available multiple displays for temperature depend on the presently selected sensor type, except for the multiple display that shows temperature in three different units:

+0000.0 °C
+0000.0 °F +0000.0 K

RTD measurements have a multiple display for the resistance of the RTD, such as:

RTD Resistance = +0.0000 Ω

Thermocouple measurements have multiple displays for the thermocouple voltage and reference junction temperature. Sample displays are:

Thermocouple Voltage = 0.0000mV

Reference junction = 00.0 °C

Note that the reference junction temperature is shown in the units selected by the SET TEMP UNITS menu. The display of two blinking question marks at the right of the reference junction temperature indicates an overflow of the reference junction measurement. Thermocouple measurements will be made normally using the existing reference temperature value.

3.5 Range

The selected measurement range affects both the ultimate resolution and accuracy of the measurements as well as the maximum signal that can be measured. The range setting (fixed or auto) for each measurement function is saved when changing functions.

The following paragraphs discuss range resolution and manual and auto-range operation.

3.5.1 Display resolution

The display resolution of a Model 2001 reading depends on the selected range and the resolution setting. The default and maximum display resolutions for every range on each function are included in the specifications of Appendix A.

You can set the display resolution, as described in paragraph 3.4.

3.5.2 Maximum readings

The full scale readings for every range on each function are included in the specifications of Appendix A. Input values more than the maximum reading listed cause the "Overflow" message to be displayed.

3.5.3 Manual ranging

To select a manual range, simply press the RANGE ▲ or RANGE ▼ key. The instrument changes one range per key press. The selected range is displayed on the bottom line of the display, such as:

```
+000.0094 mVDC
Range: 200 mVDC
```

Once the highest or lowest range has been selected, pressing the corresponding key has no further effect, except for the display of a momentary informational message, for example:

```
Range at maximum: 1000 VDC
```

If the instrument displays the "Overflow" message on a particular range, select a higher range until an on-range reading is displayed. Use the lowest range possible without causing an overflow to ensure best accuracy and resolution.

Note that the frequency and temperature functions have just one range. For the frequency functions, the RANGE ▲ and ▼ keys increase and decrease the trigger level by 0.5%. On temperature the keys have no effect.

3.5.4 Autoranging

To enable autoranging, press the AUTO key. The AUTO annunciator turns on when autoranging is selected. While autoranging is selected, the instrument automatically chooses the best range to measure the applied signal.

NOTE

Autoranging should not be used when optimum speed is required. Autoranging speeds are covered in the specifications of Appendix A.

Note that up-ranging occurs at 105% of range, while down-ranging occurs at 10% of range.

To cancel autoranging, press AUTO or the RANGE ▲ or ▼ key. Pressing AUTO to cancel autoranging leaves the instrument on the present range.

Pressing the RANGE ▼ key when the instrument has autoranged to the lowest range displays the following momentary typical message and leaves the instrument in autorange:

Range at minimum: 200 mVDC

The instrument operates similarly if the RANGE ▲ key is pressed when the instrument has autoranged to the highest range.

For the frequency function, pressing the AUTO key returns the trigger level to 0.0V. The AUTO key has no effect for the temperature function.

3.6 Relative

The rel (relative) operation subtracts a reference value from actual readings. When rel is enabled by the REL key, the instrument uses the present reading as a relative value. Subsequent readings will be the difference between the actual input value and the rel value. You can also enter and enable a relative value from the CONFIG-REL display.

A rel value can be established for each measurement function. For example, a 10μA reference can be set for DC current measurements, and a 100Ω reference for 2-wire resistance. The state and value of rel for each measurement function are saved when changing functions.

Once a rel value is established for a measurement function, the value is the same for all ranges. For example, if 100μA is set as a rel value on the 200μA range, then the rel is also 100μA on the 2mA, 20mA, 200mA, and 2A ranges. Similarly, if 150V is set as a rel value on the 200V range, the rel is also 150V on the 1000V, 20V, 2V, and 200mV ranges.

A relative value can be as large as the highest range for the particular function. Table 3-27 lists the allowable range of rel values for each function.

Selecting a range that cannot accommodate the rel value does not cause an overflow condition, but it also does not increase the maximum allowable input for that range. For example, on the 2mA range, the Model 2001 still overflows for a 2.1mA input.

Table 3-27
Allowable rel values

Function	Rel range	
DC voltage	-1.1e3 to +1.1e3	(±1100V)
AC voltage	-7.75e2 to +7.75e2	(±775V)
DC current	-1.2e1 to +1.2e1	(±12A)
AC current	-2.1e0 to +2.1e0	(±2.1A)
2-wire resistance	0 to +1.05e9	(0 to 1.05GΩ)
4-wire resistance	0 to +2.1e5	(0 to 210kΩ)
Frequency	0 to +1.5e7	(0 to 15MHz)
Temperature	-3.28e2 to +3.31e3	(-328 to +3310°)

3.6.1 Configuring rel

From the CONFIG-REL display, you can view or change the rel value for the present measurement function. To view or change the rel value of a different function, you must first select it by pressing the appropriate function key.

Press the CONFIG key, and then the REL key to access the following display:

RELVAL=+0.000000e+00

Use the cursor (◄ and ►) and RANGE keys to move among the digits and set their desired values. If the value is too large for the present measurement function, the following typical message is displayed when you press ENTER:

MAXIMUM ALLOWED VAL:
1.100000e+03

and rel is not enabled. If the value is within the limits shown in Table 3-27, you are returned to the normal reading display with that value of rel already enabled.

Previously stored rel values are converted if temperature or AC voltage units are changed. For example, a rel value of 100 that was stored with units of DEG-C is converted to 212 if temperature units are changed to DEG-F.

Note that a bench or GPIB reset clears any stored rel values and disables rel for all functions.

3.6.2 Enabling rel

From the normal reading display, the REL key toggles the rel operation on and off. The present state is indicated by the REL annunciator. Each time rel is enabled by the REL key, the present reading becomes the new rel value for that function. You cannot rel an overflow reading.

To make a new reading the rel value, rel must first be disabled and then enabled again. Disabling rel does not clear any stored rel value.

The present rel value for each measurement function can be viewed from the CONFIG-REL display, as described in paragraph 3.6.1.

When rel is enabled, the resulting reading is the algebraic difference between the actual input value and the rel value:

rel'd reading = actual value - relative value

With percent or mX+b math enabled, the rel'd reading is acted on by the math operation:

displayed reading = math operation (rel'd reading)

A rel value expressed in dB or dBm is applied after the reading is referenced to the selected level.

3.6.3 Multiple display of rel

One of the "multiple displays" allows you to view the reading without rel applied on the bottom line of the display and the rel'd reading on the top line. The display is available by repeatedly pressing either the NEXT or PREVious DISPLAY key to scroll through the multiple displays of the particular function. The following is a typical message for a rel multiple display:

+000.012 mVAC RMS
Actual=+001.012 (without REL)

3.7 Triggers

The following paragraphs discuss front panel triggering, trigger configuration, and external triggering, including example setups.

Model 2001 triggers are set up in the CONFIGURE TRIGGER menu. The menu structure is shown and summarized in Table 3-28. Some general rules to navigate menus are given in paragraph 3.3.

3.7.1 Trigger model

The following information describes triggering of the Model 2001 from the front panel. The flowchart of Figure 3-22 summarizes front panel triggering. It is called the Trigger Model because it is patterned after the SCPI commands sent over the IEEE-488 bus to control triggering.

Table 3-28
CONFIGURE TRIGGER menu structure

Menu item	Description
MEASURE	Measure layer menu:
SOURCE	Select measure source:
IMMEDIATE	Use to make measurements immediately.
EXTERNAL	Use external triggers to control measuring.
MANUAL	Use TRIG key to control measuring.
GPIB	Use bus triggers to control measuring.
TRIGLINK	Use Trigger Link triggers to control measuring. Enter Trigger Link mode and lines.
TIMER	Use a timer to control measuring and enter interva between triggers (0.001-999999.999sec.).
HOLD	Use to hold up the measurement in the measure layer.
DELAY	Use to delay measurement in the measure layer (0.001-999999.999sec.).
COUNT	Define number of measurements to make:
INFINITE	Repeat measuring indefinitely.
ENTER-CHAN-COUNT	Count = use defined value (1-99999).
CONTROL	Select trigger control mode:
SOURCE	Enable Source Bypass.
ACCEPTOR	Disable Source Bypass.
SCAN	Scan layer menu:
SOURCE	Select scan source:
IMMEDIATE	Use to pass operation immediately into the measure layer.
EXTERNAL	Use external triggers to control scanning.
MANUAL	Use TRIG key to control scanning.
GPIB	Use bus triggers to control scanning.
TRIGLINK	Use Trigger Link triggers to control scanning. Enter Trigger Link lines.
TIMER	Use a timer to control scanning and enter interval between scans (0.001-999999.999sec.).
HOLD	Use to hold up the measurement in the scan layer.
DELAY	Use to delay scan in the scan layer (0.001-999999.999sec.).
COUNT	Define number of scans to be performed:
INFINITE	Repeat scanning indefinitely.
ENTER-SCAN-COUNT	Count = user defined value (1-99999).
CONTROL	Select trigger control mode:
SOURCE	Enable Source Bypass.
ACCEPTOR	Disable Source Bypass.
ARM	Arm layer menu:
SOURCE	Select arm source:
IMMEDIATE	Use to arm meter immediately and pass operation into the scan layer.
EXTERNAL	Use external triggers to arm meter.
MANUAL	Use TRIG key to arm meter.
GPIB	Use bus triggers to arm meter.
TRIGLINK	Use Trigger Link triggers to arm meter. Enter Trigger Lin lines.
HOLD	Use to hold up the measurement in the arm layer.
COUNT	Define number of times to arm meter:
INFINITE	Continuously re-arm meter.
ENTER-ARM-COUNT	User defined count value (1-99999).
CONTROL	Select trigger control mode:
SOURCE	Enable Source Bypass.
ACCEPTOR	Disable Source Bypass.
HALT	Use to halt triggers. Press TRIG key to resume triggering.

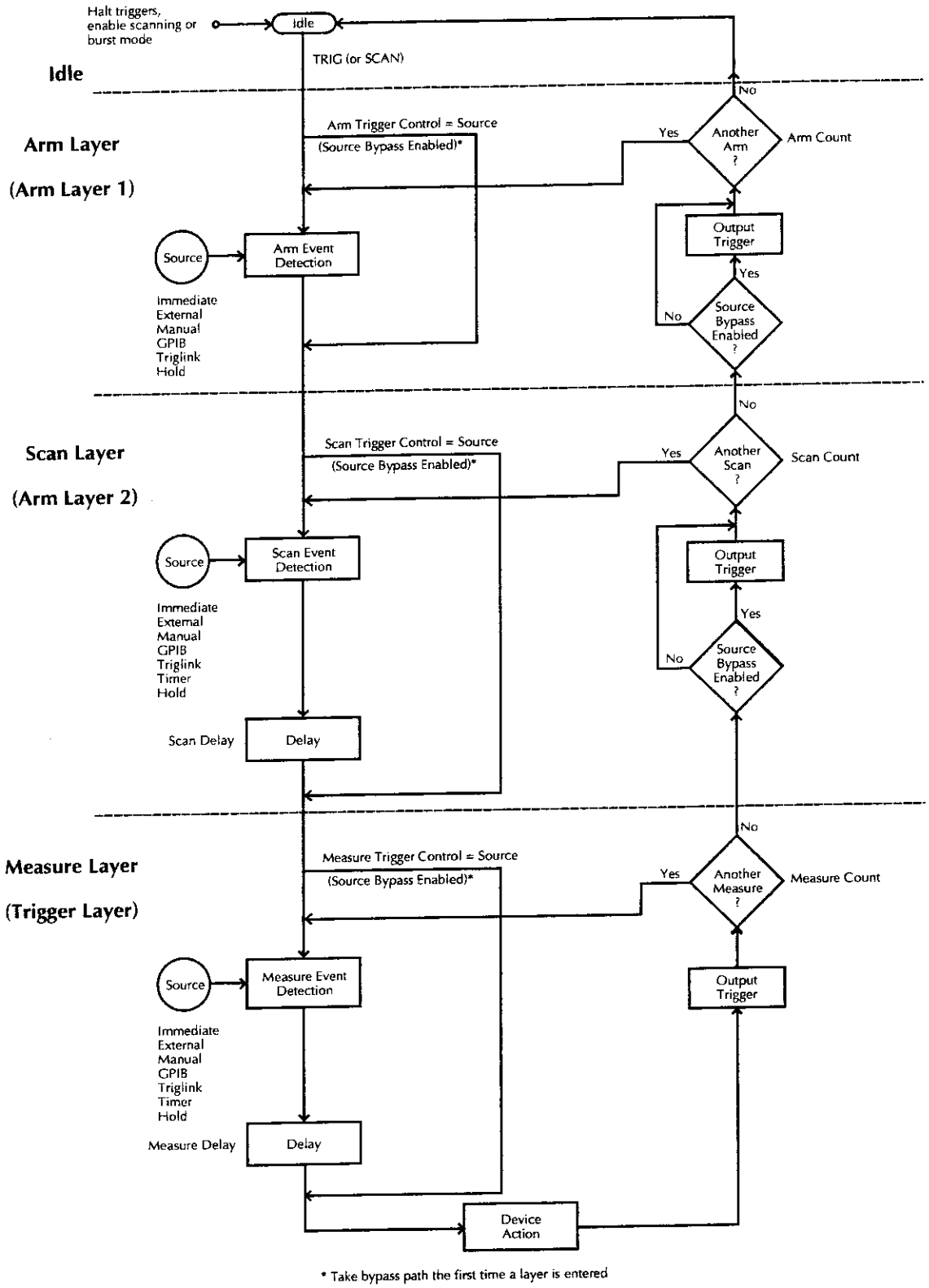


Figure 3-22
Trigger model (front panel operation)

Idle

The instrument is considered to be in the idle state whenever it is not operating within one of the three layers of the Trigger Model. The front panel ARM indicator is off when the instrument is in the idle state. While in the idle state, the instrument cannot perform any measurement or scanning functions.

From the front panel there are four ways to put the instrument into idle:

- Select RESET GPIB from the SAVESETUP option of the main menu. Press the TRIG key to take a reading. After each reading, the instrument returns to the idle state.
- Select HALT from the CONFIGURE TRIGGER menu. Press the TRIG key to resume triggering.
- Enable BURST-MODE from the CONFIGURE DATA STORE menu. This places the instrument in idle until the TRIG key is pressed. After each burst acquisition the instrument returns to idle.
- Configure an internal or external scan with the SCAN key. Disabling the scan resumes triggering.

Once the instrument is taken out of the idle state, operation proceeds into the arm layer (arm layer 1) of the Trigger Model.

Arm layer

NOTE

For bus operation, this layer is called arm layer 1.

In general, the instrument requires an arm event to allow operation to proceed to the next layer (scan layer). With an arm source of Immediate, operation proceeds to the next layer when the instrument is taken out of the idle state. Selecting BENCH or GPIB RESET from the SAVESETUP option of the main menu also sets the arm source to Immediate. With one of the other sources selected, the instrument waits until the appropriate event occurs:

- With the External source selected, the instrument waits for an input trigger via EXTERNAL TRIGGER on the rear panel.
- With the Manual source selected, the instrument waits until the front panel TRIG key is pressed.
- With the GPIB source selected, the instrument waits for a bus trigger (GET or *TRG).
- With the Trigger Link source selected, the instrument waits for an input trigger via TRIGGER LINK on the rear panel.
- With the HOLD source selected, the instrument does not respond to any of the event sources.

As can be seen in the flowchart, there is a path that allows operation to loop around the source. When Source Bypass is enabled (Arm Trigger Control set to Source) and the event source is External or Trigger Link, operation loops around the source on the initial pass through the arm layer. If programmed for another arm (arm count > 1), the bypass loop is not in effect even though it is still enabled. The Source Bypass loop resets (is in effect) if operation goes into Idle.

Enabling Source Bypass also enables the Output Trigger. When operation returns to the arm layer from the scan layer, an output trigger pulse occurs. If the event source is Trigger Link, an output trigger pulse is available on the programmed TRIGGER LINK output line. For all other event sources, the output trigger pulse is available at the METER COMPLETE connector. The Output Trigger in this layer is disabled when Source Bypass is disabled (Arm Trigger Control set to Acceptor).

After all other instrument operations are complete, the instrument can be returned to the arm layer by programming the instrument for additional arms. The Arm Count option is used to set the arm count to a finite value (where n = 1 to 99999) or for an infinite number of arms. Selecting BENCH or GPIB RESET from the SAVESETUP option of the main menu sets the arm count to one.

After the instrument leaves the arm layer, operation proceeds into the scan layer (arm layer 2).

Scan layer

NOTE

For bus operation, this layer is called arm layer 2.

In general, the instrument requires a scan event to allow operation to proceed to the next layer (measure layer). With a scan source of Immediate, operation immediately proceeds to the next layer. Selecting BENCH or GPIB RESET from the SAVESETUP option of the main menu also sets the scan source to Immediate. With one of the other sources selected, the instrument waits until the appropriate event occurs:

- With the External source selected, the instrument waits for an input trigger via EXTERNAL TRIGGER on the rear panel.

- With the Manual source selected, the instrument waits until the front panel TRIG key is pressed.
- With the GPIB source selected, the instrument waits for a bus trigger (GET or *TRG).
- With the Trigger Link source selected, the instrument waits for an input trigger via TRIGGER LINK on the rear panel.
- With the Timer source selected, operation immediately proceeds into the measure layer on the initial pass through the scan layer. Each additional scan does not occur until the programmed timer interval elapses. The timer can be set from 1msec to 999999.999sec.
- With the HOLD source selected, the instrument does not respond to any of the event sources.

After the programmed scan event is detected, the instrument waits for the programmed Delay to time out. The scan layer Delay can be set from 0 to 999999.999sec. Selecting BENCH or GPIB RESET from the SAVESETUP option of the main menu sets the Delay to zero seconds.

As can be seen in the flowchart, there is a path that allows operation to loop around the source. When Source Bypass is enabled (Scan Trigger Control set to Source) and the event source is External or Trigger Link, operation loops around the source on the initial pass through the scan layer. If programmed for another scan (scan count > 1), the bypass loop is not in effect even though it is still enabled. The Source Bypass loop resets (is in effect) if operation goes back into the arm layer.

Enabling Source Bypass also enables the Output Trigger. When operation returns to the scan layer from the measure layer, an output trigger pulse occurs. If the event source is Trigger Link, an output trigger pulse is available on the programmed TRIGGER LINK output line. For all other event sources, the output trigger pulse is available at the METER COMPLETE connector. The Output Trigger in this layer is disabled when Source Bypass is disabled (Scan Trigger Control set to Acceptor).

After all other operations in the next layer are complete, the instrument can be returned to the scan layer by programming the instrument for additional scans. The Scan Count option is used to set the scan count to a finite value (where n = 1 to 99999) or for an infinite number of scans. Selecting BENCH RESET from the SAVESETUP option of the main menu sets the scan count to infinite; selecting GPIB RESET sets the scan count to one.

After the instrument leaves the scan layer, operation proceeds into the measure layer (trigger layer).

Measure layer

NOTE

For bus operation, this layer is called Trigger.

In general, measure events control the measurement (or scan) rate. With a measure source of Immediate, operation immediately proceeds to the Delay. Selecting BENCH or GPIB RESET from the SAVESETUP option of the main menu also sets the measure source to Immediate. With one of the other sources selected, the instrument waits until the appropriate event occurs:

- With the External source selected, the instrument waits for an input trigger via EXTERNAL TRIGGER on the rear panel.
- With the Manual source selected, the instrument waits until the front panel TRIG key is pressed.
- With the GPIB source selected, the instrument waits for a bus trigger (GET or *TRG).
- With the Trigger Link source selected, the instrument waits for an input trigger via TRIGGER LINK on the rear panel.
- With the Timer source selected, the first measurement occurs immediately. Each additional measurement occurs at a rate determined by the programmed timer interval (1msec to 999999.999sec).
- With the HOLD source selected, the instrument does not respond to any of the event sources. Another source must be selected to acquire a reading.

After the programmed measure event is detected, the instrument waits for the programmed Delay to time out. The measure layer Delay can be set from 0 to 999999.999sec. Selecting BENCH or GPIB RESET from the SAVESETUP option of the main menu sets the Delay to zero seconds.

As can be seen in the flowchart, there is a path that allows operation to loop around the source. When Source Bypass is enabled (Measure Trigger Control set to Source) and the event source is External or Trigger Link, operation loops around the source on the initial pass through the measure layer. If programmed for another measurement (measure count > 1), the bypass loop is not in effect even though it is still enabled. The Source Bypass loop resets (is in effect) if operation goes back into the scan layer.

At this point, a measurement is performed (Device Action). Note that a Device Action could include, among others, a function change, range change, or a channel scan (if scanner

is enabled). A channel is scanned (closed) before a measurement is taken. When scanning channels, the previous channel opens and the next channel closes (break-before-make). In this case, the settling time delay for the relay is included in the Device Action.

After a Device Action is performed, an Output Trigger occurs. If the measure source is programmed for Immediate, External, Manual, GPIB, or Timer, the output trigger pulse is available at the METER COMPLETE connector. If the Trigger Link source is selected, Output Trigger action occurs as follows:

- If the asynchronous Trigger Link mode is selected, the output trigger pulse is available on the programmed TRIGGER LINK output line.
- If the semi-synchronous Trigger Link mode is selected and the Source Bypass is disabled (Measure Trigger Control set to Acceptor), the Trigger Link line is released (goes high).
- If the semi-synchronous Trigger Link mode is selected and the Source Bypass is enabled (Measure Trigger Control set to Source), the Trigger Link line is pulled low and then released.

NOTE

See paragraph 3.7.7 for details on using the Trigger Link.

After the Device Action and an output trigger occurs, the instrument returns (if programmed to do so) to the beginning of the measure layer to perform another measurement. The Measure Count option is used to set the measure count to a finite value (where n = 1 to 99999) or for an infinite number of measurements. Selecting BENCH RESET from the SAVESETUP option of the main menu sets the measure count to infinite; selecting GPIB RESET sets the measure count to one.

3.7.2 Configuring the measure layer

The measure layer is used for the following operations:

- To select the measuring event (SOURCE) for the instrument.
- To delay operation in the measure layer.
- To designate the number of measurements the instrument will make (COUNT).
- To enable or disable the Source Bypass.

Perform the following steps to display the measure layer menu:

1. Display the CONFIGURE TRIGGER menu by pressing the CONFIG key and then the TRIG key.
2. Use the cursor keys (◀ and ▶) to place the cursor on MEASURE and press ENTER to access the following menu:

SETUP MEASURE LAYER
SOURCE DELAY COUNT CONTROL

SOURCE

This menu item selects the event that controls the measure source. To select it, place the cursor on SOURCE and press ENTER. The following menu is displayed:

SELECT MEASURE SRC
IMMEDIATE EXTERNAL MANUAL ▶
◀ GPIB TRIGLINK TIMER HOLD

IMMEDIATE: With this selection, events (such as TIMER and EXTERNAL triggers) do not control the measurement interval. Once the Model 2001 starts measuring, it will take readings as fast as its measurement configuration allows.

Select immediate triggering from the SELECT MEASURE SRC menu by placing the cursor on IMMEDIATE and pressing ENTER. The instrument returns to the SETUP measure layer menu.

EXTERNAL: With this selection, external triggers are used to control the measure source. Each trigger stimulus applied to the Model 2001 performs a device action, as defined by the trigger model. In addition to a measurement, this may include range changing, filtering, calculations, data storing, scanning, and other operations.

The external trigger is applied to the rear panel "EXTERNAL TRIGGER" BNC connector. See paragraph 3.7.6 for detailed information on external triggering.

NOTE

Front panel TRIG key (see MANUAL) is active with external triggering selected. Pressing the TRIG key performs a device action.

To select external triggering from the SELECT MEASURE SRC menu, place the cursor on EXTERNAL and press ENTER. The instrument returns to the SETUP measure layer menu.

MANUAL: With this selection, the front panel TRIG key controls the measure source. A device action is performed when the TRIG key is pressed.

NOTE

Front panel TRIG key is active when EXTERNAL, GPIB, TRIGLINK, or TIMER is selected.

To select manual triggering (TRIG key) from the SELECT MEASURE SRC menu, place the cursor on MANUAL and press ENTER. The instrument returns to the SETUP measure layer menu.

GPIB: With this selection, bus triggers control the measure source. When the Model 2001 receives a bus trigger (GET or *TRG), it performs a device action, as defined by the trigger model. In addition to a measurement, this may include range changing, filtering, calculations, data storing, scanning, and other operations. See Section 4 for detailed information on bus triggers.

NOTE

Front panel TRIG key (see MANUAL) is active with bus triggering selected. Pressing the TRIG key performs a device action.

To select bus triggering from the SELECT MEASURE SRC menu, place the cursor on GPIB and press ENTER. The display returns to the SETUP measure layer menu.

TRIGLINK: With this selection, the measure source is controlled by the Trigger Link of the Model 2001. Trigger Link is an enhanced trigger system that uses up to six lines to direct trigger pulses to and from other instruments.

When the Model 2001 receives a trigger over the Trigger Link, it performs a device action, as defined by the trigger model. In addition to a measurement, this may include range changing, filtering, calculations, data storing, scanning, and other operations.

See paragraph 3.7.7 for details on using the Trigger Link.

NOTE

Front panel TRIG key (see MANUAL) is active with the Trigger Link selected. Pressing the TRIG key performs a device action.

To select the Trigger Link from the SELECT MEASURE SRC menu, place the cursor on TRIGLINK and press ENTER. The following menu is displayed:

```
SET TRIGGERLINK MODE
ASYNCHRONOUS  SEMI-SYNCHRONOUS
```

Asynchronous: The asynchronous trigger link mode is used for trigger configurations that require input and output triggers to be routed on separate lines. Perform the following steps to select the asynchronous mode, and to select the input and output trigger lines for the Model 2001:

1. With the SET TRIGGERLINK MODE menu displayed, place the cursor on ASYNCHRONOUS and press ENTER. The following message is displayed:

   ```
   SELECT INPUT LINE
   #1  #2  #3  #4  #5  #6
   ```

   The position of the cursor indicates the presently selected input line.

2. To select a trigger input line for the Model 2001, place the cursor on the desired line number and press ENTER. The following message is displayed:

   ```
   SELECT OUTPUT LINE
   #1  #2  #3  #4  #5  #6
   ```

   The position of the cursor indicates the presently selected output line.

3. To select a trigger output line for the Model 2001, place the cursor on a different line number and press ENTER. The instrument returns to the SELECT MEASURE SOURCE menu. Note that you cannot use the same trigger line for both input and output.

Semi-Synchronous: In this mode, the input and output triggers for the Model 2001 are assigned to the same line. Perform the following steps to select the semi-synchronous mode, and to select the trigger line:

1. With the SET TRIGGERLINK MODE menu displayed, place the cursor on SEMI-SYNCHRONOUS and press ENTER. The following message is displayed:

   ```
   SET SEMI-SYNC LINE
   #1  #2  #3  #4  #5  #6
   ```

   The position of the cursor indicates the presently selected trigger line.

2. To select a trigger line for the Model 2001, place the cursor on the desired line number and press ENTER. The instrument returns to the SELECT MEASURE SRC menu.

TIMER: Use the timer to control the time interval between measurements.

The timer can be set for an interval from 0.001 seconds (1msec) to 999999.999 seconds with 1msec resolution.

After a measurement is triggered to start, the next measurement starts at the end of the programmed timer interval. If however, the programmed timer interval is shorter than the time it takes to complete a single measurement, the next measurement does not start until the previous one is done.

NOTE

Front panel TRIG key (see MANUAL) is active with the timer selected. Pressing the TRIG key after the completion of a measurement starts the next measurement (assuming the Model 2001 is programmed for another measurement; see COUNT).

Perform the following steps to use the timer:

1. With the SELECT MEASURE SRC menu displayed, place the cursor on TIMER and press ENTER. A message indicating the presently set time interval (in seconds) is displayed:

   INTRVL = 000001.000

2. To retain the displayed timer interval, press EXIT or ENTER. The instrument returns to the SELECT MEASURE SRC menu.
3. To set a different time interval, use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits. Press ENTER when done to return to the SELECT MEASURE SRC menu.

HOLD: When HOLD is selected, the measure source is suppressed. As a result, measuring is stopped and does not continue until HOLD is cancelled by selecting one of the other measure source selections. Select HOLD from the SELECT MEASURE SRC menu by placing the cursor on HOLD and pressing ENTER. The instrument returns to the SETUP measure layer menu.

DELAY

This delay is used to hold up operation in the measure layer. After the measure event occurs, the instrument waits until the delay period times out (0 - 999999.999sec) before performing a device action.

COUNT

With this selection, you determine the number (count) of measurements per scan sequence. The user programmed count can be smaller, equal to, or larger than the number of channels in the scan list. For example, if the scan list is made up of four channels, you can program a count of 12. With this count value, the instrument repeats the scan three times. An advantage of repeating channels (rather than scans) is that delays in the scan layer of operation are avoided. The measure delays among all 12 channels are the same.

With the SETUP measure layer menu displayed, select this menu item by placing the cursor on COUNT and pressing ENTER. The following menu is displayed:

MEASURE COUNT
INFINITE ENTER-CHAN-COUNT

INFINITE: Use this selection to continuously repeat measurements (and looping in the measure layer). With the MEASURE COUNT menu displayed, select this menu item by placing the cursor on INFINITE and pressing ENTER. The display returns to the SETUP measure layer menu.

ENTER-CHAN-COUNT: With this selection, the user determines the number of readings per scan. You can program the Model 2001 to measure up to 99999 times. Perform the following steps to enter the measure count:

1. With the MEASURE COUNT menu displayed, place the cursor on ENTER-CHAN-COUNT and press ENTER. A message indicating the present scan count is displayed:

   MEASURE COUNT = 00001

2. The above measure count indicates that the instrument will measure one time.
3. To program for a different count (1 to 99999), use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits.
4. With desired count value displayed, press ENTER. The display returns to the SETUP measure layer menu.

CONTROL

Use this menu item to enable or disable the source bypass. The source bypass is used to bypass the measure event on the first pass through the measure layer. With the SETUP measure layer menu displayed, select this menu item by placing the cursor on CONTROL and pressing ENTER. The following menu is displayed:

TRIGGER CONTROL
SOURCE ACCEPTOR

SOURCE: With this selection, the source bypass is enabled. The measure event will be bypassed on the first pass through the scan layer. This allows operation to proceed to the Delay and Device Action without having to wait for the programmed event.

ACCEPTOR: With this selection, the source bypass is disabled.

3.7.3 Configuring the scan layer

The scan layer is used for the following operations:

- To select the scanning event (SOURCE) for the instrument.
- To delay operation in the scan layer.
- To designate the number of scan sequences the instrument will perform (COUNT).
- To enable or disable the Source Bypass.

Perform the following steps to display the SCAN LAYER menu:

1. Display the CONFIGURE TRIGGER menu by pressing the CONFIG key and then the TRIG key.
2. Use the cursor keys (◄ and ►) to place the cursor on SCAN and press ENTER to access the following menu:

SETUP SCAN LAYER
SOURCE DELAY COUNT CONTROL

SOURCE

This menu item selects the event that controls the scan source. To select it, place the cursor on SOURCE and press ENTER. The following menu is displayed:

SELECT SCAN SOURCE
IMMEDIATE EXTERNAL MANUAL ►
◄ GPIB TRIGLINK TIMER HOLD

IMMEDIATE: With this selection, operation passes immediately into the measure layer.

Select immediate triggering from the SELECT SCAN SOURCE menu by placing the cursor on IMMEDIATE and pressing ENTER. The instrument returns to the SETUP SCAN LAYER menu.

EXTERNAL: With this selection, external triggers are used to control the scan source. A trigger stimulus applied to the Model 2001 passes operation into the measure layer. The external trigger is applied to the rear panel "EXTERNAL TRIGGER" BNC connector. See paragraph 3.7.6 for detailed information on external triggering.

NOTE

Front panel TRIG key (see MANUAL) is active with external triggering selected. Pressing the TRIG key passes operation into the measure layer.

To select external triggering from the SELECT SCAN SOURCE menu, place the cursor on EXTERNAL and press ENTER. The instrument returns to the SETUP SCAN LAYER menu.

MANUAL: With this selection, the front panel TRIG key controls the scan source. Operation passes into the measure layer when the TRIG key is pressed.

NOTE

The front panel TRIG key is active when EXTERNAL, GPIB, TRIGLINK, or TIMER is selected.

To select manual triggering (TRIG key) from the SELECT SCAN SOURCE menu, place the cursor on MANUAL and press ENTER. The instrument returns to the SETUP SCAN LAYER menu.

GPIB: With this selection, bus triggers control the scan source. Operation passes immediately into the measure layer when a bus trigger (GET or *TRG) is received by the Model 2001. See Section 4 for detailed information on bus triggers.

NOTE

Front panel TRIG key (see MANUAL) is active with bus triggering selected. Pressing the TRIG key passes operation into the measure layer.

To select bus triggering from the SELECT SCAN SOURCE menu, place the cursor on GPIB and press ENTER. The display returns to the SETUP SCAN LAYER menu.

TRIGLINK: With this selection, the scan source is controlled by the Trigger Link of the Model 2001. Trigger Link is an enhanced trigger system that uses up to six lines to direct trigger pulses to and from other instruments. Operation passes into the measure layer when the Model 2001 receives a trigger over the Trigger Link. See paragraph 3.7.7 for details on using the Trigger Link.

NOTE

Front panel TRIG key (see MANUAL) is active with the Trigger Link selected. Pressing the TRIG key passes operation into the measure layer.

To select the Trigger Link from the SELECT SCAN SOURCE menu, place the cursor on TRIGLINK and press ENTER. The following menu is displayed:

```
SELECT INPUT LINE
#1  #2  #3  #4  #5  #6
```

The position of the cursor indicates the presently selected input line.

To select a trigger input line for the Model 2001, place the cursor on the desired line number and press ENTER. The following message is displayed:

```
SELECT OUTPUT LINE
#1  #2  #3  #4  #5  #6
```

The position of the cursor indicates the presently selected output line.

To select a trigger output line for the Model 2001, place the cursor on a different line number and press ENTER. The instrument returns to the SELECT SCAN SOURCE menu. Note that you cannot use the same trigger line for both input and output.

TIMER: Use the timer feature to control the time interval between scan sequences when scanning. The timer can be set for an interval from 0.001 seconds (1msec) to 999999.999 seconds with 1msec resolution.

After a scan sequence is triggered to start, the next scan sequence starts at the end of the programmed timer interval. If however, the programmed timer interval is shorter than the time it takes to complete a single scan sequence, the next scan sequence does not start until the previous one is done.

NOTE

Front panel TRIG key (see MANUAL) is active with the timer selected. Pressing the TRIG key after the completion of a scan sequence starts the next scan sequence (assuming the Model 2001 is programmed for another scan sequence; see COUNT).

Perform the following steps to use the timer:

With the SELECT SCAN SOURCE menu displayed, place the cursor on TIMER and press ENTER. A message indicating the presently set time interval (in seconds) is displayed:

```
INTRVL = 000001.000
```

1. To retain the displayed timer interval, press EXIT or ENTER. The instrument returns to the SELECT SCAN SOURCE menu.
2. To set a different time interval, use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits. Press ENTER when done to return to the SELECT SCAN SOURCE menu.

HOLD: When HOLD is selected, the scan source is suppressed. As a result, operation does not pass into the measure layer until HOLD is cancelled by selecting one of the other scan source selections. Select HOLD from the SELECT SCAN SOURCE menu by placing the cursor on HOLD and pressing ENTER. The instrument returns to the SETUP SCAN LAYER menu.

DELAY

This delay is used to hold up operation in the scan layer. After the scan event occurs, the instrument waits until the delay period times out (0 to 999999.999sec) before proceeding to the measure layer.

COUNT

This menu item defines the number of times operation returns to the scan layer. With the SETUP SCAN LAYER menu displayed, select this menu item by placing the cursor on COUNT and pressing ENTER. The following menu is displayed:

```
NUMBER OF SCANS
INFINITE  ENTER-SCAN-COUNT
```

INFINITE: Use this selection to continuously return operation to the scan layer. Select continuous scanning from the SCAN COUNT menu by placing the cursor on INFINITE and pressing ENTER. The display returns to the SETUP SCAN LAYER menu.

ENTER-SCAN-COUNT: With this selection, the user determines the number of times operation returns to the scan layer. You can program the Model 2001 to scan up to 99999 times. Perform the following steps to enter the scan count:

1. With the SCAN COUNT menu displayed, place the cursor on ENTER-SCAN-COUNT and press ENTER. A message indicating the present scan count is displayed:

SCAN COUNT = 00001

The above scan count indicates that the instrument will scan one time.

2. To program for a different count (1 to 99999), use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits.
3. With desired count value displayed, press ENTER. The display returns to the SETUP SCAN LAYER menu.

CONTROL

Use this menu item to enable or disable the source bypass. The source bypass is used to bypass the scan event on the first pass through the scan layer. With the SETUP SCAN LAYER menu displayed, select this menu item by placing the cursor on CONTROL and pressing ENTER. The following menu is displayed:

TRIGGER CONTROL
SOURCE ACCEPTOR

SOURCE: With this selection, the source bypass is enabled. The scan event will be bypassed on the first pass through the scan layer. This allows operation to proceed into the measure layer without having to wait for the programmed event.

ACCEPTOR: With this selection, the source bypass is disabled.

3.7.4 Configuring the arm layer

The arm layer is used for the following operations:

- To select the arming event (SOURCE) for the instrument.
- To designate the number of times the instrument is to be armed (COUNT).
- To enable or disable the Source Bypass.

Perform the following steps to display the arm layer menu:

1. Display the CONFIGURE TRIGGER menu by pressing the CONFIG key and then the TRIG key.
2. Use the cursor keys (◄ and ►) to place the cursor on ARM and press ENTER to access the following menu:

SETUP ARM LAYER
SOURCE COUNT CONTROL

SOURCE

This menu item selects the event that controls the arm source. To select it, place the cursor on SOURCE and press ENTER. The following menu is displayed:

SELECT ARM SOURCE
IMMEDIATE EXTERNAL MANUAL ►
◄ GPIB TRIGLINK HOLD

IMMEDIATE: With this selection, operation passes immediately into the scan layer.

Select immediate triggering from the SELECT ARM SOURCE menu by placing the cursor on IMMEDIATE and pressing ENTER. The instrument returns to the SETUP arm layer menu.

EXTERNAL: With this selection, external triggers are used to control the arm source. A trigger stimulus applied to the Model 2001 passes operation into the scan layer. The external trigger is applied to the rear panel "EXTERNAL TRIGGER" BNC connector. See paragraph 3.7.6 for detailed information on external triggering.

NOTE

Front panel TRIG key (see MANUAL) is active with external triggering selected. Pressing the TRIG key passes operation into the scan layer.

To select external triggering from the SELECT ARM SOURCE menu, place the cursor on EXTERNAL and press ENTER. The instrument returns to the SETUP arm layer menu.

MANUAL: With this selection, the front panel TRIG key controls the arm source. Operation passes into the scan layer when the TRIG key is pressed.

NOTE

The front panel TRIG key is active when EXTERNAL, GPIB, or TRIGLINK is selected.

To select manual triggering (TRIG key) from the SELECT ARM SOURCE menu, place the cursor on MANUAL and press ENTER. The instrument returns to the SETUP arm layer menu.

GPIB: With this selection, bus triggers control the arm source. Operation passes immediately into the scan layer

when a bus trigger (GET or *TRG) is received by the Model 2001. See Section 4 for detailed information on bus triggers.

NOTE

Front panel TRIG key (see MANUAL) is active with bus triggering selected. Pressing the TRIG key passes operation into the scan layer.

To select bus triggering from the SELECT ARM SOURCE menu, place the cursor on GPIB and press ENTER. The display returns to the SETUP arm layer menu.

TRIGLINK: With this selection, the arm source is controlled by the Trigger Link of the Model 2001. Trigger Link is an enhanced trigger system that uses up to six lines to direct trigger pulses to and from other instruments. Operation passes into the scan layer when the Model 2001 receives a trigger over the Trigger Link. See paragraph 3.7.7 for details on using the Trigger Link.

NOTE

Front panel TRIG key (see MANUAL) is active with the Trigger Link selected. Pressing the TRIG key passes operation into the scan layer.

To select the Trigger Link from the SELECT ARM SOURCE menu, place the cursor on TRIGLINK and press ENTER. The following menu is displayed:

```
SELECT INPUT LINE
#1  #2  #3  #4  #5  #6
```

The position of the cursor indicates the presently selected input line.

To select a trigger input line for the Model 2001, place the cursor on the desired line number and press ENTER. The following message is displayed:

```
SELECT OUTPUT LINE
#1  #2  #3  #4  #5  #6
```

The position of the cursor indicates the presently selected output line.

To select a trigger output line for the Model 2001, place the cursor on a different line number and press ENTER. The instrument returns to the SELECT ARM SOURCE menu. Note that you cannot use the same trigger line for both input and output.

HOLD: When HOLD is selected, the arm source is suppressed. As a result, operation does not pass into the scan layer until HOLD is cancelled by selecting one of the other arm source selections. Select HOLD from the SELECT ARM SOURCE menu by placing the cursor on HOLD and pressing ENTER. The instrument returns to the SETUP arm layer menu.

COUNT

This menu item defines the number of times operation returns to the arm layer. With the SETUP arm layer menu displayed, select this menu item by placing the cursor on COUNT and pressing ENTER. The following menu is displayed:

```
ARM COUNT
INFINITE  ENTER-ARM-COUNT
```

INFINITE: Use this selection to continuously return operation to the arm layer. Select continuous arming from the ARM COUNT menu by placing the cursor on INFINITE and pressing ENTER. The display returns to the SETUP arm layer menu.

ENTER-ARM-COUNT: With this selection, the user determines the number of times operation returns to the arm layer. You can program the Model 2001 to arm up to 99999 times. Perform the following steps to enter the arm count:

1. With the ARM COUNT menu displayed, place the cursor on ENTER-ARM-COUNT and press ENTER. A message indicating the present arm count is displayed:

   ```
   ARM COUNT = 00001
   ```

   The above arm count indicates that the instrument will arm one time.
2. To program for a different count (1 to 99999), use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits.
3. With desired count value displayed, press ENTER. The display returns to the SETUP arm layer menu.

CONTROL

Use this menu item to enable or disable the source bypass. The source bypass is used to bypass the arm event on the first pass through the arm layer. With the SETUP arm layer menu displayed, select this menu item by placing the cursor on CONTROL and pressing ENTER. The following menu is displayed:

```
TRIGGER CONTROL
SOURCE  ACCEPTOR
```

SOURCE: With this selection, the source bypass is enabled. The arm event will be bypassed on the first pass through the arm layer. This allows operation to proceed into the scan layer without having to wait for the programmed event.

ACCEPTOR: With this selection, the source bypass is disabled.

3.7.5 Halting triggers

The Halt option of the CONFIGURE TRIGGER menu is used to disarm the instrument and place it in the idle state. You can press the TRIG key to resume front panel triggers.

Perform the following steps to halt triggers:

1. Display the CONFIGURE TRIGGER menu by pressing the CONFIG key and then the TRIG key.
2. Use the cursor keys (◄ and ►) to place the cursor on HALT and press ENTER to display the following temporary message:

   TRIGGERS HALTED
   Press TRIG key to resume.

3.7.6 External triggering

The Model 2001 has BNC connections on the rear panel for external triggering (see Figure 3-23). The EXTERNAL TRIGGER INPUT jack allows the Model 2001 to be triggered by other instruments. The METER COMPLETE OUTPUT jack allows the Model 2001 to trigger other instruments.

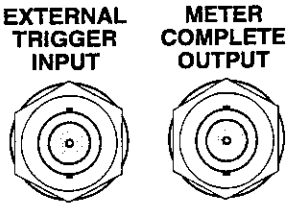


Figure 3-23
External triggering connectors (BNC)

External trigger

The EXTERNAL TRIGGER INPUT jack requires a falling-edge, TTL-compatible pulse with the specifications shown in Figure 3-24.

In general, external triggers can be used as events to control measure operations. For the Model 2001 to respond to external triggers, the appropriate layers of trigger model must be configured for it. Paragraphs 3.7.2 through 3.7.4 explain how to program the three layers of the measurement.

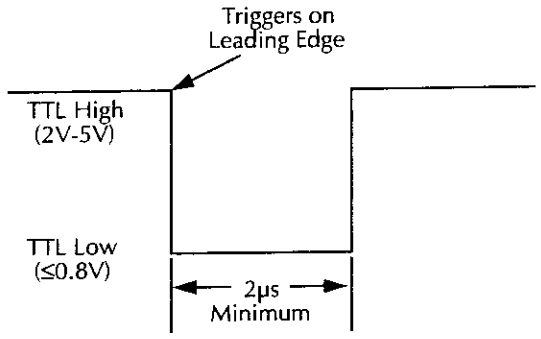


Figure 3-24
External triggering and asynchronous trigger link input pulse specifications

Meter complete

The METER COMPLETE OUTPUT jack provides a TTL-compatible output pulse that can be used to trigger other instruments. The specifications for this trigger pulse are shown in Figure 3-25.

Typically, you would want the Model 2001 to output a trigger after the settling time of each measurement. (Settling time includes the internally set measurement settling time and the user programmed DELAY period.) An output completion pulse occurs after each measurement as long as the measure source is set to external, timer, manual, or immediate. See paragraph 3.7.2 for details on programming the measure layer.

The Model 2001 can also output a completion pulse while in the scan and/or arm layers of operation. Figure 3-22 shows where these triggers occur in the trigger model. If the scan layer Source Bypass is enabled (Control = Source) and the Scan Source is programmed for External, an output trigger occurs on each return path through the scan layer. If the arm layer Source Bypass is enabled (Control = Source) and the Arm Source is programmed for External, an output trigger occurs on each return path through the arm layer. See paragraphs 3.7.3 and 3.7.4 for programming the Scan and arm layers.

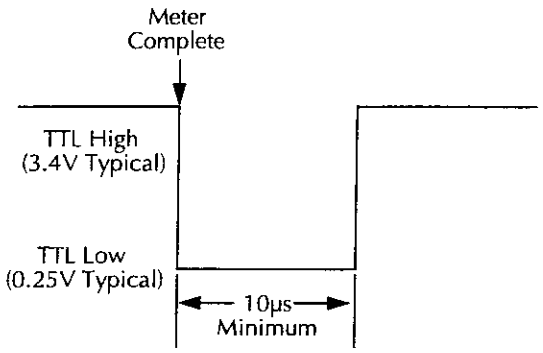


Figure 3-25
Meter complete and asynchronous trigger link output pulse specifications

External triggering example #1

In a typical test system, you may want to close a channel and then measure the DUT connected to that channel with a multimeter. Such a test system is shown in Figure 3-26, which uses a Model 2001 Multimeter to measure ten DUTs switched by a Model 7011 multiplexer card in a Model 7001 Switch System.

The external trigger connections for this test are shown in Figure 3-27. Channel Ready (output) of the Model 7001 is connected to External Trigger Input of the Model 2001. Meter Complete Output of the Model 2001 is connected to External Trigger (input) of the Model 7001.

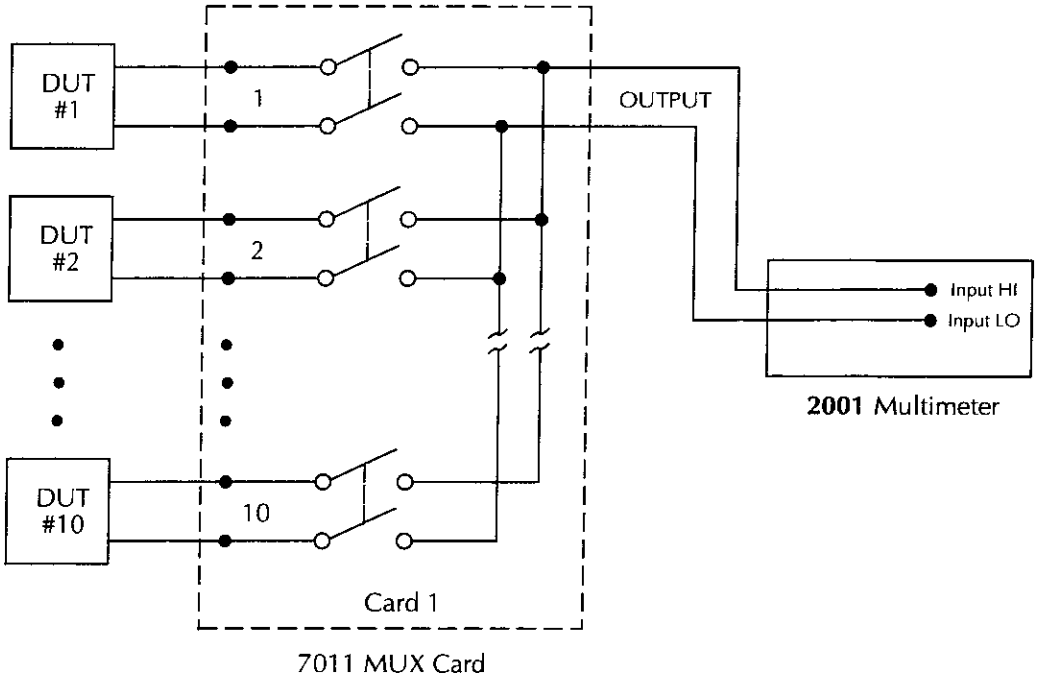


Figure 3-26
DUT test system

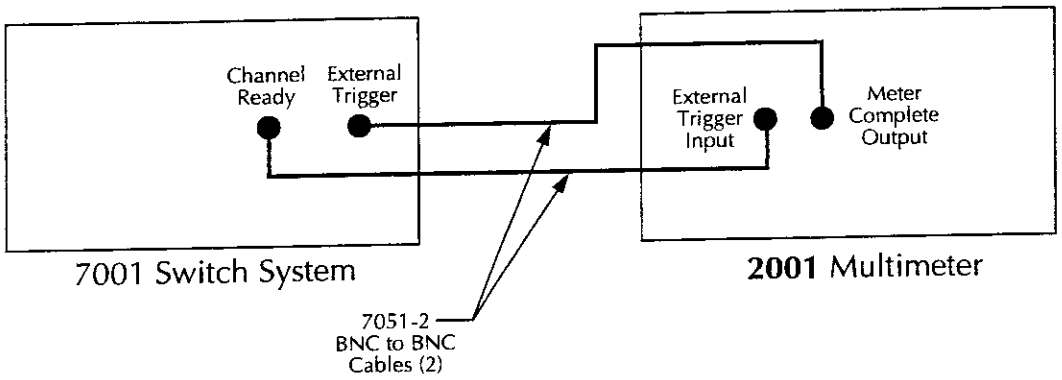


Figure 3-27
External trigger connectors

For this example, the Models 2001 and 7001 are configured as follows:

Model 2001:

Idle State:
Bench reset = :INIT:CONT ON*

Arm layer:
Arm source = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan source = Immediate*
Scan count = Infinite*
Scan trigger control = Acceptor*

Measure layer:
Measure source = External
Measure count = Infinite*
Measure trigger control = Acceptor*

* Indicates that the setting is the BENCH RESET (and factory) default condition.

Model 7001:

Idle State:
Reset = :INIT:CONT OFF*

Scan List = 1!1-1!10,

Arm layer:
Arm spacing = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan spacing = Immediate*
Number of scans = 1
Scan trigger control = Acceptor*

Channel Layer:
Channel spacing = External
Number of channels = Use Scanlist length*
Channel trigger control = Source*

* Indicates that the setting is the RESET (and factory) default condition.

Notice that the Model 2001 is reset to BENCH defaults. With this selection, the multimeter stays armed. Since the arm source and scan source are set to Immediate, the Model 2001 waits in the measure layer for a trigger.

With the Channel Trigger Control of the Model 7001 set for Source, scan operation initially bypasses the need for an external trigger to close the first channel. Since arm spacing and scan spacing are set to Immediate, the scan starts as soon as the scanner is taken out of the idle state by pressing the STEP key. When the front panel STEP key is pressed:

- The scanner arms and closes the first channel.
- After Channel 1!1 settles, a trigger is sent from Channel Ready of the Model 7001 to External Trigger Input of the Model 2001 to trigger a measurement of DUT #1.
- After the Model 2001 completes the measurement, it outputs a trigger from Meter Complete Output to External Trigger of the Model 7001, which closes the next channel.
- After Channel 1!2 settles, a trigger is sent to the Model 2001 to trigger a measurement of DUT #2.

This process continues until all ten channels are scanned and measured.

The data store capability of the Model 2001 could be used to store the measurements as they occur. Just press the STORE key to set the number of readings to store, then press ENTER. The Model 2001 waits (with the asterisk annunciator lit) for an external trigger from the Model 7001 before taking a reading, storing it, and sending a trigger pulse.

External triggering example #2

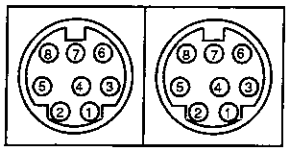
External triggering can also be used in a test system consisting of a Model 2001 Multimeter and a Model 706 Scanner with an appropriate scanner card.

The external trigger connections are the same as those shown in Figure 3-27 for the Models 2001 and 7001. Channel Ready Output of the Model 706 is connected to External Trigger Input of the Model 2001. External Trigger Input of the Model 706 is connected to Meter Complete Output of the Model 2001.

The trigger configuration of the Model 2001 does not change from the previous example. The Model 706 is configured for external triggering.

3.7.7 Trigger Link

The Model 2001 has enhanced external triggering capabilities using the Trigger Link. The Trigger Link has six lines allowing up to six instruments to be controlled over this trigger bus. The 8-pin micro-DIN sockets used for the Trigger Link are shown in Figure 3-28.



Pin	Trigger Link Line
1	Line #1
2	Line #2
3	Line #3
4	Line #4
5	Line #5
6	Line #6
7	Digital Common
8	Digital Common

Figure 3-28
Trigger link connectors

NOTE

The two rear panel Trigger Link connectors are actually connected in parallel. It does not matter which connector you use when connecting the Trigger Link to another instrument.

In general, Trigger Link input triggers to the Model 2001 are used to control the measure operation. For the Model 2001 to respond to Trigger Link compatible triggers, the appropriate layers of the trigger model must be programmed for it. For example, if you want Trigger Link input triggers to control the measuring process, you must program Measure Source for TRIGLINK trigger events. Typically, a Trigger Link output trigger from the Model 2001 would be used to trigger a scanner to close the next channel.

There are two modes of operation for Trigger Link: asynchronous and semi-synchronous. In the asynchronous mode, separate lines are used for input and output triggers; in the semi-synchronous mode, the same line is used for both input and output triggers.

Asynchronous operation

In the asynchronous operating mode, Trigger Link functions fundamentally in the same manner as External Triggering (see paragraph 3.7.6). Like External Triggering, the asynchronous mode uses separate lines for input and output triggers. Also, the asynchronous mode uses the same TTL-compatible pulses as External Triggering. The specifications for the input and output trigger signals of asynchronous mode are shown in Figure 3-24 and Figure 3-25, respectively.

For typical asynchronous Trigger Link operation, the measure layer is configured with Measure Source set to TRIGLINK and Triggerlink mode set to ASYNCHRONOUS. You must also select input and output lines for the measure layer. Input and output triggers can be set to any of the six lines, but they cannot use the same line. For example, if you select line #1 for input triggers, then output triggers must use one of the other five lines (#2 through #6).

During operation in the measure layer, each Trigger Link input trigger makes a measurement. After the user-programmed DELAY and the measurement settling time, the Model 2001 outputs a Trigger Link completion pulse (typically to a scanner to close the next channel). The measure layer is configured using the CONFIG-TRIG menu (see paragraph 3.7.2).

The scan layer and/or arm layer can also be programmed for Trigger Link, where Scan Source is set to TRIGLINK, and Arm Source is set to TRIGLINK. When using Trigger Link in these layers, you must also select input and output lines as you did in the measure layer. Keep in mind that you can use the same lines in the Scan and arm layers as selected in the measure layer.

Asynchronous Trigger Link example #1

In a typical test system, you may want to close a channel and then measure the DUT connected to the channel with a multimeter. Such a test system is shown in Figure 3-29, which uses a Model 2001 Multimeter to measure ten DUTs switched by a Model 7011 multiplexer card in a Model 7001 Switch System.

The Trigger Link connections for this test system are shown in Figure 3-30. Trigger Link of the Model 2001 is connected to Trigger Link of the Model 7001 Switch System. Notice that only one Trigger Link cable is needed.

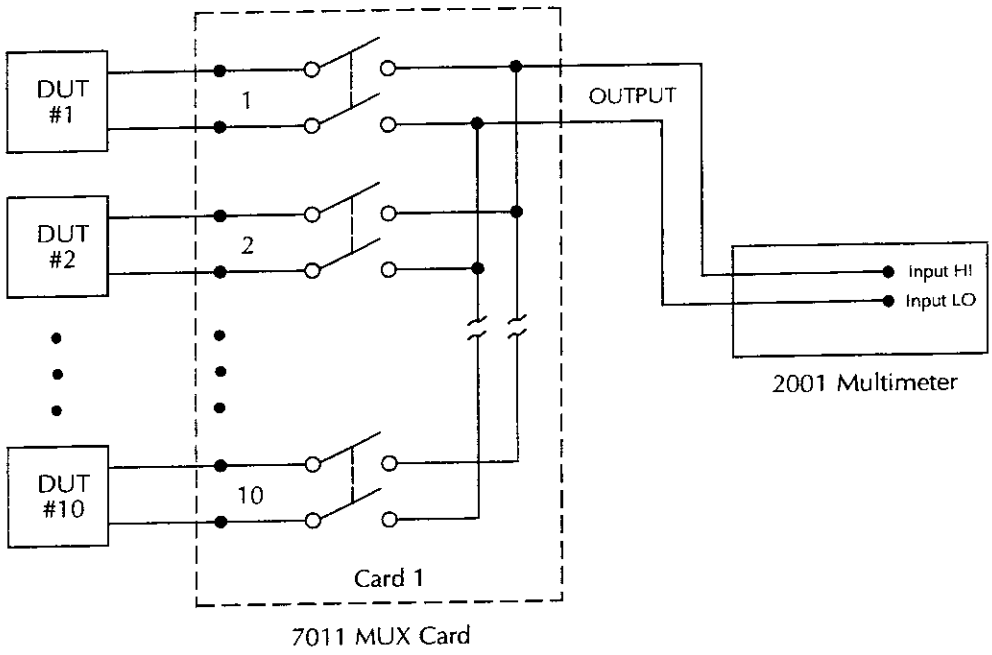


Figure 3-29
DUT test system

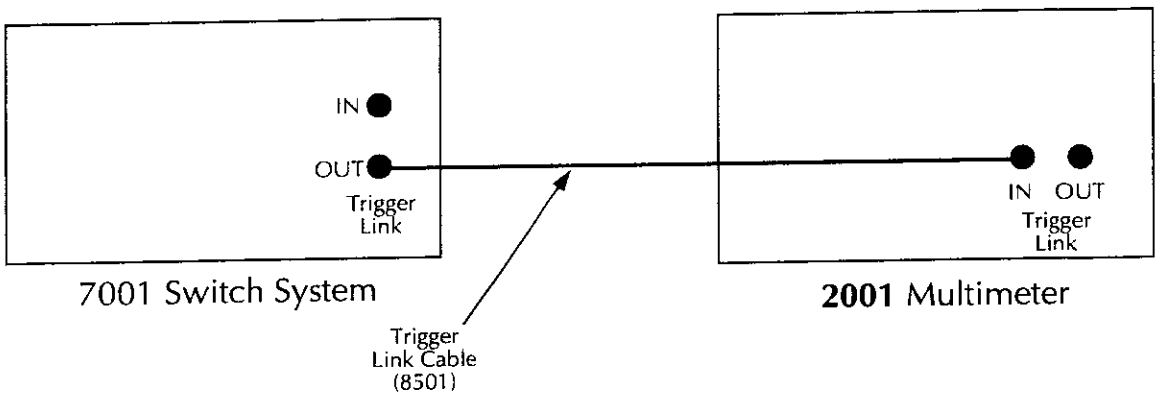


Figure 3-30
Trigger Link connections (asynchronous example #1)

For this example, the Models 2001 and 7001 are configured as follows:

Model 2001:

Idle state:
Bench reset = :INIT:CONT ON*

Arm layer:
Arm source = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan source = Immediate*
Scan count = Infinite*
Scan trigger control = Acceptor*

Measure layer:
Measure source = TrigLink
Trigger link mode = Asynchronous*
Input line = #2*
Output line = #1*
Measure count = 10
Measure trigger control = Acceptor*

* Indicates that the setting is the BENCH RESET (and factory) default condition.

Model 7001:

Idle state:
Reset = :INIT:CONT OFF*

Scan list = 1!1-1!10,

Arm layer:
Arm spacing = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan spacing = Immediate*
Number of scans = 1
Scan trigger control = Acceptor*

Channel Layer:
Channel spacing = TrigLink
Trigger link mode = Asynchronous*
Input line = #1*
Output line = #2*
Number of channels = Use Scanlist length*
Channel trigger control = Source*

* Indicates that the setting is the RESET (and factory) default condition.

Notice that the Model 2001 is reset to BENCH defaults. With this selection, the multimeter stays armed. Since the arm source and scan source are set to Immediate, the Model 2001 waits in the measure layer for a trigger.

With the Channel Trigger Control of the Model 7001 set for Source, scan operation initially bypasses the need for a Trigger Link trigger to close the first channel. Since arm spacing and scan spacing are set to Immediate, the scan starts as soon as the scanner is taken out of the idle state by pressing the STEP key.

To run the test and store the readings in the Model 2001, press STORE on the multimeter, enter the desired number of readings (ten), and press ENTER. The Model 2001 waits (with the asterisk annunciator lit) for a Trigger Link trigger from the Model 7001.

Press STEP on the Model 7001 to start the scan. The scanner's output pulse triggers the Model 2001 to take a reading, store it, and send a trigger pulse. The following explanation on operation is referenced to the operation model shown in Figure 3-31.

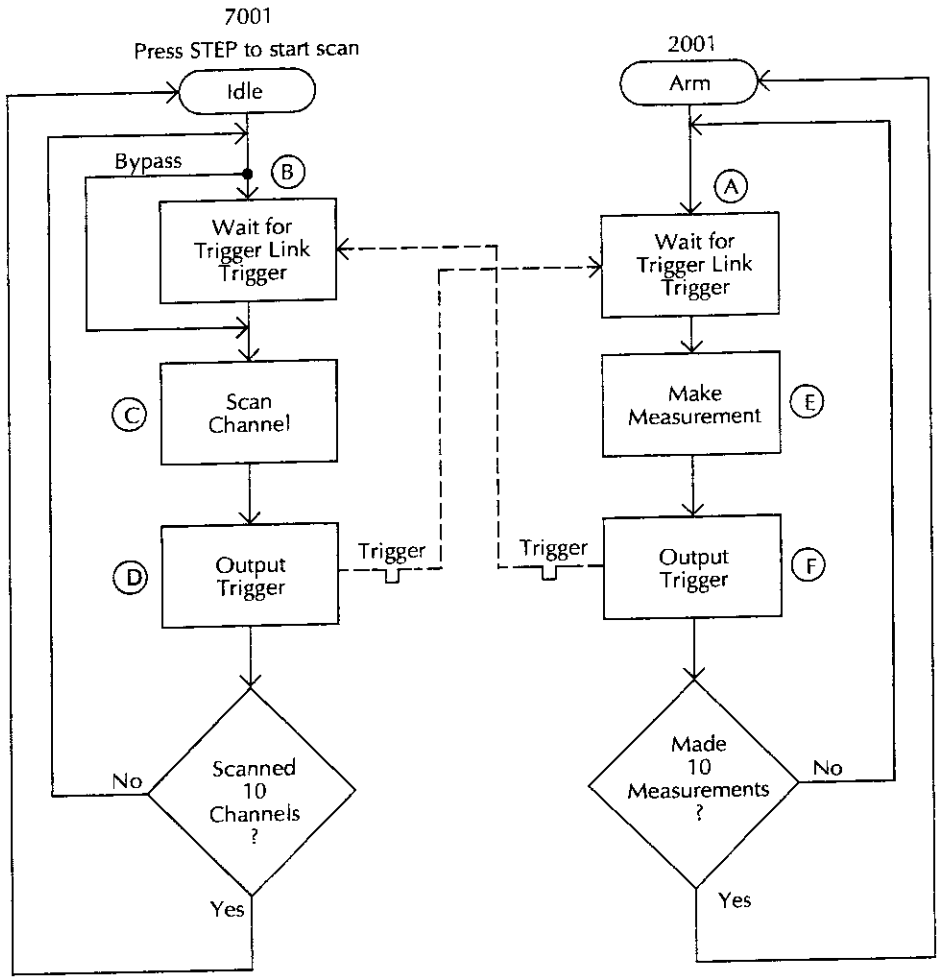


Figure 3-31
Operation model for asynchronous trigger link example #1

(A) The BENCH RESET condition arms the Model 2001 and places multimeter operation at point A in the flowchart, where it is waiting for a Trigger Link trigger. Note that since both the arm layer and scan layer are programmed for Immediate Source, operation immediately drops down to the measure layer at point A.

(B) Pressing STEP takes the Model 7001 out of the idle state and places operation at point B in the flowchart. Since both the arm layer and scan layer are programmed for Immediate Spacing, operation drops down to the channel layer at point B.

(C) Since Channel Trigger Source is set to Source, the scan does not wait at point B for a trigger. Instead, it bypasses "Wait for Trigger Link Trigger" and closes the first channel (point C). Note that the Bypass is in effect only on the first pass through the model into a layer.

(D) After the relay settles, the Model 7001 outputs a Channel Ready pulse (point D). Since the instrument is programmed to scan ten channels, operation loops back up to point B, where it waits for an input trigger. Note that Bypass is no longer in effect.

(E) and (F) Remember that the Model 2001 operation is at point A waiting for a trigger. The output Channel Ready pulse from the Model 7001 triggers the multimeter to measure DUT #1 (point E). After the measurement is complete, the Model 2001 outputs a completion pulse (point F) and then loops back to point A, where it waits for another input trigger.

The trigger applied to the Model 7001 from the Model 2001 closes the next channel in the scan. This triggers the multimeter to measure the next DUT. The process continues until all ten channels are scanned and measured.

External Triggering and Trigger Link

As previously mentioned, the trigger pulses for the asynchronous Trigger Link are identical to the trigger pulses used for External Triggering. The only thing that prevents them from being used together in a test system is connection incompatibility. Trigger Link uses 8-pin micro-DIN connectors while External Triggering uses BNC connectors.

This connection problem can be solved by using the Model 8502 Trigger Link Adapter. The adapter has two 8-pin micro-DIN connectors and six BNC connectors. The micro-DIN connectors mate directly to the Trigger Link connector on the Model 2001 using a trigger link cable. The BNC connectors mate directly to the External Triggering BNC connectors on other instruments using standard male BNC to BNC cables.

Figure 3-32 shows how a Keithley Model 706 Scanner can be connected to the Trigger Link of the Model 2001 using the adapter. With this adapter, a Model 706 could be substituted for the Model 7001 in the previous example (Asynchronous Trigger Link example #1). With the Model 706 set for External Triggering, the test would start when the single scan mode is selected and initiated.

Asynchronous Trigger Link example #2

In this example, the test system (Figure 3-33) includes a Model 2001 to measure each DUT at two different bias levels that are provided by a Model 230 voltage source. With the source set to the first voltage level, the ten channels are scanned and measured. The source is then set to the second voltage level and the ten channels are again scanned and measured.

Since this example uses an instrument that does not have Trigger Link (Model 230), the Model 8502 Trigger Link Adapter is required. Connections are shown in Figure 3-34.

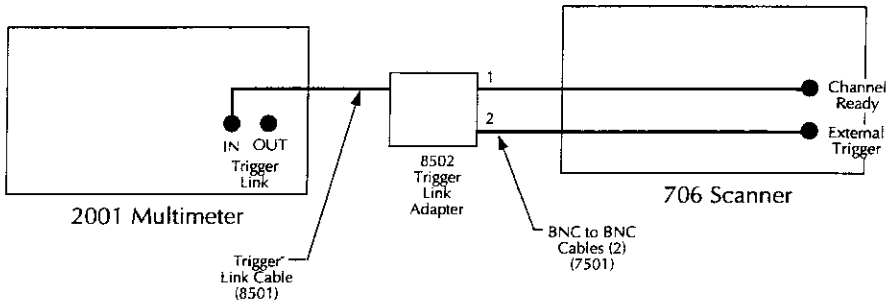


Figure 3-32
Connections using Trigger Link adapter

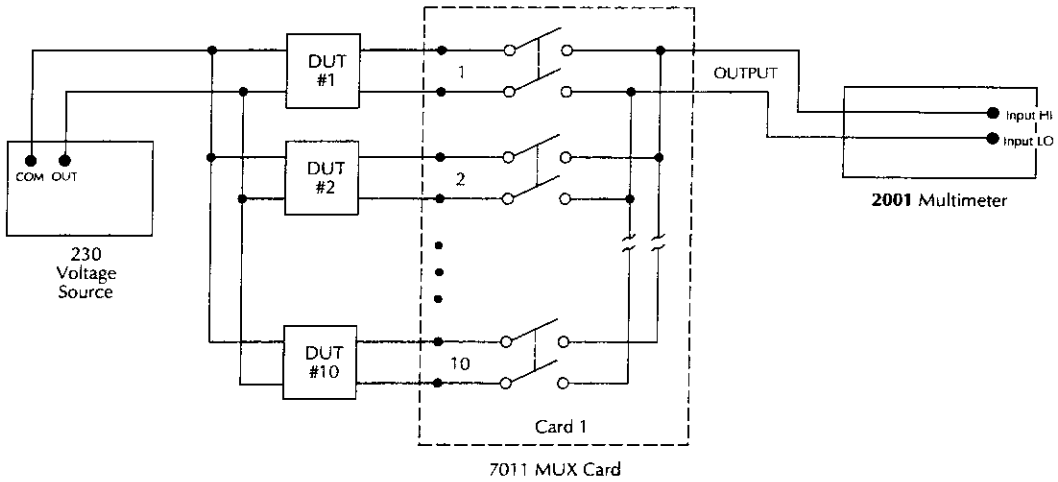


Figure 3-33
DUT test system (asynchronous example #2)

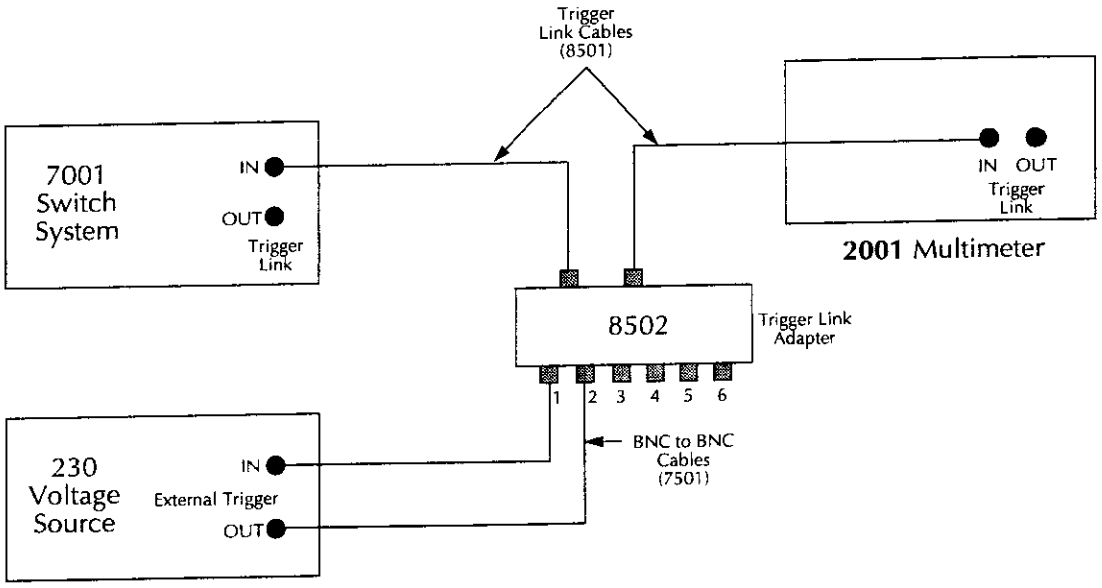


Figure 3-34
Trigger Link connections (asynchronous example #2)

For this example, the Model 230 is programmed for External Triggering and is set to source the first voltage level. The Models 2001 and 7001 are configured as follows:

Model 2001:

Idle state:
Bench reset = :INIT:CONT ON*

Arm layer:
Arm source = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan source = Immediate*
Scan count = Infinite*
Scan trigger control = Acceptor*

Measure layer:
Measure source = TrigLink
Trigger link mode = Asynchronous
Input line = #3
Output line = #4
Measure count = 20
Measure trigger control = Acceptor*

* Indicates that the setting is the BENCH RESET (and factory) default condition.

Model 7001:

Idle state:
Reset = :INIT:CONT OFF*
Scan list = 1!1-1!10,

Arm layer:
Arm spacing = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan spacing = TrigLink
Trigger link mode = Asynchronous
Input line = #2
Output line = #1
Number of scans = 2
Scan trigger control = Source

Channel layer:
Channel spacing = TrigLink
Trigger link mode = Asynchronous
Input line = #4
Output line = #3
Number of channels = 20
Channel trigger control = Source*

* Indicates that the setting is the RESET (and factory) default condition.

Notice that the Model 2001 is reset to BENCH defaults. With this selection, the multimeter stays armed. Since the arm source and scan source are set to Immediate, the Model 2001 waits in the measure layer for a trigger.

To run the test and store the readings in the Model 2001, press STORE on the multimeter, enter the desired number of readings (20), and press ENTER. The Model 2001 waits (with the asterisk annunciator lit) for a Trigger Link trigger from the Model 7001.

Press STEP on the Model 7001 to start the scan. The following explanation on operation is referenced to the operation model shown in Figure 3-35.

(A) Pressing STEP on the Model 7001 takes it out of the idle state and places operation at point A in the flowchart. Since the arm layer is programmed for Immediate Spacing, operation drops down to the scan layer at point A.

(B) Since Scan Trigger Control of the Model 7001 is set for Source, the scan does not wait at point A for a trigger. Instead, it bypasses "Wait for Trigger Link Trigger" and proceeds to point B. Note that this Bypass is in effect only on the first pass through the model.

(C) Since Channel Trigger Source of the Model 7001 is also set to Source, the scan does not wait at point B for a trigger. Instead, it bypasses "Wait for Trigger Link Trigger" and closes the first channel (point C). Note that the Bypass is in effect only on the first pass through the model.

(D) After the relay settles, the Model 7001 outputs a Trigger Link trigger pulse (point D). Since the instrument is programmed to scan ten channels, operation loops back up to point B, where it waits for an input trigger. Note that Bypass is no longer in effect.

(E) The trigger pulse from the Model 7001 triggers the Model 2001 to make a measurement of DUT #1. After the measurement is complete, the multimeter outputs a Trigger Link trigger pulse (point E).

The trigger applied to the Model 7001 from the Model 2001 closes the next channel in the scan, which in turn triggers the multimeter to measure the next DUT. This process continues until all ten channels are scanned and measured.

(F) After the last channel is scanned and measured, operation proceeds to point F, where the Model 7001 outputs a trigger pulse. Since the Model 7001 is programmed to perform two scans, its operation loops back up to point A, where it waits for an input trigger. Note that Bypass is no longer in effect.

(G) The trigger pulse from the Model 7001 triggers the Model 230 to output the next programmed voltage level. After the voltage level is set, the Model 230 outputs a trigger pulse (point G).

The trigger pulse applied to the Model 7001 from the Model 230 places operation at point B. The Bypass is again in effect because this is the beginning of a new scan. This allows operation to drop down to point C, where the first channel is again closed and eventually measured. As previously explained, all ten channels are scanned and measured.

After the last channel of the second scan is closed and measured, the Model 7001 returns to the idle state.

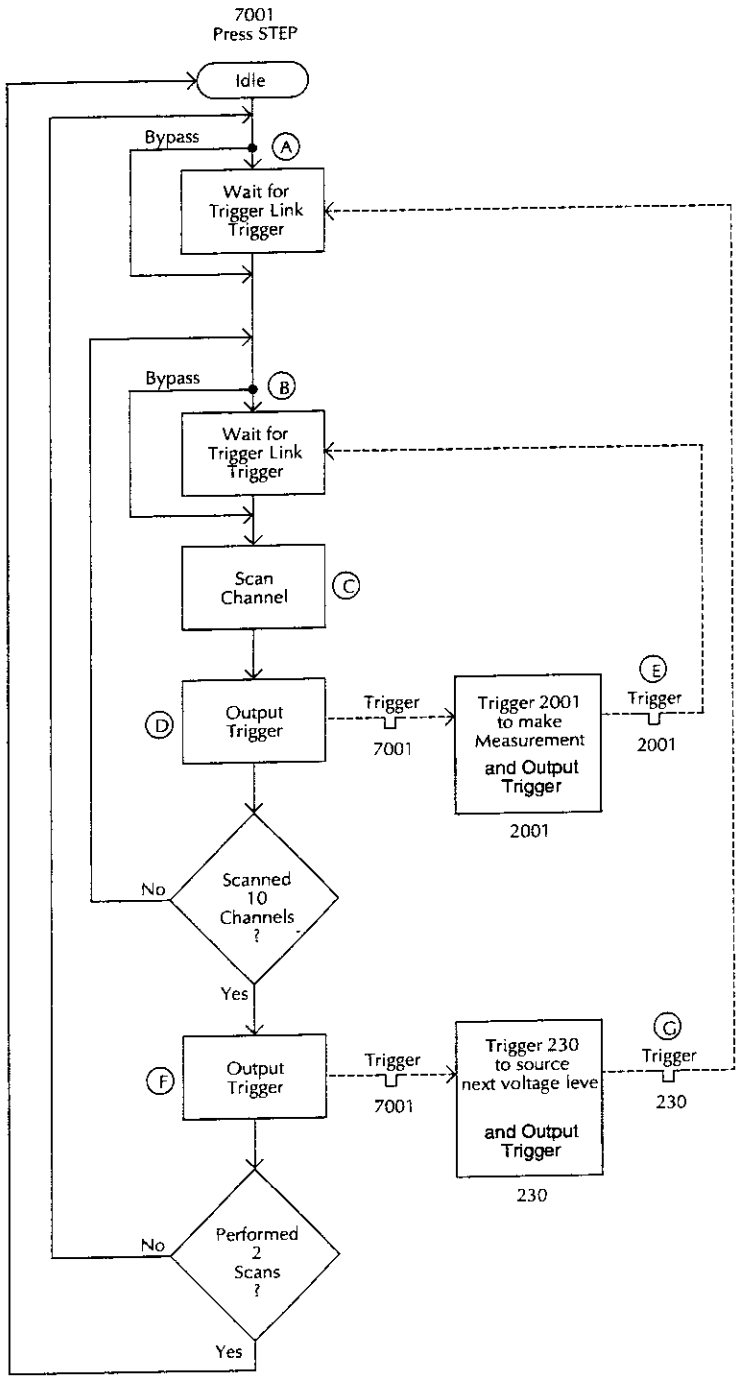


Figure 3-35
Operation model for asynchronous Trigger Link example #2

Semi-synchronous operation

In the Semi-synchronous Trigger Link mode, all triggering (input and output) is controlled by a single line. When the normally high (+5V) trigger line is pulled low (0V), a trigger occurs on the negative-going edge. When the trigger line is released, a trigger occurs on the positive-going edge (see Figure 3-36). The advantage of this single line trigger is that as long as one of the instruments in the system holds the line low, the trigger is suppressed. In other words, the trigger does not occur until all instruments in the system are ready.

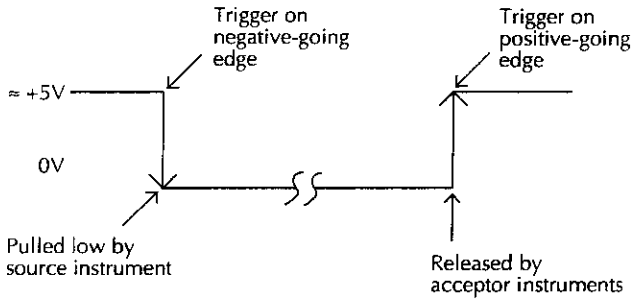


Figure 3-36
Semi-synchronous Trigger Link specifications

For example, assume that a Model 2001 is connected to two Model 7001 Switch Systems for semi-synchronous operation, as shown in Figure 3-37. All three instruments are programmed to use trigger line #1. The two Model 7001s have relay settling times of 10msec and 50msec, respectively. The Model 2001 is designated as the trigger control source and the two Model 7001 units as trigger control acceptors.

Assume that the Model 2001 initially performs a measurement. After the reading is done, the Model 2001 drives the trigger line low. The negative-going edge triggers both Model 7001s to close a channel. While the Model 7001s are in the process of closing a channel, they hold the trigger line low. Ten milliseconds after switch closure, the first Model 7001 releases the trigger line. However, the second Model 7001 continues to hold the line low since it is not finished. Fifty milliseconds after switch closure, the second Model 7001 releases the trigger line. The positive-going edge triggers the Model 2001 to make a measurement and subsequently pull the trigger line back down to close the next channels. This process continues until all channels are scanned and measured.

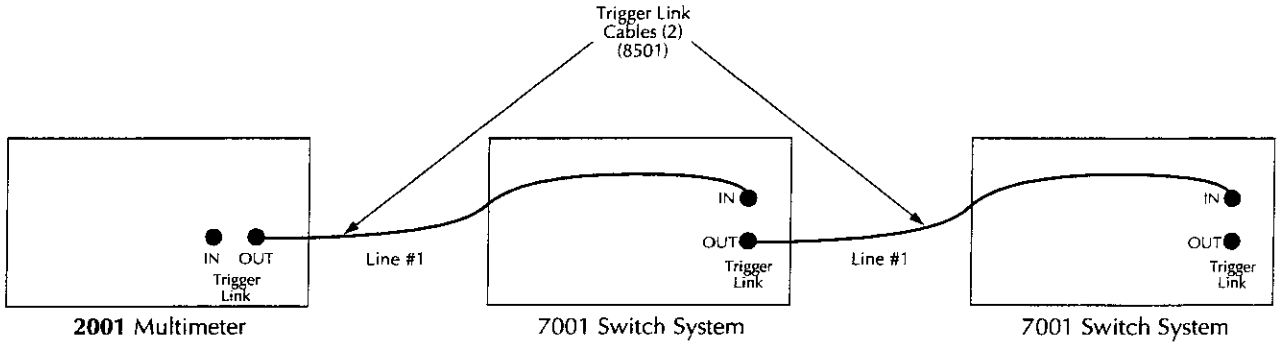


Figure 3-37
Typical semi-synchronous mode connections

Semi-synchronous Trigger Link example

This example uses the same test system (Figure 3-29) that was used for the Asynchronous Trigger Link example #1. However, triggering is done using the Semi-synchronous mode. Trigger Link connections are shown in Figure 3-38.

The two instruments are configured as follows:

Model 2001:

Idle state:
Bench reset = :INIT:CONT ON*

Arm layer:
Arm source = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan source = Immediate*
Scan count = Infinite*
Scan trigger control = Acceptor*

Measure layer:
Measure source = TrigLink
Trigger link mode = Semi-synchronous
Semi-sync line = #1*
Measure count = 10
Measure trigger control = Acceptor*

* Indicates that the setting is the BENCH RESET (and factory) default condition.

Model 7001:

Idle state:
Reset = :INIT:CONT OFF*

Scan list = 1!1-1!10,

Arm layer:
Arm spacing = Immediate*
Arm count = 1*
Arm trigger control = Acceptor*

Scan layer:
Scan spacing = Immediate*
Number of scans = 1
Scan trigger control = Acceptor*

Channel layer:
Channel spacing = TrigLink
Trigger link mode = Semi-synchronous
Semi-sync line = #1
Number of channels = Use Scanlist length*
Channel trigger control = Source*

* Indicates that the setting is the RESET (and factory) default condition.

To run the test and store the readings in the Model 2001, press STORE on the multimeter, enter the desired number of readings (ten), and press ENTER. The Model 2001 waits (with the asterisk annunciator lit) for a Trigger Link trigger from the Model 7001. Press STEP on the Model 7001 to start the scan.

The following explanation on operation is referenced to the operation model shown in Figure 3-39.

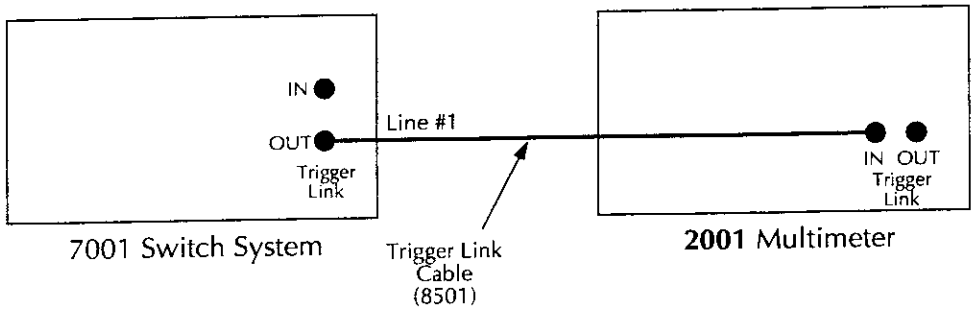


Figure 3-38
Trigger Link connections (semi-synchronous example)

(A) The BENCH RESET condition arms the Model 2001 and places multimeter operation at point A in the flowchart, where it is waiting for a Trigger Link trigger. Note that since both the arm layer and scan layer are programmed for Immediate Source, operation immediately drops down to the measure layer at point A.

(B) Pressing STEP takes the Model 7001 out of the idle state and places operation at point B in the flowchart. Since both the arm layer and scan layers are programmed for Immediate Spacing, operation drops down to the Channel Layer at point B.

(C) Since Channel Trigger Source is set to Source, the scan does not wait at point B for a trigger. Instead, it bypasses "Wait for Trigger Link Trigger" and closes the first channel (point C). Note that the Bypass is in effect only on the first pass through the model.

(D) After the relay settles, the Model 7001 pulls down the Trigger Link trigger line (point D). Since the instrument is programmed to scan ten channels, operation loops back up to point B, where it waits for an input trigger. Note that Bypass is no longer in effect.

(E) and (F) Remember that the Model 2001 operation is at point A waiting for a trigger. When the trigger line is pulled low by the Model 7001, the leading negative-going edge triggers the Model 2001 to measure DUT #1 (point E). Note that the multimeter holds the trigger line low. After the measurement is complete, The Model 2001 releases the trigger line (point F) and then loops back to point A where it waits for another input trigger.

When the Model 2001 releases the trigger line, the leading positive-going edge triggers the Model 7001 to close the next channel in the scan. This pulls the trigger line low, triggering the Model 2001 to measure the next DUT. The process continues until all ten channels are scanned and measured.

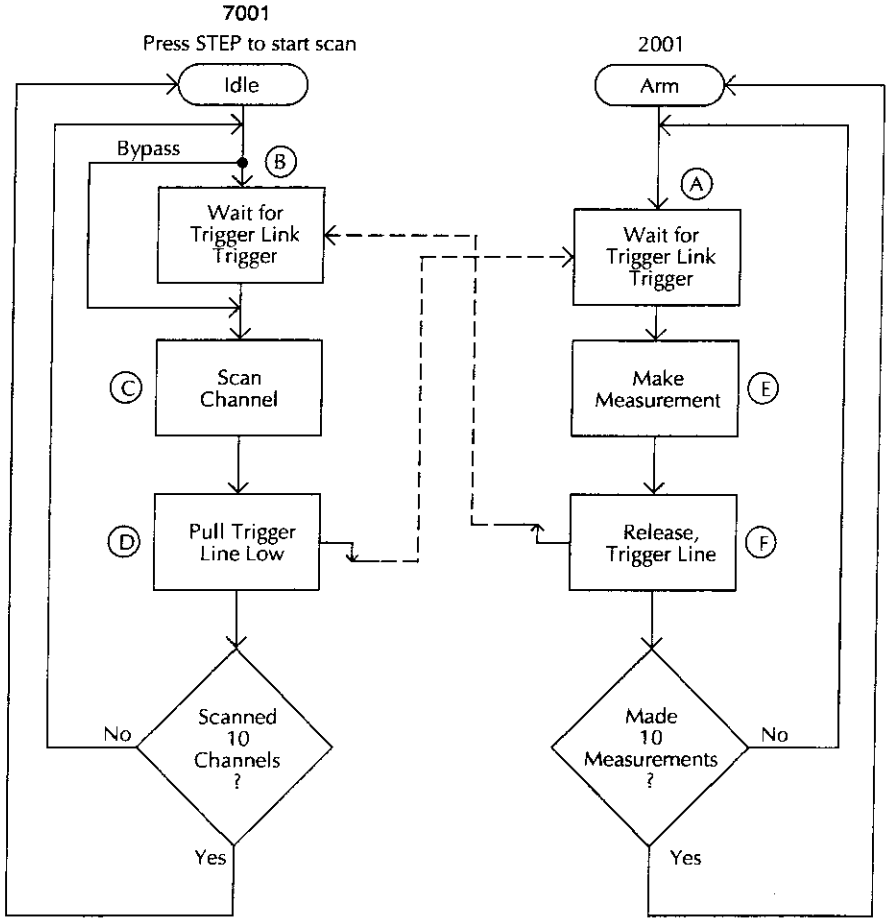


Figure 3-39
Operation mode for semi-synchronous Trigger Link example

3.8 Buffer

The Model 2001 has a buffer to store reading data. It can acquire readings at two different rates (normal and burst modes). The maximum possible number of stored readings depends on the installed memory option and the user-programmable data group. (See Table 3-29.)

Table 3-29
Reading storage options

Memory	Data group		
	Full	Compact	Type
Standard	250	850	Volatile
MEM1 option	1400	7000	Non-volatile
MEM2 option	6000	30000	Non-volatile

A full data group includes the readings, units, channel#, reading#, time-stamp, and status (overflow). A compact data group does not include channel# or time-stamp information. In addition to these items, recalled data also includes statistical information, such as minimum, maximum, average, and standard deviation.

The following paragraphs discuss configuration of the buffer acquisition speed, data grouping, and buffer control, as well as recalling buffered data. The CONFIG DATA STORE menu structure is shown and summarized in Table 3-30.

3.8.1 Burst mode

The burst data acquisition mode maximizes the reading rate of the Model 2001. Burst mode consists of two distinct phases:

- Acquiring raw readings (A/D counts).
- Post-processing the raw readings by applying calibration constants and storing the resulting readings in the buffer.

In burst mode, the Model 2001 acquires 4.5-digit readings at 2000 readings/second. The post-processing takes about 2msec/reading. If any filter or math operations are enabled, the post-processing time is longer. To make this reading rate possible, certain tradeoffs are made with the unit's functionality, as described in the following paragraph.

Table 3-30
CONFIG DATA STORE menu structure

Menu item	Description
Burst-mode	Acquire 4.5-digit readings at 2000 readings/sec and store in buffer.
Data-group	Select data types to store in buffer.
Full	Store reading, units, channel#, reading#, time-stamp, and status (overflow).
Compact	Store reading, units, reading#, and status (overflow).
Control	Select type of buffer control.
Fill-and-stop	Fill buffer with readings and stop.
Pretrigger	Wait for pretrigger event; store before and after readings.
Percentage	Enter percentage of stored readings before trigger.
Reading-count	Enter count of stored readings before trigger.
Event	Select source for pretrigger event.
Continuous	Store readings in buffer continuously.
Never	Readings are not stored.
Clear-all	Clear all stored readings and buffer statistics.
Count	Select buffer size.
Enter-count	Enter number of readings to store.
Use-trigger-model	Use (finite) measure count from trigger model.
Feed	Select type of reading to store.
After-calc	Store readings after percent or mX+b calculation.
Before-calc	Store readings before percent or mX+b calculation.

Configuring the unit for burst mode

Before burst mode can be enabled, the following changes must be made to the present instrument configuration:

- Select a valid measurement function for the burst mode, as listed in Table 3-31.
- Select a fixed range for the expected signal, or choose autorange to let the instrument select a fixed range when burst mode starts.
- Set the trigger event source in the measure layer to immediate, external, trigger link, or timer.
- Disable any "multiple displays".
- Disable scanning.

If these changes are not made, a "Settings conflict" error or similar message is displayed when you attempt to turn on burst mode.

When burst mode is selected, the Model 2001 is automatically configured for taking fast measurements. (The instrument's previous settings are restored when burst mode is aborted.) Selecting burst mode makes these temporary changes:

- Triggers are idled between bursts.
- Autoranging is disabled.
- Autozero is disabled.
- Integration time is set to 0.01 PLC (167μsec).
- Resolution is fixed at 4.5 digits.
- Buffer data group is set to compact.
- Buffer control is set to fill-and-stop.

NOTE

Some instrument settings allowed in burst mode, such as a trigger event source of timer in the measure layer, may affect the acquisition speed of 2000 readings/second.

Table 3-31
Available functions in burst mode

Function	Type
DC voltage	Normal
AC voltage	RMS, average
DC current	Normal
AC current	RMS, average
2-wire resistance	Normal

Enabling burst mode

Once burst mode is enabled, the instrument is dedicated to that purpose. Other than setting the buffer size, you cannot change any configuration parameters until burst mode is aborted. Burst mode is enabled through the CONFIG DATA STORE menu, as follows:

1. Configure the instrument's function, range, and triggering to be compatible with burst mode.
2. Display the CONFIG DATA STORE menu by pressing the CONFIG key and then STORE. The following menu is displayed:

   CONFIG DATA STORE
   BURST-MODE DATA-GROUP CONTROL ▶
   ◀ CLEAR-ALL COUNT FEED

3. Use the cursor keys (◀ and ▶) to highlight BURST-MODE and press ENTER. After a message about the enabling of burst mode clearing the buffer, the display reads:

   BURST MODE
   OFF ON

4. Select ON and press ENTER. If the instrument configuration is compatible with burst mode, this action puts the unit into idle, and takes it out of autorange. The following typical message is shown:

   BURST:00100 READINGS

   NOTE

   If the error message "Settings conflict" is displayed, the configuration of the instrument is incompatible with burst mode. The configuration must be changed to use burst mode.

5. Use the cursor and RANGE ▲ and ▼ keys to choose the buffer size. Press ENTER when done to view the following typical message:

   00100 READING BURST
   Use TRIG to start; EXIT to abort

Burst mode operation

Table 3-32 details the sequence of steps during burst mode. The steps assume just one burst of readings before aborting the burst mode, but you are able to initiate more than one burst, each time overwriting the previously stored readings.

As can be seen from the table, a front panel trigger starts the burst acquisition. The Model 2001 remains looping in the

measure layer of the trigger model until the requested number of readings is acquired. To enhance burst acquisition speed, the front panel is not updated until the raw readings are being post-processed.

Meter Complete output pulses are sent at the rate of 2kHz during the acquisition phase. (Note: The last one is not sent until post-processing is done.)

After the acquisition phase, the unit returns to the idle state and starts post-processing, which consists of converting the raw readings into measurements by applying the calibration constants. During the post- processing phase, the front panel "*" annunciator is lit.

The acquisition phase of burst mode can be aborted by pressing the EXIT key. Then the Model 2001 starts post-processing on that portion of the reading buffer.

Since burst mode turns off autozero, an autozero refresh is required once every 24 hours (by changing functions, resolution, or issuing an autozero bus command).

Table 3-32
Burst mode sequence

Action	Result	Annunciators
BURST MODE ON		ARM and AUTO off
ENTER	BURST:00100 READINGS Use ◄ ,► , ▲, ▼, ENTER, EXIT, or INFO	
ENTER	00100 READING BURST Use TRIG to start; EXIT to abort	
TRIG	(burst readings acquired)	ARM on
	(post-processing of readings) BURST:00100 READINGS Processing rdg #xx of 1000	* on
	BURST:00100 READINGS Storage complete; press RECALL	ARM and * off
	BURST:00100 READINGS Use ◄ ,► , ▲, ▼, ENTER, EXIT, or INFO	
RECALL	Rdg#+00000 ... Rdg#+00099	
EXIT	BURST:00100 READINGS Use ◄ ,► , ▲, ▼, ENTER, EXIT, or INFO	
	(press ENTER to loop back to start)	
EXIT	BURST MODE ABORTED Use CONFIG → STORE to resume	ARM and AUTO on
	(normal reading display)	

Notes:
1. This table assumes the unit was set for autorange before enabling burst.
2. Multiple displays of buffered readings are available when burst data is recalled. (See paragraph 3.5.4.)

3.8.2 Configuring data storage

The data storage configuration menu is used for the following operations:

- To acquire a burst of readings at high speed.
- To select the data types stored in the buffer.
- To select the buffer control.
- To clear the buffer of readings and statistics.
- To specify the number of readings to store.
- To specify the source of readings to be stored.

Perform the following steps to display the CONFIG DATA STORE menu:

1. From the normal reading display, press the CONFIG key, and then the STORE key. The following menu is displayed:

   CONFIG DATA STORE
   BURST-MODE DATA-GROUP CONTROL ▶
   ◀ CLEAR-ALL COUNT FEED

2. Use the cursor keys (◀ and ▶) to highlight the appropriate item and press ENTER to select it.

BURST-MODE

The burst mode is discussed in paragraph 3.8.1.

DATA-GROUP

This menu selection chooses the data items that are stored in the buffer. To select it, highlight it with the cursor and press ENTER. The following menu is displayed after a message about changing the data group clearing the buffer:

BUFFER DATA GROUPING
FULL COMPACT

FULL: With this selection, for each reading, the following information is stored: units, channel number (if applicable), reading number, time-stamp, and status (overflow). The first reading stored has a time-stamp of zero seconds; subsequent readings are referenced to it.

The "full" data group should be used for 6.5 digits or greater resolution. It also allows you to change function, range, or channel while storing.

COMPACT: With this selection, readings, units, reading numbers, and status (overflow) are stored. This allows more readings to be stored in the buffer.

"Compact" is only accurate and displayed to 5.5 digits. It does not allow changes of function, range, or channel while storing.

CONTROL

This menu item controls the type of data storage. It is selected by highlighting it with the cursor and pressing ENTER. The following menu is shown:

BUFFER CONTROL
FILL-AND-STOP PRETRIGGER ▶
◀ CONTINUOUS NEVER

FILL-AND-STOP: This control selection fills the buffer with the requested number of readings and stops. You can then recall the readings.

PRETRIGGER: This selection continuously stores readings until a user-programmed trigger event occurs. It then stores post-trigger readings. For example, with a buffer size of 100 readings, there will be 50 readings stored before the trigger event and 50 readings stored after the trigger.

The first reading after the trigger is reading zero. Pretrigger readings have reading numbers and time-stamps with a minus sign; post-trigger readings have reading numbers and time-stamps with a plus sign.

Pretrigger control must be further configured. Selecting it displays the following menu:

CONFIGURE PRETRIGGER
PERCENTAGE READING-COUNT EVENT

Percentage and reading-count specify the number of readings to store before the trigger event, either as a percentage of the total number of readings, or as a number of pretrigger readings.

Event selects the source of the pretrigger, or "mark point" event. This can be a Manual, GPIB, Trigger Link, or external trigger.

CONTINUOUS: With this control selection, readings are always stored in the buffer. The process continues, with the oldest readings being overwritten in a circular manner, until storage is interrupted with the EXIT key.

NEVER: Gets set to this if data storage has been interrupted. Pressing the STORE key changes NEVER to FILL-AND-STOP.

CLEAR-ALL

This action can be used at any time to clear the data buffer of all stored readings and buffer statistics. Since the MEM1 and MEM2 memory options are non-volatile, clear-all is the only way for the operator to clear the reading buffer.

COUNT

With this menu selection, you specify the number of readings to store. Highlighting it and pressing ENTER yields the following display:

SET BUFFER SIZE
ENTER-COUNT USE-TRIGGER-MODEL

ENTER-COUNT: This item allows you to specify the buffer size in number of readings.

USE-TRIGGER-MODEL: This selection lets you default to the measure count in the present trigger configuration, as long as the measure count is a finite value.

FEED

This selection allows you to select the source of readings to be placed in the buffer. It has the following submenu:

CHOOSE BUFFER FEED
AFTER-CALC BEFORE-CALC NONE

AFTER-CALC: With this item, readings are stored in the buffer after any enabled math operations are performed (mX+b or percent).

BEFORE-CALC: With this item selected, readings are placed in the buffer before any math is performed (mX+b or percent).

NONE: With NONE selected, no readings are placed in the buffer when storage is performed. Pressing the STORE key changes NONE to the AFTER-CALC selection.

3.8.3 Storing and recalling readings

Tables 3-33 through 3-35 detail the sequence of steps for the various modes of buffer control. The tables assume the buffer is configured as explained in paragraph 3.8.2.

Note that during data storage, the reading number on the bottom line of the display is one ahead of the reading on the top line.

There are "multiple displays" available when recalling buffered readings. These are explained in paragraph 3.8.4.

Table 3-33
Fill-and-stop sequence

Action	Result	Annunciator
STORE	STORE 00100 READINGS	
ENTER	Storing reading #xx of 100	(* on)
	Storage complete; press RECALL	(* off)
RECALL	Rdg#+00000 @Time=+000.000000 sec	
	...	
	Rdg#+00099 @Time=+002.700473 sec	
EXIT	(normal reading display)	

Table 3-34
Pretrigger sequence

Action	Result	Annunciator
STORE	STORE 00100 READINGS	
ENTER	Waiting for pretrigger event	(* on)
TRIG	Storing reading #xx of 50	
	Storage complete; press RECALL	(* off)
RECALL	Rdg#-00050 @Time=-004.999990 sec	
	...	
	Rdg#+00000 @Time=+000.000000 sec	
	...	
	Rdg#+00049 @Time=+004.899996 sec	
EXIT	(normal reading display)	

Note: A manual trigger is used as an example. Other pretrigger events include GPIB, trigger link, and external.

Table 3-35
Continuous sequence

Action	Result	Annunciator
STORE	STORE 00100 READINGS	
ENTER	Storing reading #xx of 100	(* on)
	100 rdgs stored; continuous ON	
RECALL	Rdg#+00000 @Time=+003.903546 sec	
	...	
EXIT	100 rdgs stored; continuous ON	
RECALL	Rdg#+00000 @Time=+067.709331 sec	
	...	
EXIT	100 rdgs stored; continuous ON	
EXIT	STORAGE INTERRUPTED	(* off)
	Acquired 100 of 100 readings	
	(normal reading display)	

3.8.4 Buffer multiple displays

Math operations performed on buffered readings are available when readings are recalled. Just press NEXT DISPLAY to view the math operation on the bottom line of front panel display, in the following order:

1. MAX — maximum reading in buffer, for example:

   MAX=+1.635968e+00 at RDG# +00090

Notes:

A. Display response may be slow due to calculation of statistics for large buffers.

B. Exponents are in terms of primary units of function on top line (i.e., volts, not millivolts).

2. MIN — minimum reading in buffer, for example:

   MIN=+1.627611e+00 at RDG# +00012

3. AVG — This math operation displays the mean value of the buffered readings, for example:

   AVG=+1.6345e+00

The equation used to calculate the mean is:

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

where: x_i is a stored reading, and
n is the number of stored readings.

Note: If n = 0, the result is NAN (not a number).

4. SDEV — This operation displays the standard deviation of the stored readings, for example:

   SDEV=1.4944e-03

   The equation used to calculate the standard deviation is:

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

   where: x_i is a stored reading, and
   n is the number of stored readings.

   Note: If n ≤ 1, the result is NAN (not a number).

   NOTE

   These statistics are invalid if the measurement function changed during data store (e.g., when scanning different functions).

   NOTE

   The Model 2001 uses IEEE-754 floating point format for math calculations.

The last display in this series allows you to dump the buffered readings to a printer. See paragraph 3.12.2 for details on configuring printers.

3.9 Filters

Filtering stabilizes noisy measurements. The Model 2001 uses a digital filter and an analog filter.

The digital filter is based on reading conversions. The displayed, stored or transmitted reading is simply an average of a number of reading conversions. When the digital filter is enabled, the selected digital filter configuration for that measurement function is in effect. Digital filtering is performed only on primary display measurements; it has no effect on multiple displays. Paragraphs 3.9.1 through 3.9.6 explain how to configure and control the digital filter.

The analog filter is simply an RC network for the DCV function that filters out high frequency noise (>10kHz) seen at the input of the instrument. Detailed information on using the analog filter is contained in paragraph 3.9.7.

3.9.1 Digital filter types

The Model 2001 has two types of digital filters: averaging and advanced. Both types are a simple average of one to 100 reading conversions. The difference between them is the user-programmable noise "window" of the advanced filter.

The noise window, which is expressed as a percentage of range (0-100%), allows a faster response time to large signal step changes (e.g., scanned readings). A reading conversion outside the plus or minus noise window fills the filter "stack" immediately.

If the noise does not exceed the selected percentage of range, the reading is based on an average of reading conversions. In this case, the advanced filter works the same as the averaging filter. If the noise does exceed the selected percentage, the reading is a single reading conversion, and new averaging starts from this point. The two filter types are compared in Figure 3-40A.

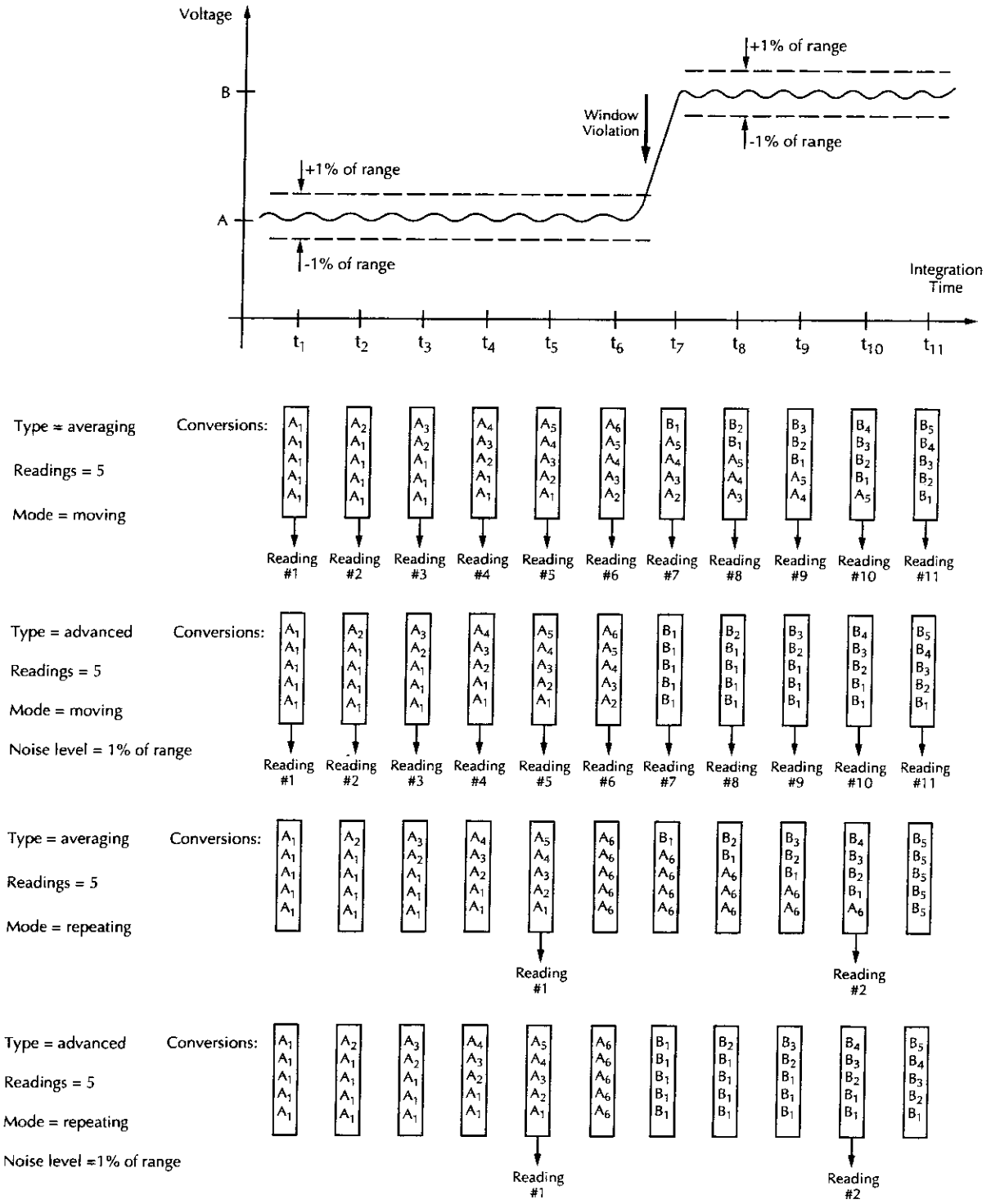
3.9.2 Digital filter modes

An additional filter parameter is the mode, either moving or repeating. A moving filter is a first-in, first-out stack, where the newest reading conversion replaces the oldest. An average of the stacked reading conversions yields a reading. Therefore, after a selected number of conversions, a moving filter gives a new reading for every new conversion.

A repeating filter takes a selected number of reading conversions, averages them, and yields a reading. It then flushes its stack and starts over. This characteristic is useful when scanning channels.

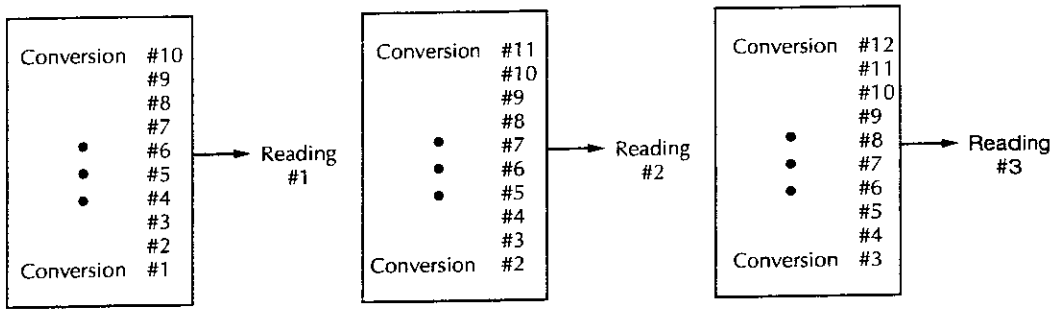
If burst mode is enabled with filtering, the post-processing time increases. A filter mode setting of repeating is ignored in burst mode.

Filter modes are compared in Figures 3-40B and 3-40C.

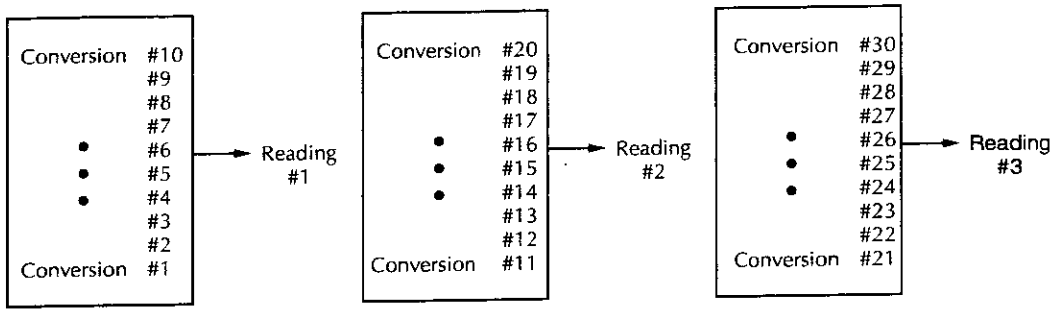


A. Averaging and advanced filter types

Figure 3-40
Digital filter



B. Moving filter mode; Type - Average, Readings = 10



C. Repeating filter mode; Type - Average, Readings = 10

Figure 3-40 (cont.)
Digital filter

3.9.3 Response time (Digital filter)

The various filter parameters have the following effects on the time needed to display, store, or output a filtered reading:

- Filter type: The time to the first reading is the same for both types, but thereafter averaging mode yields a faster reading than repeating mode. Also, advanced has a faster response to changes in the input signal than averaging.
- Number of reading conversions: Speed and accuracy are tradeoffs.
- Noise window: For the advanced type, a tradeoff of speed, accuracy, and response to input signal changes.

3.9.4 Auto filtering (Digital)

For those measurement functions with a filter, one of the possible selections is automatic filtering. Depending on the measurement function and type, the AUTO selection may disable filtering. Auto filtering is summarized in Table 3-36.

3.9.5 Configuring the digital filter

Each measurement function except frequency has its own configuration for a digital filter. A digital filter configuration menu is shown in Table 3-37.

Table 3-36
Auto filters

Measurement		Filter				
Function	**Type**	**State**	**Type**	**Readings**	**Averaging Mode**	**Noise Tolerance Level**
DC voltage	--	On	Advanced	10	Moving	1%
AC voltage	RMS, average, low frequency RMS	Off	Advanced for volts; Average for dB, dBm	10	Moving	5%
	Peak, pos. peak spikes, neg. peak spikes	On	Advanced for volts; Average for dB, dBm	10	Moving	5%
DC current	Normal	On	Advanced	10	Moving	1%
	In-circuit	On	Advanced	10	Moving	1%
AC current	RMS, average	Off	Advanced	10	Moving	5%
2-wire resistance	--	On	Advanced	10	Moving	1%
4-wire resistance	--	On	Advanced	10	Moving	1%
Frequency	--	*				
Temperature	--	On	Average	10	Moving	-

*Note: A filter is not available on the frequency function.

Table 3-37
CONFIG-FILTER menu structure

Menu item	Description
Auto	Default to filter appropriate for measurement function and type.
Averaging	Program simple average filter (1-100 readings).
Advanced	Program simple average filter (1-100 readings), with a noise tolerance window (0-100% of range).
Averaging-mode	Select moving average or repeating average mode.

Choosing the filter parameters for each function follows the same procedure. You can program a digital filter as follows:

1. There are three ways to display a filter configuration menu:
   - To configure the filter of the present function, just press CONFIG, then FILTER.
   - To configure the filter of another function and remain in the present function, press CONFIG, and the appropriate function key, then select FILTER from its menu.
   - To configure the filter of another function and change to that function, press the appropriate function key, and CONFIG, then FILTER.
2. As an example, consider the DCV digital filter menu. Display the CONFIGURE DCV menu by pressing the CONFIG key and then the DCV key.
3. Use the cursor keys (◄ and ►) to place the cursor on FILTER and press ENTER to access the following menu:

   DCV DIGITAL FILTER
   AUTO AVERAGING ADVANCED ►
   ◄ AVERAGING-MODE

AUTO

This menu item selects auto filtering. When chosen, auto filtering enables the filter parameters listed in Table 3-17 for the function you are presently configuring. Note that selecting AUTO immediately enables the filter for that function when the state listed in Table 3-17 is ON. In this case, if you are configuring the filter for the present measurement function, the FILT annunciator comes on.

AVERAGING

Use this selection for a non-windowed averaging filter. A message indicating the presently set number of reading conversions to average (the "stack" size) is displayed:

AVG:010 RDGS (1-100)

1. To retain the displayed number, press ENTER or EXIT.
2. To set a different number, use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits. Press ENTER when done.

   Note that the number of reading conversions selected for the averaging filter type is coupled to that for the advanced filter type.

ADVANCED

This selection is for an averaging filter with a noise window. (It is not available with dB or dBm units, ratio or delta, temperature or frequency.) A message indicating the presently set number of reading conversions to average (the "stack" size) is displayed:

ADV:010 RDGS (1-100)

1. To retain the displayed number, press ENTER. To set a different number, use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits. Press ENTER when done.

   Note that the number of reading conversions selected for the advanced filter is coupled to that for the averaging filter.
2. The next message is for the maximum noise window, which is expressed in percent of range, as follows:

   LEVEL = 00.000000%RNG

   This is the plus or minus percentage of range window around the first reading conversion in the stack. To set a different percentage, use the cursor keys and RANGE keys. Press ENTER when done.

AVERAGING-MODE

This selection determines the mode of a digital filter for a measurement function, either a moving or repeating average. The AVERAGING MODE menu is shown as follows; its present selection is highlighted:

AVERAGING MODE
MOVING REPEAT

MOVING: This item selects a moving filter, where a new reading conversion is shifted into a stack as the oldest conversion is shifted out (FIFO). When the stack is full, a simple average is taken to yield a reading.

REPEAT: This menu item selects a repeating filter, where an average of a selected number of reading conversions is taken for each reading.

3.9.6 Enabling/disabling the filter

The FILTER key toggles the filter on and off for the present measurement function. With the FILT annunciator on, the filtering action depends on the selections chosen in the FILTER menu for the present function. With the FILT annunciator off, the digital filter for that function is completely disabled.

The state and configuration of the digital filter for each function is saved when changing functions.

- Pressing the FILTER key to enable the filter momentarily displays one of the following typical messages:

  Filter Enabled
  Digital = AVG(10)

  or

  Filter Enabled
  Digital = ADV(10)

  or

  Filter Enabled
  Digital = AUTO

where: AVG is the averaging filter.
ADV is the advanced filter.
AUTO is the type listed in Table 3-36.
(10) is the number of reading conversions to average.

3.9.7 Analog filter

The Model 2001 has an analog filter for use with the DCV function. This filter reduces the number of overflow errors caused by noise seen on the input signal. The analog filter is most effective when measuring voltages greater than 2 Vp-p frequencies ranging from 10kHz to 1MHz.

Controlling the analog filter

Perform the following steps to enable or disable the analog filter:

1. Press CONFIG and then DCV to display the DCV configuration menu.
2. Place the cursor (using ▲ and ▼ keys) on ANALOG-FILTER and press ENTER to display the control options (ON or OFF). Cursor position indicates the present state of the analog filter.
3. To change the state of the analog filter, place the cursor on the alternate state and press ENTER.
4. Use the EXIT key to back out of the menu structure.

NOTE

The FILT annunciator on the display only indicates the state of the digital filter. It is not used for the analog filter.

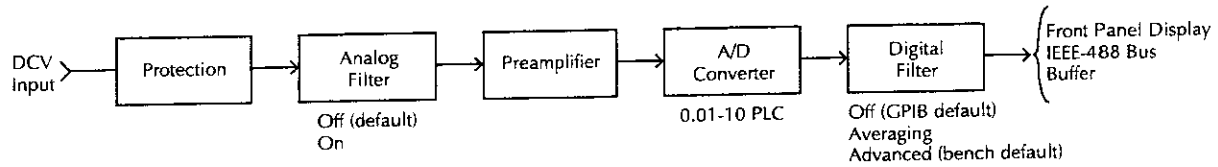
Selecting the first multiple (NEXT) display for DCV enables the analog filter. Leaving this multiple display returns the analog filter to its previous state.

Analog filter characteristics

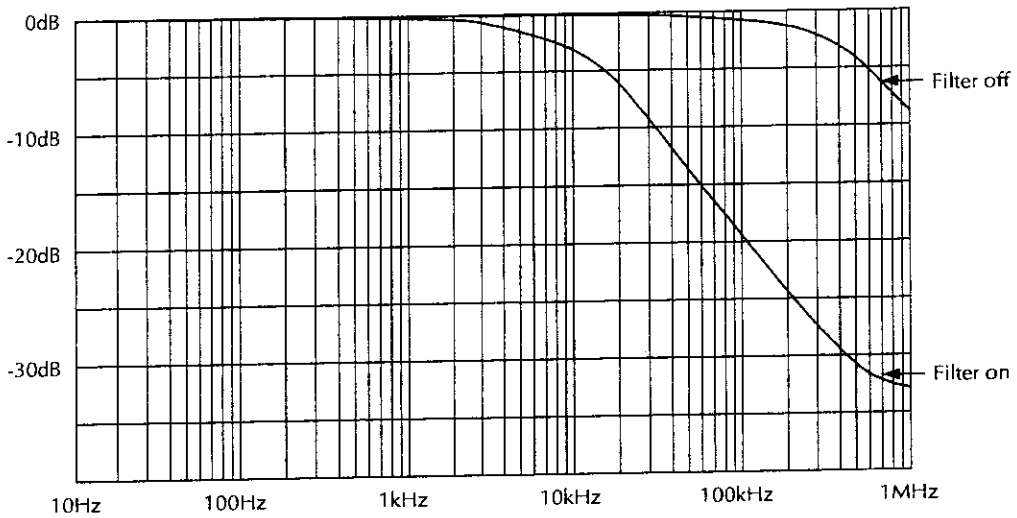
Figure 3-41A provides a simplified block diagram of the Model 2001 showing the location of the analog filter. When enabled, it provides a "cleaner" signal to the preamplifier. As a result, readings are less noisy. The analog filter does not affect any of the instrument's specifications beyond those dealing specifically with the filter function.

The analog filter is a single stage, single-pole, low-pass RC network that rolls off the signal at an approximate rate of 20dB per decade above the cutoff frequency of 10kHz. The analog filter has a zero at 600kHz. Figure 3-41B shows the general frequency response for the analog filter.

The analog filter is most effective on the 2V or 20V range with line synchronization enabled. On the 200mV range, a noisy input signal may cause overflow readings even though the analog filter is enabled.



A. Model 2001 block diagram (DCV input)



B. Analog filter frequency response

Figure 3-41
Analog filter

3.10 Math

Model 2001 math operations are divided into four categories:

- Math performed on single readings (mX+b and percent).
- Math performed on buffered readings (maximum and minimum values, average, and standard deviation).
- Math performed on single readings as a part of a pass/fail limits test.
- Math performed on scanned readings (ratio and delta).

The first category is configured from the CONFIG-MATH menu and is described in this paragraph. Math operations on buffered readings are available in multiple displays of recalled data and are discussed in paragraph 3.8. Limit tests are described in paragraph 3.12, under main menu operations. Ratio and delta calculations on scanned channels are available from the CONFIG-SCAN menu, as discussed in paragraph 3.11.

Note that once enabled for a function, the mX+b, percentage, and percent deviation calculations are in effect across function changes.

NOTE

The Model 2001 uses IEEE-754 floating point format for math calculations.

3.10.1 mX+b

This math operation allows you to automatically multiply normal display readings (X) by a scale factor (m) and add an offset (b). The result (Y) is displayed on the top line according to the formula:

$$Y = mX + b$$

The mX+b math operation is useful when slope calculations are required for a series of measurements.

The values of the "m" and "b" constants can be changed through the CONFIG-MATH menu. The before and after calculation can be viewed with one of the next displays, as described in paragraph 3.10.5. When necessary, the resulting Y value is displayed in scientific notation.

3.10.2 Percent

This operation lets you specify a target reading value. The displayed reading will be expressed as a percentage of the target value, often in scientific notation. The percentage calculation is performed as follows:

$$\text{Percent} = \frac{\text{Input Reading}}{\text{Target Value}} \times 100$$

As an example, consider the default target value for percentage calculations, where:

100% = +1.000000e+00

Therefore, on the 200µA range, a 100µA input would be 0.01% of the target value and a typical reading would be displayed as follows:

+1.0000e+04µAAC%
Range: 200 µAAC Coupling: AC

Note that the value is not 10000%, but 10000µ%, which equals 0.01%. With the calculate multiple display selected, as described in paragraph 3.10.5, the display would be:

+1.0000e+04µAAC%
Reading = +100.000

where the bottom line shows the reading (in the units and multiplier prefix of the top line) before the percentage calculation is performed.

3.10.3 Percent deviation

The following math calculation provides the percent deviation between the normal display reading and the currently stored REL value for the selected function:

$$PD = \frac{(X - Y)}{Y} \times 100\%$$

Where: X is the normal display reading
Y is the REL value for the selected function
PD is the displayed percent deviation result

Percent Deviation is enabled through the CONFIGURE MATH menu as described in paragraph 3.10.4 below.

Note that Percent Deviation does not scale based on the m, k, or M range factor. For example, 10% deviation on the 20kΩ range will be displayed as 10.00000. If the number is too large for the allowed number of leading zeroes (for example 10 on the 2kΩ range), the display will switch to 7-1/2 digit scientific notation.

3.10.4 Configuring math

The mX+b, percent, and percent deviation math operations are programmed from the CONFIGURE MATH menu. The selections are shown in Table 3-38.

To program the math parameters from the normal reading display, press the CONFIG key, and then the MATH key to access the following menu:

CONFIGURE MATH
NONE mX+b PERCENT

Table 3-38
CONFIGURE MATH menu structure

Menu item	Description
None	Select no calculation when MATH key is pressed.
mX+b	Select mX+b calculation and enter constants.
Percent	Select percent calculation and enter target (reference) value.
Percent deviation	Select percent deviation calculation.

NONE

With this menu item, no math operation goes into effect when the MATH key is pressed. The MATH annunciator lights, but NONE is displayed on the top line.

mX+b

This menu item allows you to program the mX+b constants, where m is the scale factor, and b is the offset. After highlighting the mX+b selection and pressing ENTER, the default display shows:

m = +1.000000e+00

Use the cursor (◄ and ►) and RANGE keys to move among the digits and set their desired values. Once the scale factor is configured, press ENTER to view the following default display:

b = +0.000000e+00

The cursor and RANGE keys are used to set the desired value of offset. Pressing ENTER returns you to the CONFIGURE MATH menu.

PERCENT

This selection lets you specify the target value for the percentage calculation. The default message indicating the presently set target value is displayed as follows:

100%= +1.000000e+00

1. To retain the displayed target value, press ENTER or EXIT.
2. To set a different target, use the cursor keys (◄ and ►) to select the digits, and the RANGE ▲ and ▼ keys to increment and decrement the digits. Press ENTER when done.

PERCENT DEVIATION

This menu item selects the percent deviation calculation and returns the display to the normal measurement state.

3.10.5 Enabling math

The MATH key toggles the selected math operation on and off from the normal reading display. Once a math operation is enabled, it is in effect across function changing. This is indicated by the MATH annunciator and, at the right side of the top line, the type of math enabled (NONE, mX+b, or %).

Pressing the MATH key to enable a math operation momentarily displays one of the following typical messages:

Math Enabled
Display = NONE (Reading)

or

Math Enabled
Display = mX+b (Reading)

or

Math Enabled
Display = % (Reading)

Then the Model 2001 displays the result of the calculation on the top line, using scientific notation where necessary.

3.10.6 Calculate multiple display

One of the multiple displays lets you view the reading on the bottom line of the display and the result of the calculation on the top line. This display is available by repeatedly pressing either the NEXT or PREVious DISPLAY key to scroll through the multiple displays for the particular function. The following is a typical message for a percentage calculation:

-7.0431e+01 VDC %
Reading = -0.704311

The display resolution on the bottom line follows that chosen for the top line. If scientific notation is required on the top line, it is fixed at 4.5 digits. The value on the bottom line tracks the units and prefix of the top line. (For example, if the top line displays μA, then the units on the bottom line are μA.)

Note that this multiple display is not available on the frequency function.

3.11 Scanning

The Model 2001 can be used with an internal scanner card (Model 2001-SCAN) or with external scanner cards installed in switching mainframes such as the Models 706 and 7001. The following paragraphs discuss various aspects of using scanning with the Model 2001.

3.11.1 Scanning overview

A scanner allows you to switch among a number of input signals to the Model 2001 for measurement. The channel control and scanning capabilities depend on whether an internal or external scanner card is being used, as well as on the capabilities of the scanner card in question. Refer to the documentation supplied with the scanner card for specific connection information.

Using an internal scanner card

The optional Model 2001-SCAN scanner card allows you to switch or scan up to ten 2-pole channels, or five 4-pole channels. Two of the channels use solid-state switching for high-speed multiplexing, ratio, or delta applications.

When using this card, the Model 2001 can:

- Close and open individual channels.
- Scan through channels using a separate measurement function for each channel, if desired.
- Perform ratio and delta measurements using two user-defined channels.

Using external scanner cards

When using external scanning, you can define separate measurement functions for a maximum of 80 channels. Note

however, that you cannot close or open external channels using Model 2001 controls. Use the switching mainframe controls to open and close individual channels.

In order to synchronize Model 2001 measurements with external channel closure, connect the Model 2001 external trigger inputs or the trigger link to the external switching mainframe trigger inputs and outputs. Refer to paragraphs 3.7.6 and 3.7.7 for information on using external triggering and the trigger link.

3.11.2 Front panel scanner controls

Controls that affect scanner card operation include:

- CHAN: Allows you to open and close internal scanner card channels.
- CONFIG-CHAN: Defines the measurement functions for each internal and external scanner card channel, selects the number of external channels, defines channels assigned to the internal scan list, and saves/restores an alternate measurement function.
- CONFIG-SCAN: Selects internal or external scanning and controls ratio/delta operation when using the internal scanner.
- SCAN: Starts/stops scanning using the selected scan list. Configures scan count, scan interval, and enables buffer storage and recall if internal or external list is selected.
- EXIT: Disables scanning and returns to normal operation. (Trigger model is restored to pre-scanning configuration.)
- ◄ and ► : Allows you to manually scan through channels.
- PREV/NEXT DISPLAY: Allows you to display the two adjacent channels (manual scanning only).

3.11.3 Using CHAN to close and open internal channels

CHAN key operation

The CHAN key controls channels on the internal scanner card only. The CHAN key allows you to directly:

- Close a specific channel (or channel pair for 4-wire functions).
- Immediately open any internal closed channel (or channel pair for 4-wire functions).

Channel selection menu

Table 3-39 summarizes the channel selection menu structure along with a brief description of each item. More detailed descriptions of these menu items are presented in the following paragraphs. See paragraph 3.3 for general rules on navigating menus.

Pressing CHAN will display the following menu choices:

```
CHANNEL SELECTION
CLOSE-CHANNEL   OPEN-ALL-CHANNELS
```

Table 3-39
CHANNEL SELECTION menu structure

Menu item	Description
CLOSE-CHANNEL ENTER CHAN#01 (1-10) OPEN-ALL-CHANNELS	Close channel menu: Use cursor, range, and ENTER keys. Press ENTER to open closed channel(s).

CLOSE-CHANNEL: Selecting CLOSE-CHANNEL will display the following message prompting you to select the channel to close:

```
ENTER CHAN#01 (1-10)
```

The field entry after "ENTER CHAN#" indicates the channel to close. To close a channel, simply use the cursor and range keys to select the number of the channel to close, then press ENTER. The number of the closed channel will be displayed on the front panel along with normal readings.

Selecting a different channel from the one that is presently closed will cause the closed channel to open and allow a settling time before closing the selected channel.

Channel relays will be closed according to the presently selected function. If a 2-wire function is used, only the relay for that one channel will be closed. If a 4-wire function is selected, both the selected channel relay and the matching relay pair will close. For example, closing the matching relay pair will close. For example, closing channel 2 will also close the channel 7 relay. Fixed 4-pole relay pairs are:

- 1 and 6
- 2 and 7
- 3 and 8
- 4 and 8
- 5 and 10.

OPEN-ALL-CHANNELS: Selecting OPEN-ALL-CHANNELS will immediately open any closed scanner card channels or channel pair for 4-wire functions.

3.11.4 Using CONFIG-CHAN to configure channels

CONFIG-CHAN operation

CONFIG-CHAN allows you to:

- Select measurement functions for internal scanner card channels, and define which channels to use when scanning.
- Select measurement functions and the number of channels in an external scanner used with the Model 2001.
- Define, save, and restore an alternate measurement function which can then be assigned to specific channels.

CONFIGURE CHANNELS menu

Table 3-40 summarizes the CONFIGURE CHANNELS menu structure, which is discussed in detail in the following paragraphs. Again, see paragraph 3.3 for more information on navigating menus.

Pressing CONFIG then CHAN will display the following menu:

CONFIGURE CHANNELS
INTERNAL-CHANS EXTERNAL-INPUTS ▶
◀ SAVE-ALT-FCN RESTORE-ALT-FCN

INTERNAL-CHANS: The INTERNAL-CHANS selection allows you to set the measuring function for each of the internal scanner card channels. When this selection is made, the following submenu will be displayed:

SET INTERNAL CHANS
1=DCV 2=DCV 3=DCV 4=DCV 5=DCV ▶
◀ 6=DCV 7=DCV 8=DCV 9=DCV 10=DCV

With this menu displayed, use the cursor keys to select the channel, and use the range keys to select the desired measuring function for each channel:

DCV: DC volts
ACV: AC volts
Ω2W: 2-wire ohms
Ω4W: 4-wire ohms
FRQ: Frequency
TMP: Temperature
ALT: alternate function (see below)
JN1...JN5: Reference junction type
--- : None

Table 3-40
CONFIGURE CHANNELS menu structure

Menu item	Description
INTERNAL-CHANS SET INTERNAL CHANS 1=DCV 2=DCV 3=DCV 4=DCV 5=DCV	Defines internal functions: Use range and cursor keys to select channels and functions.
EXTERNAL INPUTS # EXTERNAL INPUTS=80 DEFAULT CHOOSE-FUNCTIONS SELECT CHAN=01 CHANNEL #01 FUNCTION	Sets number of external channels and functions: # of external channels (1-80). Selects default function for all external channels. Use to select channel functions. Select channel using range and cursor keys. Select function using cursor keys.
SAVE-ALT-FCN RESTORE-ALT-FUNCTION	Stores present function as alternate. Restores saved alternate function.

Ω4W function: The Ω4W function is valid only for channels 1-5. If selected, "PRD" (paired) will be shown on the corresponding paired channel 6-10 even if you just step through with the cursor keys and do not press ENTER. Once Ω4W is selected on channels 1 to 5, changing the assignment to a different function will de-assign the paired channel and change the function to "---" (none).

TMP function: Similarly, the TMP selection is valid only for channels 1-5 if the temperature sensor is a 4-wire RTD type. If a 2-wire RTD type is used, channels 6-10 could be assigned to the TMP function, but if the sensor type is later changed to 4-wire RTD, any channel from 6-10 will then be set to "---" (none).

JN functions: Note that there are five reference temperature functions available (JN1-JN5). Junction types are defined using the CONFIGURE TEMPERATURE menu.

NOTE

The JN functions in the internal menu are intended for use with a possible future internal thermocouple scanner card. The Model 2001-SCAN internal scanner card is not intended to be used with thermocouples.

No function (---): Selecting none (---) effectively removes that channel from the scan list. When scanning, the instrument will skip any channels that have no function defined.

EXTERNAL-INPUTS: This menu item allows you to select measurement functions for external scanner cards used with the Model 2001 Multimeter. When the EXTERNAL-INPUTS menu item is selected, the instrument will prompt you to enter the number of channels being used:

```
# EXTERNAL INPUTS=80
```

Use the cursor and range keys to select the number of channels (1-80), then press ENTER. Once the number of inputs is selected, you will be prompted for channel functions:

```
SET CHAN FUNCTIONS
DEFAULT  CHOOSE-FUNCTIONS
```

Briefly, these menu items allow you to select the following:

Default: This selection assigns the presently selected measurement function to all external channels.

Choose-Function: This menu choice allows you to define functions for each external channel through the following prompt:

```
SELECT CHAN= 01 (DCV)
```

Select the channel to be programmed using the range and cursor keys, then press ENTER. The instrument will display available functions:

```
CHANNEL#01 FUNCTION
DCV  ACV  DCI  ACI  Ω2W  Ω4W  FRQ  TMP ▶
◀ ALT  JN1  JN2  JN3  JN4  JN5  ---
```

Use the cursor keys to select the desired function, then press ENTER. Repeat the procedure for every external channel to be defined.

SAVE-ALT-FCN/RESTORE-ALT-FCN: An ALT (alternate) function is one that cannot be directly accessed with one of the eight function keys. For example, assume that you select the ACV peak function using CONFIG-ACV. You can then use SAVE- ALT to assign peak ACV to the ALT function. Whenever the ALT function is encountered in the scan list, the instrument will switch to the ACV peak function for that channel even if the instrument is measuring a different type of ACV (RMS for example).

You can also use the ALT function to store an existing main function but with a different set of operating parameters. For example, you could set up a specific set of operating parameters for the straight DCV function and a second DCV setup as the ALT function. This arrangement allows you to specify changes in virtually any measurement parameter from channel to channel even if the measurement functions are the same.

NOTE

Some functions may not be compatible with certain scanner cards. For example, you should not use the DCI and ACI functions with the Model 2001-SCAN internal scanner card.

SAVE-ALT-FCN: Stores the presently selected function and all its configured settings as the ALT function.

RESTORE-ALT-FCN: Restores the function that was saved as the ALT function and all associated settings as if a normal function change were taking place.

3.11.5 Using CONFIG-SCAN to configure scanning

CONFIG-SCAN operation

CONFIG-SCAN allows you to configure the following scanner aspects:

- Select the internal or external channel list for scanning.
- Enable ratio and delta operation.

SCAN OPERATION menu

Table 3-41 summarizes the SCAN OPERATION menu structure, which is discussed in more detail in the following paragraphs. See paragraph 3.3 for more information on menu navigation.

Table 3-41
SCAN OPERATION menu structure

Menu item	Description
INTERNAL	Enables internal scanning.
EXTERNAL	Enables external scanning.
RATIO	Enables ratio mode (internal).
MEASURE	Selects measure channel.
REFERENCE	Selects reference channel.
FUNCTION	Selects ratio function.
DELTA	Enables delta mode (internal).
MEASURE	Selects measure channel.
REFERENCE	Selects reference channel.
FUNCTION	Selects delta function.

Pressing CONFIG-SCAN will display the following menu:

SCAN OPERATION
INTERNAL EXTERNAL RATIO DELTA

These choices select the action the instrument will take when it is triggered.

INTERNAL: This selection enables scanning with the internal scanner card. When this selection is chosen, the Model 2001 will change to the function specified for the first channel and then close the channel and take a reading. When the next trigger is received, the instrument will open the present channel, change to the specified measuring function for the next channel, and then close the channel and take a reading. The process repeats until all channels in the list are scanned.

The instrument defaults to this selection if it detects a scanner card on power-up.

EXTERNAL: This menu selection enables scanning with an external scanner card located in a switching mainframe. This selection operates in a manner similar to INTERNAL except that the internal scanner is not used. When this menu item is selected, the instrument will immediately change to the selected measuring function for the first channel. When the multimeter is triggered, it will take a measurement and then change to the measurement function for the next channel. This process repeats until all channels in the scan list are scanned.

The instrument defaults to this selection if it does not detect a scanner card on power-up.

RATIO/DELTA: Either of these two selections configures the Model 2001 to measure the two specified internal scanner channels and then compute the ratio or difference (delta) between them. When RATIO or DELTA is selected, the instrument will close the scanner reference channel and then wait for a trigger. When the reading is triggered, the unit will make a measurement on the reference channel, switch to the measurement channel, and then take a second measurement. After measuring the measurement channel, the unit will compute and display the ratio or delta value, and switch back to the reference channel to wait for the next trigger.

RATIO/DELTA channel selection: To select channels for RATIO and DELTA, select RATIO or DELTA as appropriate.

Selecting RATIO will display the following menu and allow you to set the measure or reference channel:

CONFIGURE RATIO
MEASURE REFERENCE FUNCTION

Selecting MEASURE will display the following:

RATIO MEASURE CHAN
CH1 2 3 4 5 6 7 8 9 10

Use the cursor keys to select the measure channel, then press ENTER.

Similarly selecting REFERENCE will display:

RATIO REFERENCE CHAN
CH1 2 3 4 5 6 7 8 9 10

Again, use the cursor keys to select the channel to be used as the ratio reference channel, then press ENTER.

The FUNCTION menu appears as follows:

SET RATIO FUNCTION
DCV Ω2 Ω4

Use the cursor keys to select the desired function, then press ENTER.

Selections for DELTA measure and reference channels, and function are essentially the same, except that you would select DELTA under the SCAN OPERATION menu.

Ratio and Delta computation: During configuration, one channel is defined as the reference channel, and a second channel is defined as the measurement channel. Ratio and delta are computed from signals measured on these channels as follows:

$$\text{Ratio} = \frac{\text{Measurement}}{\text{Reference}}$$

$$\text{Delta} = \text{Measurement} - \text{Reference}$$

3.11.6 Using SCAN to configure scan parameters

Once an internal or external scan list is enabled, you use the SCAN key to configure internal or external scanning. The menu structure of Figure 3-42 shows the procedure.

The procedure changes scan layer parameters in the trigger model. When scanning is disabled by the EXIT key, the trigger model is restored to its pre-scanning configuration.

3.11.7 Starting and stopping scanning

Internal and external scanning

After an internal or external scan is configured, pressing the ENTER key from the SCAN menu starts scanning. Pressing the EXIT key disables scanning. An internal or external scan cannot be temporarily disabled.

Ratio/delta measurements

After ratio or delta measurements are selected from the CONFIG-SCAN menu, the SCAN, TRIG, and EXIT keys control scanning. Press the SCAN key to start the operation, as shown in Figure 3-43.

Manual scanning

When using internal scanning, you can manually scan channels by pressing the ◄ or ► keys. To use this feature, first close a channel by using the CLOSE-CHANNEL option accessible with the CHAN key. Use ► to increment channels, or use ◄ to decrement channels. Hold down either key to continuously scan through channels manually.

Adjacent channel display

The multiple display mode can be used to display the two adjacent channels only when manually controlling channels. To use this feature, first manually close the desired channel, then press PREV to display alternate channels. You can then use the ◄ and ► keys to scroll through channel displays normally.

NOTE

The adjacent channel display mode cannot be used when scanning channels automatically using the internal or external scan list.

As an example, assume that you close channel 5 using the CHAN key. With the multiple display enabled, channels 4 and 6 will appear on the lower display line.

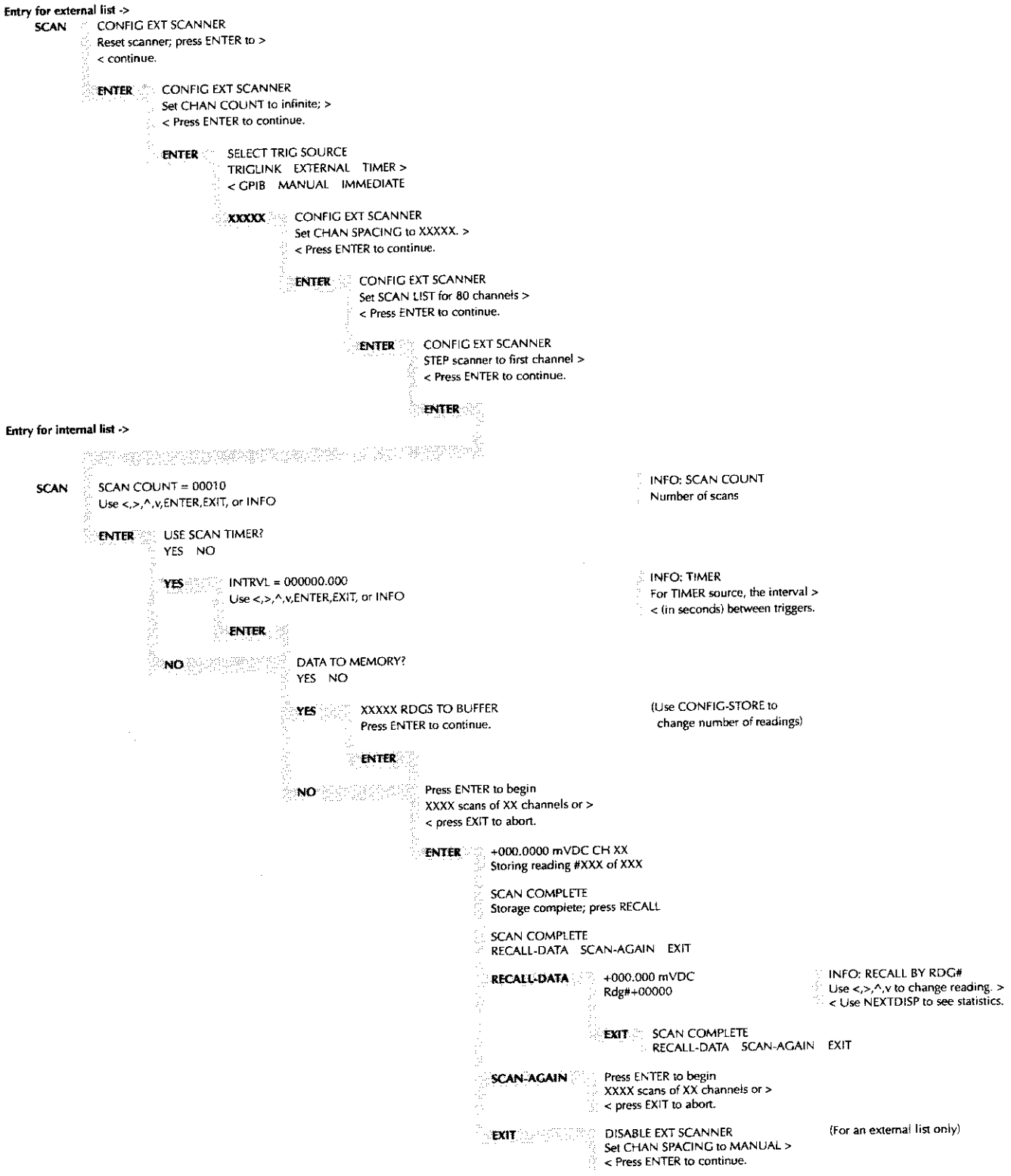


Figure 3-42
SCAN key menu structure

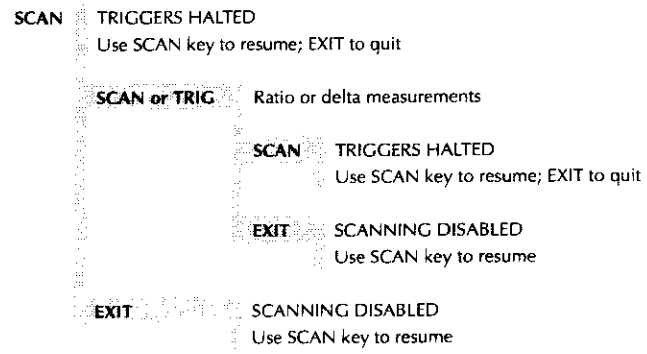


Figure 3-43
SCAN key menu structure for ratio and delta

3.11.8 Scanner operation examples

The following paragraphs give step-by-step procedures for various scanner operating modes.

Closing and opening channels

Use the front panel CHAN key to close and open specific channels on the internal scanner card as follows:

1. From normal display, press the CHAN key. The instrument will display the following menu:

   CHANNEL SELECTION
   CLOSE-CHANNEL OPEN-ALL-CHANNELS

2. Select CLOSE-CHANNEL, then press ENTER. The Model 2001 will display the following prompt:

   ENTER CHANNEL# 01 (1-10)

3. Use the cursor and range keys to select the channel you wish to close (1-10), then press ENTER. Any previously closed channel will open, and the selected channel will close.
4. To open the close channel, select OPEN-ALL-CHANNELS in the CHANNEL SELECTION menu, then press ENTER.

Manual scanning and using the multiple display

The ◄ and ► keys can be used to manually scan through channels on the internal scanner card. The multiple display mode can also be used to display adjacent scanner channels while scanning manually.

NOTE

Adjacent channel display cannot be used when the instrument is scanning automatically.

Follow the steps below to scan manually and display alternate channels.

1. Manually close a channel by using the CLOSE-CHANNEL selection accessible with the CHAN key.
2. Press the ► key to manually increment channels, or press the ◄ key to manually decrement channels. Hold down either key to manually scan through channels continuously. Auto-repeat of cursor keys is disabled when adjacent channel next display is shown.
3. With the unit in the normal display mode, press the PREV key to enable adjacent channel display. Note that the lower and upper adjacent channel readings will appear on the lower display section.
4. Manually scan through channels with the ◄ or ► key. Note that the adjacent display channel numbers track the channel on the main display.
5. Press the NEXT key to cancel the alternate channel display mode, then use the CHAN key to open channels when done scanning.

Scanning internal channels

Internal channels are scanned by configuring scan channels and programming the Model 2001 to perform a scan. The following steps demonstrate the basic procedures for performing basic scanning using the internal scanner card.

NOTE

Depending on selected trigger modes, it may be necessary to trigger the instrument to perform scanning. Refer to paragraph 3.7 for detailed information on triggering.

Step 1: Configure channels

Use CONFIG-CHAN to select the measurement functions for each of the scanner channels as follows:

1. Press CONFIG-CHAN. The instrument will display the following menu:

   CONFIGURE CHANNELS
   INTERNAL-CHANS EXTERNAL-INPUTS ►
   ◄ SAVE-ALT-FCN RESTORE-ALT-FCN

2. Select INTERNAL-CHANS, then press ENTER. The multimeter will display the following menu:

   SET INTERNAL CHANS
   1=DCV 2=DCV 3=DCV 4=DCV 5=DCV ▶
   ◀ 6=DCV 7=DCV 8=DCV 9=DCV 10=DCV

3. Using the cursor keys, select the desired channel (press the right cursor key to display channels 6 through 10).
4. Using the range keys, select the desired measurement function: DCV, ACV, Ω2W, Ω4W, FRQ, TMP, ALT, JN1, JN2, JN3, JN4, JN5, --- (None).
5. Repeat steps 3 and 4 for each of the channels you wish to scan. Note: Select --- (none) to omit a channel from the scan list.
6. Examine all ten channels to verify omitted channels and paired (PRD) channels.
7. After selecting all measurement functions, press ENTER to return to normal display.

Step 2: Select internal scan list

Use CONFIG-SCAN to select the internal scan list as follows:

1. Press CONFIG-SCAN. The Model 2001 will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL RATIO DELTA

2. Select INTERNAL, then press ENTER.

Step 3: Start scan

After configuring channels and scan list, simply press the SCAN key to begin scanning. The instrument will prompt you to configure the scan count and scan timer, and to enable data storage. Pressing the ENTER key will scan through selected channels and make a measurement on each channel using the previously selected measurement function for each channel. When the scan has completed, you can recall stored data and/or scan again. To disable scanning, press the EXIT key.

Using ratio and delta

The Model 2001 can display the difference (DELTA) or quotient (RATIO) between the signal on any two internal scanner channels. The following paragraphs discuss ratio and delta calculations and also give step-by-step procedures for using ratio and delta.

When the instrument is first placed in the ratio or delta mode, it will close the scanner reference channel and then wait for a trigger. When the reading is triggered, the unit will make a measurement on the reference channel, switch to the measurement channel, and then take a second measurement. After measuring the measurement channel, the unit will compute and display the ratio or delta value, and switch back to the reference channel to wait for the next trigger.

The steps below outline the basic procedure for making ratio measurements. The procedure for delta measurements is essentially the same, except that you would select DELTA in the appropriate menu.

Step 1: Connect inputs

Input signals must be connected to the two channels you intend to define as measurement and reference channels.

Step 2: Define measurement channel

1. From normal display, press CONFIG-SCAN. The instrument will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL RATIO DELTA

2. Select RATIO, then press ENTER. The Model 2001 will display the following:

   CONFIGURE RATIO
   MEASURE REFERENCE FUNCTION

3. Select MEASURE, then press ENTER. The instrument will display the following:

   RATIO MEASURE CHAN
   CH1 2 3 4 5 6 7 8 9 10

4. Using the cursor keys, select the channel you wish to define as the measure channel, then press ENTER.

Step 3: Define reference channel

1. From the CONFIGURE RATIO menu, select REFERENCE, then press ENTER. The Model 2001 will display the following message:

   RATIO REFERENCE CHAN
   CH1 2 3 4 5 6 7 8 9 10

2. Using the cursor keys, select the channel to be defined as the reference channel, then press ENTER.

Step 4: Select measurement function

1. From the CONFIGURE RATIO menu, select FUNCTION, then press ENTER. The instrument will display the following:

   SET RATIO FUNCTION
   DCV Ω2 Ω4

Note that only DC volts, and 2- and 4-wire ohms functions are available for ratio and delta modes.

2. Use the cursor keys to select the desired function, then press ENTER.
3. Press EXIT as necessary to return to normal display.

Step 5: Display ratio readings

Once the reference channel, measurement channel, and ratio function have been defined, press SCAN to halt triggers, then press TRIG or SCAN to display ratio readings. The instrument will automatically display ratio readings computed from signals applied to the reference and measurement channels. If you have selected a trigger mode that requires a separate trigger for each reading, you will, of course, have to trigger the instrument to obtain each ratio reading (refer to paragraph 3.7 for details on triggering).

Step 6: Disabling and cancelling the ratio mode

You can disable the ratio mode by pressing EXIT while ratio readings are being displayed. To cancel the ratio mode, press CONFIG-SCAN, then select another option under the SCAN-OPERATION menu.

RTD temperature measurements

The following paragraphs outline the basic procedures for making RTD temperature measurements using the internal scanner. For more detailed information on temperature measurements in general, refer to paragraph 3.4.5.

Step 1: Connect RTD probes

Connect RTD probes to the scanner using the basic resistance connections outlined in the scanner card manual. For 4-wire probes, pair the connections as follows:

- Channels 1 and 6: probe #1
- Channels 2 and 7: probe #2
- Channels 3 and 8: probe #3
- Channels 4 and 9: probe #4
- Channels 5 and 10: probe #5

Step 2: Select sensor type and units

Use CONFIG-TEMP to select the RTD sensor type and the units you wish to display. See paragraph 3.4.5 for details.

Step 3: Configure channels

1. Press CONFIG-CHAN. The instrument will display the following:

   CONFIGURE CHANNELS
   INTERNAL-CHANS EXTERNAL-INPUTS ▶
   ◀ SAVE-ALT-FCN RESTORE-ALT-FCN

2. Select INTERNAL-CHANS. The Model 2001 will display the following:

   SET INTERNAL CHANNELS
   1=DCV 2=DCV 3=DCV 4=DCV 5=DCV ▶
   ◀ 6=DCV 7=DCV 8=DCV 9=DCV 10=DCV

3. Use the cursor and range keys to select channels and functions. Set the function type to TMP for all channels connected to RTD probes. Select --- (none) for channels without probes connected.
4. Press ENTER to return to normal display.

Step 4: Configure scan

1. From normal display, press CONFIG-SCAN. The instrument will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL RATIO DELTA

2. Select INTERNAL, then press ENTER.

Step 5: Scan channels

To start scanning, press the SCAN key and program the scan count, scan timer, and data storage. Then press ENTER. When the scan has completed, you can recall stored data and/or scan again. Press EXIT while scanning to interrupt data storage and disable scanning.

Using the scanner with the data storage buffer

The Model 2001 internal data storage buffer can be used to store readings taken while using the scanner. The following paragraphs outline the basic steps necessary for data storage of scanner readings. Refer to paragraph 3.8 for additional information on using the data storage buffer.

Step 1: Configure channels

1. Press CONFIG-CHAN. The instrument will display the following:

   CONFIGURE CHANNELS
   INTERNAL-CHANS EXTERNAL-INPUTS ▶
   ◀ SAVE-ALT-FCN RESTORE-ALT-FCN

2. Select INTERNAL-CHANS. The Model 2001 will display the following:

   SET INTERNAL CHANNELS
   1=DCV 2=DCV 3=DCV 4=DCV 5=DCV ▶
   ◀ 6=DCV 7=DCV 8=DCV 9=DCV 10=DCV

3. Use the cursor and range keys to select channels and functions, then press ENTER when you have set all functions and channels.

4. Press EXIT to return to normal display.

Step 2: Configure scan

1. From normal display, press CONFIG-SCAN. The instrument will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL RATIO DELTA

2. Select INTERNAL, then press ENTER.

Step 3: Configure buffer

1. Press CONFIG-STORE. The unit will display the following:

   CONFIG DATA STORE
   BURST-MODE DATA CONTROL ▶
   ◀ CLEAR-ALL COUNT FEED

2. Select COUNT, then press ENTER. The instrument will display the following:

   SET BUFFER SIZE
   ENTER-COUNT USE-TRIGGER-MODEL

3. Select ENTER-COUNT and press ENTER to view the following:

   BUFFER SIZE = 00010

4. Using the cursor and range keys, select the number of readings to store. Usually, this number should be the same of the number of channels you are scanning. For example, if you are using all 10 scanner channels, select 10 readings. Note that channel information is not saved with compact data grouping.
5. Press ENTER to complete programming data storage; then EXIT to return to normal display.

Step 4: Trigger scan

Press SCAN to program the scan count, scan timer, and data storage. Then press ENTER. The unit will cycle through the channels, stopping to take and store a reading on each channel.

Step 5: Recall readings

From the SCAN COMPLETE menu, select the RECALL-DATA option to display readings stored in the buffer. Use the cursor and range keys to select the reading number to display. Note that the instrument will display the channel number for each buffer reading in addition to other pertinent buffer information. Press EXIT to return to the SCAN COMPLETE menu.

External scanning

Follow the general steps below to set Model 2001 modes for external scanning.

Step 1: Make scanner card connections

Be sure to connect your scanner signal lines and trigger cables as appropriate. See the scanner card documentation for details on signal connections. Paragraphs 3.7.6 and 3.7.7 provide information on external triggering and using the trigger link.

Step 2: Configure trigger parameters

Using CONFIG-TRIG, select the required trigger layer parameters based on the desired scanner and multimeter operation. See paragraph 3.7 for Model 2001 trigger parameter details.

Step 3: Configure external channels and functions

1. From normal display, press CONFIG-CHAN. The instrument will display the following:

   CONFIGURE CHANNELS
   INTERNAL-CHANS EXTERNAL-INPUTS ▶
   ◀ SAVE-ALT-FCN RESTORE-ALT-FCN

2. Select EXTERNAL-INPUTS, then press ENTER. The Model 2001 will prompt you to enter the number of channels:

   # EXTERNAL INPUTS=80

3. Use the range and cursor keys to set the number of external channel you will be using, then press ENTER. The instrument will prompt you to set functions:

   SET CHAN FUNCTIONS
   DEFAULT CHOOSE-FUNCTIONS

4. If you wish to use the current default function for all channels, select DEFAULT, then press ENTER.
5. If you intend to program a separate function for each channel, choose CHOOSE-FUNCTIONS, then press ENTER. The instrument will prompt you for a channel number, as in the following typical display:

   SELECT CHAN=01 (DCV)

6. Use the cursor and range keys to select a channel, then press ENTER. Select the desired function, then press ENTER. Repeat the procedure for all channels to be defined.
7. Press EXIT as necessary to return to normal display.

Step 4: Enable external scanning

8. From normal display, press CONFIG-SCAN. The instrument will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL RATIO DELTA

9. Select EXTERNAL, then press ENTER.

Step 5: Start scan

Press SCAN for instructions to set up the external scanner, program the scan count, scan timer, and data storage. Then press ENTER to start scanning. When the scan has completed you can recall stored data and/or scan again. Press EXIT to interrupt data storage and disable scanning.

3.12 Menu

The main menu accesses the various instrument operations for which there are no dedicated keys, such as setup storage, IEEE-488 setup, calibration, self-test, and limits. The main menu structure is summarized in Table 3-42.

The top level of the main menu is displayed by placing the instrument in the reading display state, and then pressing the MENU key. The main menu options are shown as follows:

MAIN MENU
SAVESETUP GPIB CALIBRATION ▶
◀ TEST LIMITS STATUS-MSG GENERAL

Some general rules to navigate the menu levels are given in paragraph 3.3.

Table 3-42
Main menu structure

Menu item	Description
SAVESETUP	Setup menu:
SAVE	Save setup at a memory location (up to 1, 5, or 10).
RESTORE	Return 2001 to setup stored at a memory location (up to 1, 5, or 10).
POWERON	Power-on Menu:
BENCH	Power on to bench default setup conditions.
GPIB	Power on to GPIB default setup conditions.
USER-SETUP-NUMBER	Power on to setup stored at a memory location (up to 1, 5, or 10).
RESET	Reset Menu:
BENCH	Return 2001 to bench default setup.
GPIB	Return 2001 to GPIB default setup.
GPIB	GPIB/Printer Setup menu:
ADDRESSABLE	Check/change IEEE-488 bus address (0-30).
TALK-ONLY	GPIB/Printer Talk-only mode menu:
FEED	GPIB Output Feed menu:
AFTER-CALC	Specify reading after math operation.
BEFORE-CALC	Specify reading before math operation.
NONE	Specify no readings.
INTERFACE	Select printer interface.
IEEE-488	Specify IEEE-488 printer.
CENTRONICS	Specify Centronics parallel printer.
INTERVAL	Specify printing interval (every reading to 1 out of 9999).
FORMFEED	Formfeeds menu:
CONTROL	Enable/disable page breaks.
SET-PAGE-SETUP	Set number line between form feeds (1-255).
ELEMENTS	Select GPIB data elements (reading, units, reading number, channel number, timestamp, status).
STATUS	Display IEEE-488 bus status byte.
CALIBRATION	Calibration menu:
COMPREHENSIVE	Perform DC and AC calibration.
AC-ONLY-CAL	Perform AC calibration only (open-circuit).
CALIBRATION-DATES	Check/change calibration date.
TEST	Self-test menu:
BUILT-IN-TEST	Test analog and digital boards.
AUTOMATIC	Run all tests automatically.
MANUAL	Select tests to run.
DIAGNOSTICS	Factory diagnostic tests.
FRONT-PANEL-TESTS	Test display board.
KEYS	Verify operation of front panel keys.
DISPLAY-PATTERNS	Verify operation of display.

Table 3-42 (cont.)
Main menu structure

Menu item	Description
LIMITS	Limits menu:
LIMIT-SET-1	Limit-Set-1 menu:
CONTROL	Enable/disable limit set #1.
LOLIM1	Set value of low limit #1.
HILIM1	Set value of high limit #1.
LIMIT-SET-2	Limit-Set-2 menu:
CONTROL	Enable/disable limit set #2.
LOLIM2	Set value of low limit #2.
HILIM2	Set value of high limit #2.
STROBE-CONTROL	Enable/disable limit strobe signal of digital output #4 when trigger occurs.
PASS-PATTERN	Specify patterns on digital outputs to signify limits pass.
STATUS-MSG	Enable/disable status message mode.
GENERAL	General menu:
DIGITAL-I/O	Digital I/O menu:
OUTPUT-STATE	Check/change states of digital output lines.
OUTPUT-SENSE	Check/change sense of digital output lines.
INPUT	Read digital input line.
SERIAL#	Display serial number, memory option SCPI version, and firmware revisions.
AUTOZERO	Disable or enable normal (after every reading) or synchronous (every 200ms) autozero mode.
LINE-SYNC	Enable/disable line synchronization of measurements.
DECIMAL	Select period or comma for display of decimal point.

3.12.1 SAVESETUP

The SAVESETUP option of the main menu is used for the following operations:

- To save the present instrument configuration in non-volatile memory.
- To restore the instrument to a previously saved instrument configuration.
- To set the instrument's power-on configuration.
- To reset the instrument to a factory default configuration.

To display the SAVESETUP menu from the top level of the main menu, use the cursor keys (◄ and ►) to place the cursor on SAVESETUP, then press ENTER. The following is displayed:

SETUP MENU
SAVE RESTORE POWERON RESET

SAVE

Use this menu item to save the present instrument setup in a specific memory location. Depending on the memory option, you can store up to one (STD), five (MEM1), or ten (MEM2) setups in non-volatile memory. The installed memory option is displayed on power-up, and in the SERIAL# option of the General Menu (see paragraph 3.12.7).

1. To select SAVE, place the cursor on it and press ENTER. The following message is displayed for a Model 2001/MEM1:

   SAVE SETUP #0 (4 max)

   Note that the numbering of the setup locations starts with SETUP#0.
2. To save the present instrument setup in the displayed memory location, press ENTER. After displaying the message "Saving Setup n", the instrument returns to the SETUP MENU.
3. To save the present setup in a different memory location (for those units with optional memory), use the RANGE ▲ and ▼ keys to increment and decrement the location number, then press ENTER. The instrument returns to the SETUP MENU.

RESTORE

Use this menu item to return the instrument to a setup that was previously stored in memory. Depending on the memory option, up to one (STD), five (MEM1), or ten (MEM2) setups can be saved in non-volatile memory.

1. To select RESTORE, place the cursor on it and press ENTER. The following message is displayed for a Model 2001/MEM1:

   RESTORE #0 (4 max)

   Note that the numbering of the setup locations starts with SETUP#0.
2. To restore the instrument setup saved at the displayed memory location, press ENTER. The instrument returns to the normal display of readings.
3. To restore a different setup (for those units with optional memory), use the RANGE ▲ and ▼ keys to increment and decrement the location number, then press ENTER. The instrument returns to the normal display of readings.

POWERON

Use this menu item to select the instrument setup that goes into effect on power-on.

The instrument can be set to power on to the factory bench defaults, the factory GPIB defaults, or to a user setup stored at a specific memory location.

To select the POWERON menu item, place the cursor on POWERON and press ENTER. The following menu is displayed:

SET POWER-ON DEFAULT
BENCH GPIB USER-SETUP-NUMBER

BENCH: With this option, the instrument returns to the bench default conditions (see Table 3-43) the next time it is turned on. To select the bench defaults, place the cursor on BENCH and press ENTER. The instrument returns to the SETUP MENU.

GPIB: With this option, the unit returns to the GPIB default conditions (see Table 3-43) the next time it is turned on. To select the GPIB defaults, move the cursor to GPIB and press ENTER. The instrument returns to the SETUP MENU.

USER-SETUP-NUMBER: Using this option, the instrument powers on to a user setup saved at a specific memory location. To select a user setup, place the cursor on USER-SETUP-NUMBER and press ENTER. The following message is displayed for the Model 2001/MEM1:

PWRON DFLT#0 (4 max)

1. To power on to the setup stored at the displayed memory location, press ENTER. The instrument returns to the SETUP MENU.
2. To power on to setup stored at a different memory location (for those units with optional memory), use the RANGE ▲ and ▼ keys to increment and decrement the location number, then press ENTER.

RESET

Use this menu option to reset the instrument to the bench or GPIB default conditions (see Table 3-43).

To select RESET, place the cursor on RESET and press ENTER. The following menu is displayed:

RESET ORIGINAL DFLTS
BENCH GPIB

BENCH: With this option, the instrument returns to the bench default conditions (see Table 3-43). To select the option, place the cursor on BENCH and press ENTER. The instrument returns to the normal display of readings after requesting an ENTER to confirm your selection.

GPIB: With this option, the unit returns to the GPIB default conditions (see Table 3-43). To select the option, move the cursor to GPIB and press ENTER. The instrument returns to the normal display of readings after requesting an ENTER to confirm your selection. Note that the instrument goes to the Idle state.

Table 3-43
Factory default conditions

Function or operation	Bench default	GPIB default
AC current:		
AC-type	RMS	RMS
Coupling	AC	AC
Filter	Off	Off
Auto	On	Off
Averaging	Off	Off
Readings	10	10
Advanced	On	On
Readings	10	10
Noise tolerance level	5%	5%
Filter mode	Moving	Repeat
Range	Auto	Auto
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (5.5d)	Auto (5.5d)
Speed	Normal (1 PLC)	Normal (1 PLC)
AC voltage:		
AC-type	RMS	RMS
Peak spikes window	0.1sec	0.1sec
Coupling	AC	AC
Filter	Off	Off
Auto	On	Off
Averaging	Off	Off
Readings	10	10
Advanced	On	On
Readings	10	10
Noise tolerance level	5%	5%
Filter mode	Moving	Repeat
Range	Auto	Auto
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (5.5d)	Auto (5.5d)
Speed	Normal (1 PLC)	Normal (1 PLC)
Units	Volts	Volts
dB reference	1V	1V
dBm reference	75Ω	75Ω
Autozero	On (Normal)	On (Normal)
Buffer:		
Burst mode	No effect	No effect
Control	No effect	No effect
Count	No effect	No effect
Data group	No effect	No effect
Feed	No effect	No effect

Table 3-43 (cont.)
Factory default conditions

Function or operation	Bench default	GPIB default
DC current:		
Filter	On	Off
Auto	On	Off
Averaging	Off	Off
Readings	10	10
Advanced	On	On
Readings	10	10
Noise tolerance level	1%	1%
Filter mode	Moving	Repeat
Measurement mode	Normal	Normal
Range	Auto	Auto
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (6.5d)	Auto (6.5d)
Speed	Normal (1 PLC)	Normal (1 PLC)
DC voltage:		
Filter	On	Off
Auto	On	Off
Averaging	Off	Off
Readings	10	10
Advanced	On	On
Readings	10	10
Noise tolerance level	1%	1%
Filter mode	Moving	Repeat
Range	Auto	Auto
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (6.5d)	Auto (6.5d)
Speed	Normal (1 PLC)	Normal (1 PLC)
Digital I/O:		
Output states	No effect	No effect
Output sense	No effect	No effect
Frequency:		
Coupling	AC	AC
Maximum signal level:		
Function	Voltage	Voltage
Voltage level	10V	10V
Current level	1mA	1mA
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (5d)	Auto (5d)
Terminals	Voltage	Voltage
Trigger level	0.0	0.0
Function	DCV	DCV

Table 3-43 (cont.)
Factory default conditions

Function or operation	Bench default	GPIB default
Limits:		
Limit set #1	Off	Off
Low limit #1	-1.0	-1.0
Low limit #1 action	0	0
High limit #1	1.0	1.0
High limit #1 action	0	0
Limit set #2	Off	Off
Low limit #2	-1.0	-1.0
Low limit #2 action	0	0
High limit #2	1.0	1.0
High limit #2 action	0	0
Strobe control	Off	Off
Pass pattern	0	0
Line synchronization	Off	Off
Math	Off	Off
Function	Percent	Percent
Reference for percent	1.0	1.0
Scale factor for mX+b	1.0	1.0
Offset for mX+b	0.0	0.0
Resistance (2-wire):		
Filter	On	Off
Auto	On	Off
Averaging	Off	Off
Readings	10	10
Advanced	On	On
Readings	10	10
Noise tolerance level	1%	1%
Filter mode	Moving	Repeat
Offset compensation	Off	Off
Range	Auto	Auto
Maximum autorange	1GΩ	1GΩ
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (6.5d)	Auto (6.5d)
Speed	Normal (1 PLC)	Normal (1 PLC)

Table 3-43 (cont.)
Factory default conditions

Function or operation	Bench default	GPIB default
Resistance (4-wire):		
Filter	On	Off
Auto	On	Off
Averaging	Off	Off
Readings	10	10
Advanced	On	On
Readings	10	10
Noise tolerance level	1%	1%
Filter mode	Moving	Repeat
Offset compensation	Off	Off
Range	Auto	Auto
Maximum autorange	200kΩ	200kΩ
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (6.5d)	Auto (6.5d)
Speed	Normal (1 PLC)	Normal (1 PLC)
Scanning:		
Channels	No effect	No effect
Scan list:		
Internal list	No channels	No channels
External list	No channels	No channels
Function	DC voltage	DC voltage
Scan operation	None	None
Ratio:		
Reference channel	5	5
Measure channel	10	10
Function	DC voltage	DC voltage
Delta:		
Reference channel	5	5
Measure channel	10	10
Function	DC voltage	DC voltage

Table 3-43 (cont.)
Factory default conditions

Function or operation	Bench default	GPIB default
Temperature:		
Filter	On	Off
Auto	On	Off
Averaging	On	On
Readings	10	10
Filter mode	Moving	Repeat
Relative	Off	Off
Value	0.0	0.0
Resolution	Auto (0.01°C)	Auto (0.01°C)
RTDs:		
Type	PT385	PT385
Resistance at 0°C	100Ω	100Ω
Alpha	0.00385	0.00385
Beta	0.111	0.111
Delta	1.507	1.507
Sensor	4-wire RTD	4-wire RTD
Speed	Normal (1 PLC)	Normal (1 PLC)
Thermocouples:		
Type	J	J
Reference junction	Simulated	Simulated
Default temperature	23°C	23°C
Real junction temp. coefficient	10mV/°C	10mV/°C
Offset	0mV @ 0°C	0mV @ 0°C
Units	°C	°C
Triggers:	Armed	Idled
arm layer:		
Source	Immediate	Immediate
Triglink input	Line 2	Line 2
Triglink output	Line 1	Line 1
Count	1	1
Control	Acceptor	Acceptor
scan layer:		
Source	Immediate	Immediate
Triglink input	Line 2	Line 2
Triglink output	Line 1	Line 1
Delay	0	0
Count	Infinite	1
Control	Acceptor	Acceptor
measure layer:		
Source	Immediate	Immediate
Triglink mode	Asynchronous	Asynchronous
Triglink input	Line 2	Line 2
Triglink output	Line 1	Line 1
Timer	0.1sec	0.1sec
Delay	0	0
Count	Infinite	1
Control	Acceptor	Acceptor

3.12.2 GPIB

The GPIB menu is used for the following operations:

- To view or change the IEEE-488 address.
- To select the talk-only mode and its parameters.
- To select the data elements to send.
- To view the status byte of the instrument.

To display the GPIB menu from the top level of the main menu, use the cursor keys (◄ and ►) to place the cursor on GPIB, then press ENTER. The following is displayed:

GPIB/PRINTER SETUP
ADDRESSABLE TALK-ONLY ►
◄ ELEMENTS STATUS

Changing between "Addressable" and "Talk-only" causes triggers to be halted.

ADDRESSABLE

With the instrument set for "Addressable", it can listen and talk to a bus controller. This menu item lets you check and/or change the IEEE-488 address of the instrument.

At the factory the address is set to 16, but it can be changed to any value from 0 to 30. To select ADDRESSABLE, place the cursor on it and press ENTER. If the address is presently set to 16, the following message is displayed:

ADDRESS = 16 (0-30)

1. To retain the displayed address, press ENTER or EXIT. The instrument returns to the GPIB/PRINTER SETUP menu.
2. To change the address, use the RANGE ▲ and ▼ keys to increment and decrement the number, then press ENTER. The instrument returns to the GPIB/PRINTER SETUP menu.

TALK-ONLY

In the talk-only mode, the Model 2001 ignores commands from the bus and merely outputs data, as requested by the printer. When the instrument is in the talk-only mode, the TALK annunciator turns on.

To select the talk-only mode, place the cursor on TALK-ONLY and press ENTER. The following menu is displayed:

GPIB/PNTR TALK-ONLY
FEED INTERFACE INTERVAL FORMFEED

FEED: This item has options that select the type of readings printed: readings after a math operation is performed (AFTER-MATH), readings before a math operation (BEFORE-MATH), or no readings.

INTERFACE: With the IEEE-488 option of this item, data elements are sent to an IEEE-488 bus printer set for listen always. With the CENTRONICS option, data elements are sent to a printer with a Centronics (parallel) interface. The printer must be connected with a Model 8530 IEEE-488 to Centronics Printer Adapter Cable.

INTERVAL: The INTERVAL option controls how often readings are printed (expressed as 1 out of nnnn readings).

FORMFEED: Use the FORMFEED option of the menu to enable or disable the sending of a formfeed character to the printer after printing a user-selectable number of lines per page (1-255 lines).

ELEMENTS

This menu item lets you select the data elements sent:

- Reading — The numeric value of the reading.
- Units — The units of the reading.
- Reading# — The buffer location of the reading.
- Chan# — The channel number the reading was taken on.
- Time-stamp — The elapsed time from the first buffered reading.
- Status — The reading status information (normal reading, measurement overflow, relative reading).

To select the ELEMENTS menu item, place the cursor on ELEMENTS and press ENTER. The following menu is displayed:

GPIB DATA ELEMENTS
READING=y UNITS=y READING#=y ►
◄ CHAN#=y TIMESTAMP=y STATUS=y

where a "y" designates "yes", which is sent, and an "n" designates "no", which is not sent. To retain the displayed selections, press ENTER or EXIT. The instrument returns to the GPIB/PRINTER SETUP menu.

To change a selection, use the ◄ and ► keys to move the cursor, then the RANGE ▲ and ▼ keys to select between "y" and "n". Press ENTER to retain your changes or EXIT to ignore them. In either case, the display returns to the GPIB/PRINTER SETUP menu.

STATUS

Use this menu item to view the IEEE-488 status byte. Refer to Section 4 (IEEE- 488 Reference) for information on the status byte. To select STATUS, place the cursor on STATUS and press ENTER. If, for example, all bits of the status byte are cleared, it is displayed as follows:

```
SHOW STATUS BYTE
MSB=0  EAV=0  QSB=0  MAV=0 ▶
◀ ESB=0  MSS=0  OSB=0
```

When finished viewing the status byte, press either ENTER or EXIT. The instrument returns to the GPIB/PRINTER SETUP menu.

The bits in the status byte are refreshed by exiting and re-entering its menu.

3.12.3 CALIBRATION

The CALIBRATION menu is used for the following operations:

- To perform comprehensive calibration.
- To perform AC self-calibration.
- To view or change the calibration date.

Some of the menu items are locked to prevent unintended changing of calibration constants. To display the CALIBRATION menu from the top level of the main menu, use the cursor keys (◀ and ▶) to place the cursor on CALIBRATION, then press ENTER. The following is displayed:

```
PERFORM CALIBRATION
COMPREHENSIVE  AC-ONLY-CAL ▶
◀ CALIBRATION-DATES
```

COMPREHENSIVE

The procedure for comprehensive calibration is locked; to enable it requires the CAL switch to be pressed. The procedure uses accurate calibration equipment to supply precise DC voltages and resistance values. Refer to the Model 2001 Calibration Manual for instructions.

AC-ONLY-CAL

Use this menu item to perform the AC self-calibration procedure. This procedure requires no external equipment and can be performed at any time by the user to ensure the accuracy of ACV and ACI measurements.

NOTE

The AC calibration constants generated by this procedure are not permanently stored. They are in effect only until the power is turned off. To permanently store AC calibration constants, refer to the Model 2001 Calibration Manual.

To perform an AC-only calibration, follow these steps:

1. The Model 2001 must be allowed to warm up for at least one hour before calibration.
2. Disconnect all test leads or cables from the front and rear INPUT and SENSE jacks.
3. To select AC-ONLY-CAL from the PERFORM CALIBRATION menu, place the cursor on AC-ONLY-CAL and press ENTER. The following message is displayed:

   ```
   AC CALIBRATION PHASE
   Open-circuit inputs; Press ENTER ▶
   ◀ to calibrate, or EXIT to abort
   ```

4. Press ENTER to begin AC calibration, which takes about six minutes to complete. During AC calibration, the instrument displays the following:

   ```
   Calibrating AC: Please wait
   ```

   NOTE

   All keypresses are locked out while a calibration step is in progress.

5. Once the process has successfully completed, the message below is displayed, and you can press ENTER or EXIT to return to a normal display:

   ```
   AC CAL COMPLETE
   Press ENTER or EXIT to continue.
   ```

CALIBRATION-DATES

Use this menu item to view or change the calibration dates. To select CALIBRATION-DATES, place the cursor on CALIBRATION-DATES and press ENTER. The following menu is displayed:

```
CALIBRATION DATES
VIEW  DISPLAY-AT-POWERUP  CHANGE
```

Use the VIEW option of the menu to display the last calibration date and the next calibration date. The DISPLAY-AT-POWERUP option controls whether the next calibration date is displayed during the power-up sequence.

The CHANGE option is locked, to enable it requires the CAL switch to be pressed. The option allows you to change the calibration date and next calibration date. Refer to the Model 2001 Calibration Manual for instructions.

3.12.4 TEST

The SELF-TEST MENU is used as a diagnostic tool to isolate problems with the Model 2001. Information on using these test procedures is included in the optional Model 2001 Repair Manual.

3.12.5 LIMITS

The LIMITS menu is used for the following operations:

- To set and control the limit values that determine the PASS/FAIL and HI/LO status of subsequent measurements.
- To set the digital output patterns that signify passing or failing limit checks.
- To enable/disable a binning strobe signal on digital output #4 for triggering a user-supplied device handler.

NOTE

Since the logic sense of the digital output lines is programmable (high-true or low-true), this discussion of limits uses the logical terms TRUE/FALSE and ON/OFF, rather than HIGH and LOW.

There are two sets of limits, each with high and low limit values. You can program and enable one or both limit sets. With both sets enabled, the values can overlap or one set can be included in the other. The only restriction is that, within the same set, the high limit must be greater than the low limit for a valid test.

The limit test is performed after mX+b and percent math operations. Unit prefixes are applied before the limit test, for example:

- Low limit = -1.0, High limit = 1.0.

  A 150mV reading equals 0.15V (PASS).
- Low limit = -1.0, High limit = 1.0.

  A 0.6kΩ reading equals 600Ω (FAIL).

Limit set #1 is available as a multiple display, which shows a bar graph and a pass/fail indication for the measurements. (Note: The PASS/FAIL indication is not available for ACV, ACI, and in-circuit current because other information is displayed in its place.) While the limits bar graph is displayed, the programmed values for limit set #1 can be viewed by pressing INFO.

The digital output lines can be programmed to reflect the results of limit tests. The first test that fails sets a programmable digital output pattern, where the test execution order is LOW1, HIGH1, LOW2, HIGH2. If all tests pass, another programmable pattern is set. (Also see DIGITAL I/O in paragraph 3.12.7.)

To display the LIMITS menu from the top level of the main menu, use the cursor keys (◄ and ►) to place the cursor on LIMITS, then press ENTER. The following is shown:

```
LIMITS MENU
LIMIT-SET-1  LIMIT-SET-2 ►
◄ STROBE-CONTROL  PASS-PATTERN
```

LIMIT-SET-1 and LIMIT-SET-2

These menu items are similar in that you can enable or disable either or both limit sets, and program the high and low limit values for either or both limit sets. For example, to select limit set #1, place the cursor on LIMIT-SET-1 and press ENTER. The following menu is displayed:

```
LIMIT SET #1 MENU
CONTROL  LOLIM1  HILIM1
```

CONTROL: This item enables or disables control of the digital output lines by the results of either or both limit set tests. For example, to let limit set #1 control the digital output lines, highlight the CONTROL item in the previous menu and press ENTER. Then highlight the ENABLE item in the next menu and press ENTER. The instrument returns to the LIMIT SET #1 MENU.

LOLIM1, HILIM1, LOLIM2, HILIM2: These items allow you to set values for the low and high limits, and the action performed on the digital output lines for each limit test failure.

To set a high or low limit value, place the cursor on the desired selection and press ENTER. For example, the LOLIM1 selection defaults to the following display:

```
LLIM1=+1.000000e+00
Use ◄ ,► , ▲, ▼, ENTER,EXIT, or INFO
```

Use the ◄ and ► keys and the RANGE ▲ and ▼ keys to move the cursor and increment and decrement the digits. Note that you must enter values in scientific notation. The

ENTER key selects your value and takes you to the next menu level:

```
LLIM #1 ACTION
DIGOUT1=OFF  2=OFF  3=OFF  4=OFF
```

With this menu, you select the action taken if low limit #1 is the first limit to be exceeded. The desired states of the digital outputs can be toggled between ON and OFF with the RANGE ▲ and ▼ keys.

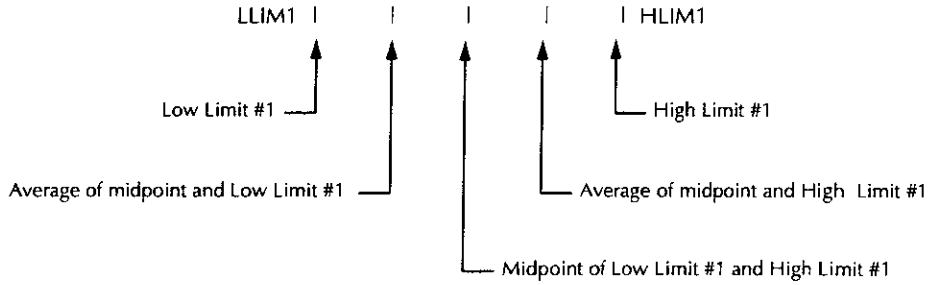
Pressing ENTER returns you to the LIMIT SET #1 menu. Then set the value of the high limit #1 and its effect on the digital outputs. Continue for limit set #2, if desired.

Each measurement function except frequency has a multiple display for the limits bar graph. It shows a pass/fail indication and a graphical representation of the reading compared to limit set #1. (Note: PASS/FAIL indication is not available on ACV, ACI, and in-circuit current.) If low limit #1 is less than high limit #1, you will see a display similar to that shown in Figure 3-44.

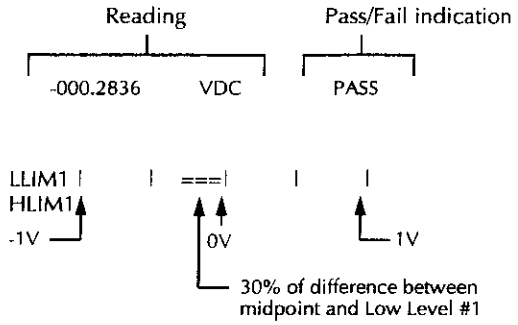
Note that the Model 2001 does not check the validity of the high and low limit values when you enter them. If low limit #1 is greater than or equal to high limit #1, the following message is shown on the bottom line of the limits bar graph next display:

```
No bar graph: LLIM1 >= HLIM1
```

The programmed values for limit set #1 are shown by pressing the INFO key from the limits bar graph next display.



A. Defined points of display



NOTES : 1. Press INFO to view the programmed Low Limit #1 and High Limit #1 values.
2. Multiple display of limit values do not use unit prefixes (i.e., volts not millivolts).

B. Example Display with Limits = ±1V

Figure 3-44
Limits bar graph example

STROBE-CONTROL

This menu item enables or disables the use of digital output #4 as a binning strobe signal.

If enabled, the strobe signal is set TRUE for greater than 10 microseconds after all limit tests have been performed on a new reading. The FALSE to TRUE transition can be used to trigger an external device handler to check digital outputs #1-3 for sorting parts into bins.

When binning is enabled from the front panel or with the bus command :CALCulate3:BSTRobe:STATe ON, the binning strobe signal is set to FALSE. When binning is disabled, the strobe signal is left unchanged.

To enable or disable strobe control, place the cursor on STROBE-CONTROL and press ENTER. The following menu is displayed:

```
LIMIT STROBE CONTROL
DISABLED  ENABLED
```

Use the ◄ and ► keys to move the cursor to the desired state, then press ENTER to select it and return you to the LIMITS MENU.

PASS-PATTERN

This item allows you to program the on/off states of the digital output lines for when all limit tests pass. Note that when the binning strobe is enabled, digital output line #4 cannot be used.

To set a pass pattern, place the cursor on PASS-PATTERN and press ENTER. The following menu is displayed:

```
PASS PATTERN
DIGOUT1=OFF  2=OFF  3=OFF  4=OFF
```

Use the ◄ and ► keys and the RANGE ▲ and ▼ keys to move the cursor and toggle the parameter values between OFF and ON. Pressing ENTER returns you to the LIMITS MENU.

Limits example

This example sorts a quantity of 100Ω resistors into five bins, according to the following tolerances:

- Values less than 90Ω (outside -10% tolerance).
- Values greater than 110Ω (outside +10% tolerance).
- Values between 90Ω and 99Ω (meets -10% tolerance).
- Values between 101Ω and 110Ω (meets +10% tolerance).
- Values between 99Ω and 101Ω (meets ±1% tolerance).

The desired test is shown in Figure 3-45. Use the following procedure to program the limits:

1. From the LIMITS menu, set the limit values and actions according to the following table:

Table 3-44
Limit values and actions

Limit	Value	Action
LOLIM1	90Ω	DIGOUT1=ON, others OFF
HILIM1	110Ω	DIGOUT2=ON, others OFF
LOLIM2	99Ω	DIGOUT1=ON, DIGOUT2= ON, others OFF
HILIM2	101Ω	DIGOUT3=ON, others OFF

2. Enable the binning strobe signal from the STROBE-CONTROL item of the LIMITS menu.
3. Set a pass pattern of all lines off from the PASS PATTERN item of the LIMITS menu.
4. Enable the control of the digital output lines by limit set #1 and limit set #2 from the LIMIT SET #1 and LIMIT SET #2 menus. This sets the digital output lines to the "pass pattern" (all OFF in this example). Since binning is enabled, digital output #4 is also OFF.

Note that the actual state (high or low) of the digital output lines depends on the polarity (ACTIVE-HIGH or ACTIVE-LOW). This is programmed from the DIGITAL I/O selection of the GENERAL menu.

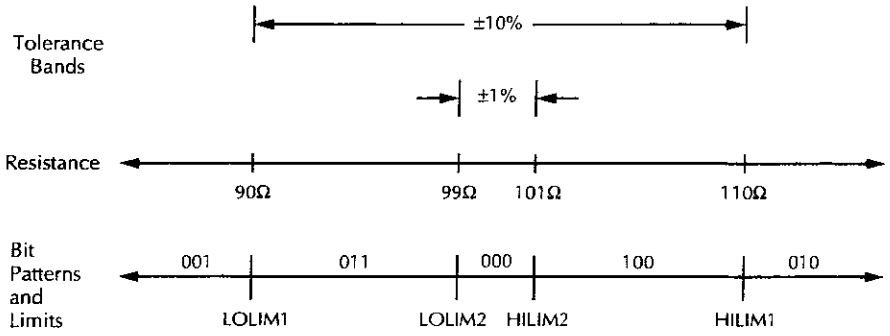


Figure 3-45
Using limit test to sort 100Ω resistors

3.12.6 STATUS-MSG

This selection is used to enable or disable the status messages mode. When enabled, status messages are displayed to identify specific operations that are performed. Place the cursor on STATUS-MSG and press ENTER. The following message is displayed momentarily:

Press EXIT key
to stop status message display.

Then the status message enable/disable menu is shown:

STATUS MESSAGES
OFF ON

Place the cursor on the desired state (OFF or ON) and press ENTER. The instrument returns to the MAIN MENU.

The instrument may become so busy displaying status messages, that keypresses are no longer acknowledged. You may have to clear status message display by pressing the EXIT key or sending a bus command (:DISPlay:SMESsage OFF) to get out of this mode.

3.12.7 GENERAL

The GENERAL menu is used for the following operations:

- To control the state and sense of the digital outputs; to view the state of the digital input.
- To view the serial number, memory option, SCPI version, and firmware revision levels of the Model 2001.
- To control the frequency of autozero readings.
- To set line synchronization of readings.
- To choose the character displayed for a decimal.

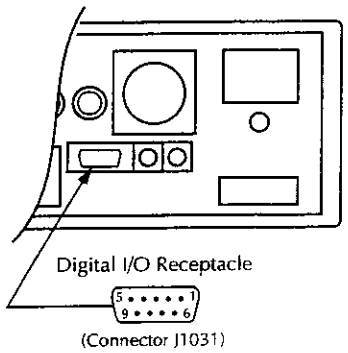
To display the GENERAL menu from the top level of the main menu, use the cursor keys (◀ and ▶) to place the cursor on GENERAL, then press ENTER. The following menu is displayed:

GENERAL MENU
DIGITAL I/O SERIAL# AUTOZERO ▶
◀ LINE-SYNC DECIMAL

DIGITAL I/O

Overview

The Model 2001's Digital I/O port is a 9-pin "D" sub-miniature connector located on the rear panel. The port's location and pin designations are shown in Figure 3-46.



Pin Designations

1 = Digital Input
2 = N/C
3 = N/C
4 = V_{ext} flyback connection (+5V to +30V)
5 = Digital Ground
6 = Digital Output #1
7 = Digital Output #2
8 = Digital Output #4
9 = Digital Output #3

Figure 3-46
Digital I/O port

The Model 2001's Digital I/O port can be used to control external circuitry. The port provides four output lines and one input line. Each open-collector output can be set high (+5V) or low (0V) and will sink up to 100mA. A TTL high on the Model 2001's digital input is read as "ON". The four output lines can also operate external supplies from +5V to +30V.

Use the DIGITAL I/O menu to select the following options:

- OUTPUT-STATE

  ON or OFF selectable for each output line (1 through 4). Use to check or change the output state.

- OUTPUT-SENSE

  ACTIVE-HIGH or ACTIVE-LOW selectable for each output line (TTL1 through TTL4). Use to check or change the output sense.

- INPUT

  ON or OFF. Use to check or change the status of the digital input line. Sense is fixed at active-high (ON=5V).

Controlling digital circuitry

Each of the four digital, open-collector outputs (connector J1031, pins 6 through 9) includes a built-in pull up resistor to +5V. The output transistor is capable of sinking up to 100mA from voltages up to +30V. The outputs can be controlled independently or tied to one of four limit values (two high, two low). Paragraph 3.12.5 contains information on controlling digital outputs from the limits menu.

Early versions of the Model 2001 have an additional 10kΩ resistor connected between the collector and the internal built-in test circuitry. Under certain combinations of output states, this resistor limits the output high to 2.5V. For example:

Output #1 set high (+5V)
Outputs #2, #3, and #4 set low (0V)
Output #1 is restricted to +2.5V

If using the digital output to sink current from external devices (see external voltage supply later in this paragraph), a Model 2001 containing the additional 10kΩ resistor will function correctly. The transistor switch is open, restricting current flow through the external device in the high state (+5V). However, if the output is directly used as an input to a typical logic input, the 2.5V high state may not be reliably detected as a high. To correct this condition (if a 2.5V high is unacceptable), add external 1kΩ pull-up resistors to the logic circuit inputs, remove the built-in test resistors (R734, R737, R739, and R741), or use an external voltage supply.

External voltage supply

Each output can be operated from external voltage supplies (voltage range from +5V to +30V applied through the device being driven). Refer to Figure 3-47 for a simplified schematic of the digital I/O port. The high current sink capacity of the output driver allows direct control of relays, solenoids, and lamps (no additional circuitry needed). Each output channel contains a fly-back diode for protection when switching inductive loads (such as a low power solenoid or relay coils). To use these fly-back diodes, connect the external supply voltage to pin 4 of J1031 (the digital I/O port). Make sure the external supply voltage is between +5V and +30V and current required by the device does not exceed 100mA.

CAUTION

Do not apply more than 100mA maximum current or exceed +30V maximum voltage on pin 4 of J1031 (the digital I/O port). Applying current or voltage exceeding these limits may damage the instrument.

An externally powered relay connected to the digital output port is shown in Figure 3-48. Other externally powered devices can be similarly connected by replacing the relay with the device. When using the Model 2001's collector outputs to turn on externally powered devices, set the corresponding digital output line parameters as follows (through the GENERAL/DIGITAL I/O menus):

OUTPUT-STATE=ON
OUTPUT-SENSE=ACTIVE-LOW

In the low state (0V), the output transistor sinks current through the external device. In the high state, the output transistor is off (transistor switch is open). This interrupts current flow through the external device. Most applications use active-low (ON=0V) OUTPUT-SENSE. Use the OUTPUT-SENSE menu to check or change the sense of the digital output line.

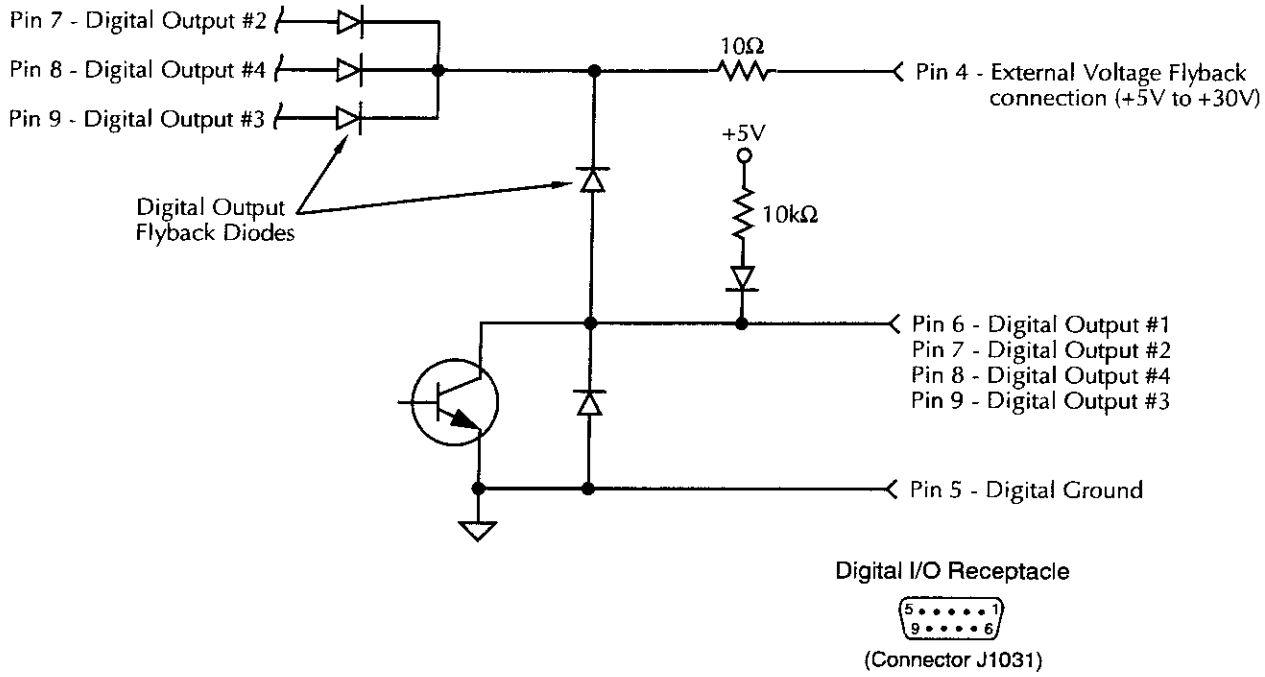


Figure 3-47
Digital I/O port simplified schematic

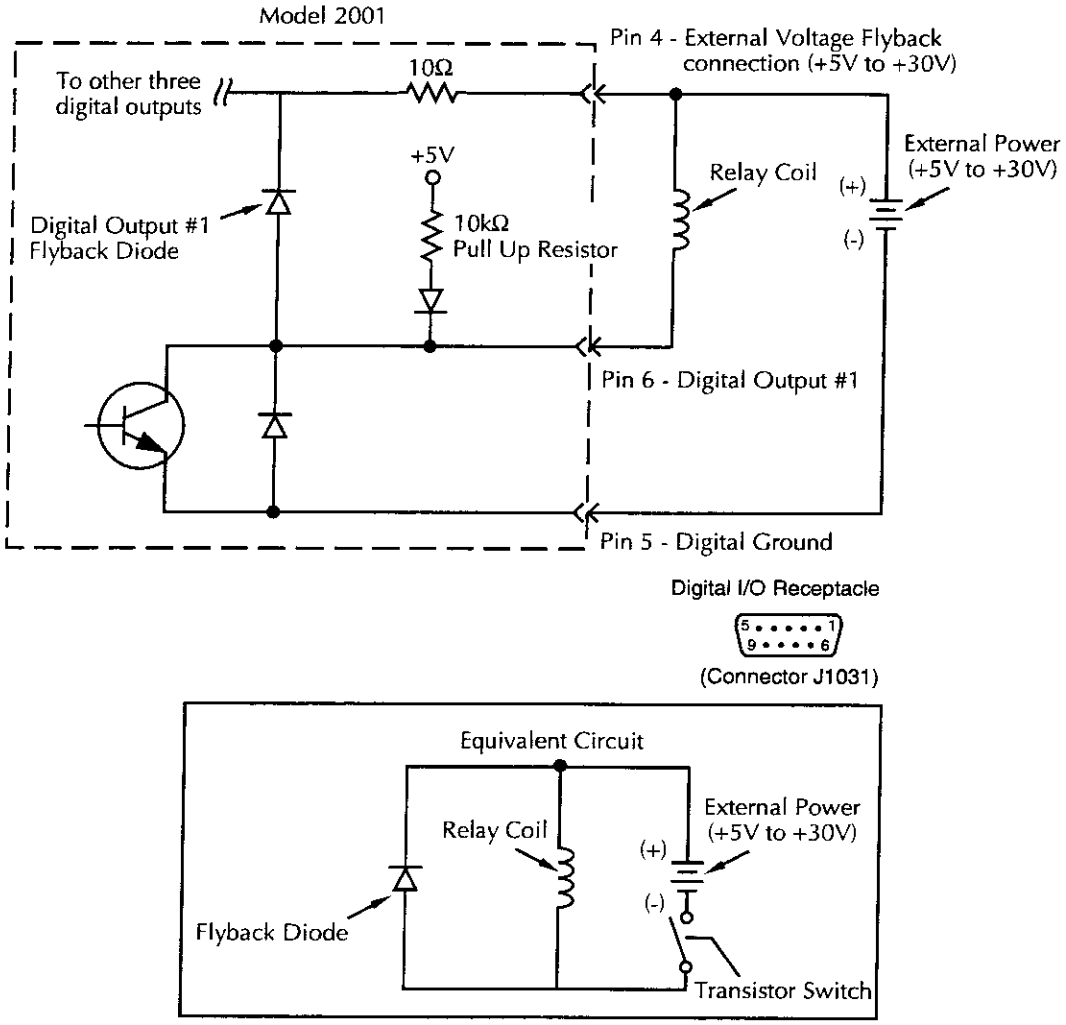


Figure 3-48
Sample externally powered relay

Outputs used as logic inputs

To use the digital outputs as logic inputs to active TTL, Low-power TTL, or CMOS inputs:

1. Connect the Model 2001 digital outputs to the logic inputs.
2. Connect the digital grounds.
3. Using the STATE menu, check the output state setting of the Model 2001 output lines. The STATE value for each output used should be ON.
4. Using the LOGIC-SENSE menu, check the logic-sense setting of the Model 2001 output lines (TTL1 through TTL4). Make sure the correct LOGIC-SENSE value is selected for each output line. The LOGIC-SENSE value varies according to the type of TTL, Low-power TTL, or CMOS inputs used (ACTIVE-HIGH or ACTIVE-LOW).

NOTE

If any LIMITS control is enabled (LOLIM1 or 2, HILIM1 or 2—High, Low, or Pass), the OUTPUT-STATE menu does not check or change the output status. Refer to paragraph 3.12.5 for information about limits.

Input

The single digital input is located on the digital I/O port (connector J1031, pin 1). The input sense is fixed at active-high (ON=5V). Use the INPUT menu to change the status of the input ON or OFF.

Digital I/O menu

Access the DIGITAL I/O menu as follows:

1. Display the GENERAL MENU.
2. Use the ◄ and ► keys to highlight DIGITAL I/O, and press ENTER. The following will be displayed:

```
DIGITAL I/O MENU
OUTPUT-STATE  OUTPUT-SENSE  INPUT
```

OUTPUT-STATE: Use this menu item to check or change the state (on or off) of the four digital output lines. The actual level of an "on" line is determined by the sense, which is controlled by the next menu item (OUTPUT-SENSE). To select OUTPUT-STATE, place the cursor on OUTPUT-STATE and press ENTER. If, for example, all the digital output lines are off, the following message is displayed:

```
DIGITAL OUT LINES
1=OFF  2=OFF  3=OFF  4=OFF
```

1. To retain the displayed states of the output lines, press ENTER or EXIT. The instrument returns to the DIGITAL I/O MENU.
2. To change the state of one or more digital output lines, perform the following steps:
   A. Position the cursor at the line that you wish to change.
   B. Press the RANGE ▲ or RANGE ▼ key. These keys simply toggle between "ON" and "OFF".
   C. Repeat steps A and B for each line that you wish to change.
   D. With the desired states displayed, press ENTER. The instrument returns to the DIGITAL I/O MENU.

OUTPUT-SENSE: Use this menu item to check or change the sense of the digital output lines. The sense of each line can be active-high (ON = +5V) or active- low (ON = 0V). To select OUTPUT-SENSE, place the cursor on OUTPUT-SENSE and press ENTER. The following message is displayed:

```
SELECT OUTPUT LINE
TTL1  TTL2  TTL3  TTL4
```

1. Place the cursor on the appropriate line and press ENTER. A message indicating the sense of the selected line is displayed. For example:

```
TTL1 LOGIC SENSE
ACTIVE-HIGH  ACTIVE-LOW
```

   The cursor position indicates the present sense of the line.
2. To retain the presently selected sense, press ENTER or EXIT. The display returns to the SELECT OUTPUT LINE menu.
3. To change sense, place the cursor on the alternate selection, using the cursor keys (◄ or ►), and press ENTER. The instrument returns to the SELECT OUTPUT LINE menu.
4. When finished, press EXIT to return to the DIGITAL I/O MENU.

INPUT: Use this menu item to read (ON or OFF) the digital input line. Its sense is fixed at active-high (ON = 5V).

To select INPUT, place the cursor on INPUT and press ENTER. If, for example, the digital input line is "ON", the following message is displayed:

```
DIGITAL INPUT LINE
Status = ON
```

The status is updated when INPUT is selected; it does not track the status from the previous message. Press ENTER or EXIT to return the instrument to the GENERAL MENU.

SERIAL

To display the serial number, memory option, SCPI version, and firmware revision levels of the instrument, place the cursor on SERIAL# and press ENTER. The following information is displayed:

```
Serial #XXXXXX MEM1
SCPI version 1991.0 ►
◄ software rev AXX/AYY
```

where: #XXXXXX is the serial number of the instrument.
MEM1 is the memory option present (also could be STD or MEM2)
AXX is the firmware level for the main microcontroller.
AYY is the firmware level for the display microcontroller.

AUTOZERO

With the AUTOZERO item of the GENERAL MENU, you control the frequency of auto zero readings taken. There are two auto zero modes, normal and synchronous. Either can be selected or the auto zero mode can be completely disabled. Using the Model 2001 with auto zero disabled has two main advantages:

- Increased measurement speed.
- Reduced multiplexer effects on high-impedance measurements.

NOTE

With auto zero disabled, internal calibration and zero are affected by changes in input level. Whenever the applied input signal changes, press the selected function key to perform an auto zero routine; otherwise, substantial measurement errors will result. Zero and calibration may also drift with time; thus, it is recommended that the selected function key be pressed periodically to attain optimum accuracy while auto zero is disabled. An auto zero is also performed whenever the range or function is changed, or when an auto zero bus command is issued.

The correlation between auto zero and measurement speed follows:

- Auto zero off is the fastest.
- Auto zero synchronous is the slowest and most accurate. An auto zero routine is performed for every reading.
- The speed of auto zero normal (default) is between auto zero off and synchronous. An auto zero routine is performed whenever necessary to achieve specified accuracy.

The burst data acquisition mode disables auto zero. This type of measurement requires an auto zero refresh once every 24 hours by performing one of the following:

- Change the display resolution.
- Change the measurement function.

Perform the following steps to display the AUTOZERO menu:

1. Display the GENERAL MENU as described in paragraph 3.12.7.
2. Use the cursor keys (◄ and ►) to highlight AUTOZERO and press ENTER to access the following menu:

   SET AUTOZERO
   DISABLE NORMAL SYNCHRONOUS

The cursor position indicates the present auto zero mode. To retain the presently selected sense, press ENTER or EXIT. The display returns to the SET AUTOZERO menu.

To change sense, place the cursor on the alternate selection, using the cursor keys (◄ or ►) and press ENTER. Any change halts triggers and puts the instrument into the idle state. Use the TRIG key to re-arm triggers. The instrument returns to the SET AUTOZERO menu.

When finished, press EXIT to return to the GENERAL MENU.

LINE-SYNC

Synchronizing A/D conversions with the power line frequency increases common mode and normal mode noise rejection. When line cycle synchronization is enabled, the measurement is initiated at the first positive-going zero-crossing of the power line cycle after the trigger. (See Figure 3-49.)

Perform the following steps to enable or disable power line cycle synchronization of measurements:

1. Display the GENERAL MENU as described in paragraph 3.12.7.
2. Use the cursor keys (◄ and ►) to place the cursor on LINE-SYNC and press ENTER to access the following menu:

   LINE SYNCHRONIZATION
   ENABLED DISABLED

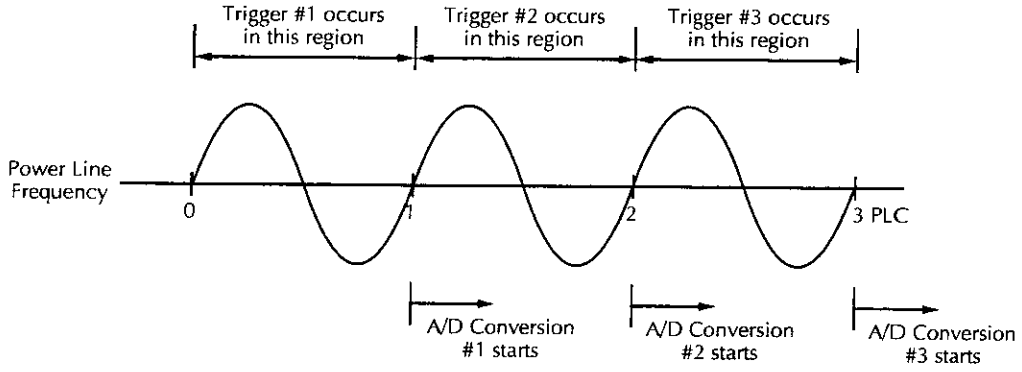
The cursor indicates the present selection. If no change is needed, press EXIT to return to the GENERAL MENU. To change the selection, move the cursor, then press ENTER. Note that this action halts triggers and puts the instrument into the idle state. Use the TRIG key to re-arm triggers.

DECIMAL

This menu item lets you select between periods and commas to signify decimal points on the front panel display. To change the selection from the GENERAL MENU, place the cursor on DECIMAL and press ENTER. The following menu is shown:

CHOOSE DECIMAL CHAR
PERIOD COMMA

Selection of one or the other returns you to the GENERAL MENU. Exit completely from the main menu to view either a period or comma in the normal display of triggered readings.



Note: A/D conversions assume an integration time of ≤ 1 PLC (Power Line Cycle)

Figure 3-49
Line cycle synchronization