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Model 2001 Multimeter

Calibration Manual

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Model 2001 Multimeter
Calibration Manual

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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.

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Safety Precautions

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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 and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product warranty may be impaired.

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 properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the user documentation. 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, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

Keithley Instruments products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the user documentation.

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.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators 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 1000V, no conductive part of the circuit may be exposed.

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, ensure that 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.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

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 the 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 means caution, risk of danger. The user should refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

The  symbol on an instrument means caution, risk of danger. Use standard safety precautions to avoid personal contact with these voltages.

The  symbol on an instrument shows that the surface may be hot. Avoid personal contact to prevent burns.

The  symbol indicates a connection terminal to the equipment frame.

If this  symbol is on a product, it indicates that mercury is present in the display lamp. Please note that the lamp must be properly disposed of according to federal, state, and local laws.

The **WARNING** heading in the user documentation 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 the user documentation 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., a 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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Appendices

1
Performance Verification

1.1 Introduction

The procedures in this section are intended to verify that Model 2001 accuracy is within the limits stated in the instrument one-year specifications. These procedures can be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy, or following calibration, if desired.

NOTE

If the instrument is still under warranty, and its performance is outside specified limits, contact your Keithley representative or the factory to determine the correct course of action.

This section includes the following:

1.2 **Environmental conditions:** Covers the temperature and humidity limits for verification.

1.3 **Warm-up period:** Describes the length of time the Model 2001 should be allowed to warm up before testing.

1.4 **Line power:** Covers power line voltage ranges during testing.

1.5 **Recommended equipment:** Summarizes recommended equipment and pertinent specifications.

1.6 **Verification limits:** Explains how reading limits were calculated.

1.7 **Restoring factory default conditions:** Gives step-by-step procedures for restoring default conditions before each test procedure.

1.8 **Verification procedures:** Details procedures to verify measurement accuracy of all Model 2001 measurement functions.

1.2 Environmental conditions

Verification measurements should be made at an ambient temperature of 18-28°C (65-82°F), and at a relative humidity of less than 80% unless otherwise noted.

1.3 Warm-up period

The Model 2001 must be allowed to warm up for at least one hour before performing the verification procedures. If the instrument has been subjected to temperature extremes (outside the range stated in paragraph 1.2), allow additional time for internal temperatures to stabilize. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

The calibration equipment should also be allowed to warm up for the minimum period specified by the manufacturer.

1.4 Line power

The Model 2001 should be tested while operating from a line voltage in the range of 90-134V or 180-250V at a frequency of 50, 60, or 400Hz.

1.5 Recommended test equipment

Table 1-1 lists all test equipment required for verification. Alternate equipment may be used as long as that equipment has specifications at least as good as those listed in the table. See Appendix D for a list of alternate calibration sources.

1.6 Verification limits

The verification limits stated in this section have been calculated using only Model 2001 one year specifications, and they do not include test equipment tolerance. If a particular measurement falls slightly outside the allowed range, recalculate new limits based both on Model 2001 specifications and pertinent calibration equipment specifications.

1.7 Restoring default conditions

Before performing **each** performance verification procedure, restore instrument bench default conditions as follows:

1. From the normal display mode, press the MENU key. The instrument will display the following:

   MAIN MENU
   SAVESETUP GPIB CALIBRATION

2. Select SAVESETUP, and press ENTER. The following will be displayed:

   SETUP MENU
   SAVE RESTORE POWERON RESET

3. Select RESET, and press ENTER. The display will then appear as follows:

   RESET ORIGINAL DFLTS
   BENCH GPIB

4. Select BENCH, then press ENTER. The following will be displayed:

   RESETTING INSTRUMENT
   ENTER to confirm; EXIT to abort

5. Press ENTER again to confirm instrument reset.

Table 1-1
Recommended equipment for performance verification

Mfg.	Model	Description	Specifications*
Fluke	5700A	Calibrator	±5ppm basic uncertainty. DC voltage: 190mV: ±11ppm 1.9V: ±5ppm 19V: ±5ppm 190V: ±7ppm 1000V: ±9ppm AC voltage, 10Hz-1MHz (40Hz-20kHz specifications): 190mV: ±150ppm 1.9V: ±78ppm 19V: ±78ppm 190V: ±85ppm DC current: 190µA: ±102ppm 1.9mA: ±55ppm 19mA: ±55ppm 190mA: ±65ppm 1.9A: ±96ppm

Table 1-1 (cont.)
Recommended equipment for performance verification

Mfg.	Model	Description	Specifications*
Fluke	5700A	Calibrator	AC current, 40Hz-10kHz (40Hz-1kHz specifications): 190µA: ±245ppm 1.9mA: ±160ppm 19mA: ±160ppm 190mA: ±170ppm 1.9A: ±670ppm Resistance: 19¾: ±26ppm 190¾: ±17ppm 1.9k¾: ±12ppm 19k¾: ±11ppm 190k¾: ±13ppm 1.9M¾: ±19ppm 19M¾: ±47ppm 100M¾: ±120ppm
Fluke	5725A	Amplifier	AC voltage, 1kHz-10kHz: 750V: ±85ppm
Fluke	5700A-03	Wideband AC option	190mV, 1.9V @ 2MHz, ±0.1%
Fluke	5440A-7002	Low thermal cable set	
Keithley	CA-18-1	Low capacitance cable	Low capacitance dual banana to dual banana shielded cable (for ACV), 1.2m (4 ft.) in length.
Keithley	R-289-1G	1G¾ resistor	NOTE: Resistor should be characterized to within ±10,000 ppm and mounted in shielded test box (see procedure).
		Metal component box (for 1G¾ resistor)	
		Insulated banana plugs (2) (for test box)	
Keithley	3940	Multifunction Synthesizer	1Hz-15MHz, ±5ppm
General Radio	1433-T	Precision Decade Resistance Box	10-400¾, ±0.02%
—	—	Megohmmeter	1G¾, ±1%

* 90-day calibrator specifications shown include total uncertainty at specified output. The 1.9V output includes 0.5ppm transfer uncertainty. See Appendix D for recommendation on alternate calibration sources.

1.8 Verification procedures

The following paragraphs contain procedures for verifying instrument accuracy specifications for the following measuring functions:

- DC volts
- AC volts
- DC current
- AC current
- Resistance
- Frequency
- Temperature

If the Model 2001 is out of specifications and not under warranty, refer to the calibration procedures in Section 2.

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. Some of the procedures in this section may expose you to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered to avoid personal injury caused by electric shock.

NOTE

Do not connect test equipment to the Model 2001 through a scanner.

1.8.1 DC volts verification

DC voltage accuracy is verified by applying accurate DC voltages from a calibrator to the Model 2001 input and verifying that the displayed readings fall within specified ranges.

Follow the steps below to verify DCV measurement accuracy.

CAUTION

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

1. Turn on the Model 2001 and the calibrator, and allow a one-hour warm-up period before making measurements.

NOTE

Use shielded, low-thermal connections when testing the 200mV range to avoid errors caused by noise or thermal offsets. Connect the shield to calibrator output LO. (See Table 1-1.)

2. Connect the Model 2001 to the calibrator, as shown in Figure 1-1. Be sure to connect calibrator HI to Model 2001 INPUT HI and calibrator LO to Model 2001 INPUT LO as shown.
3. Restore Model 2001 factory default conditions, as explained in paragraph 1.7.
4. Set digital filter averaging as follows:
   A. From normal display, press CONFIG then DCV.
   B. Select FILTER, then press ENTER.
   C. Select AVERAGING, then press ENTER.
   D. Using the cursor and range keys, set the averaging parameter to 10 readings, then press ENTER.
   E. Press EXIT as necessary to return to normal display.
   F. If the FILT annunciator is off, press FILTER to enable the filter.
5. Select the Model 2001 200mV DC range.

NOTE

Do not use auto-ranging for any of the verification tests because auto-range hysteresis may cause the Model 2001 to be on an incorrect range.

6. Set the calibrator output to 0.000000mVDC, and allow the reading to settle.
7. Enable the Model 2001 REL mode. Leave REL enabled for the remainder of the DC volts verification test.
8. Set the calibrator output to +190.0000mVDC, and allow the reading to settle.
9. Verify that the Model 2001 reading is within the limits summarized in Table 1-2.
10. Repeat steps 8 and 9 for the remaining ranges and voltages listed in Table 1-2.
11. Repeat the procedure for each of the ranges with negative voltages of the same magnitude as those listed in Table 1-2.

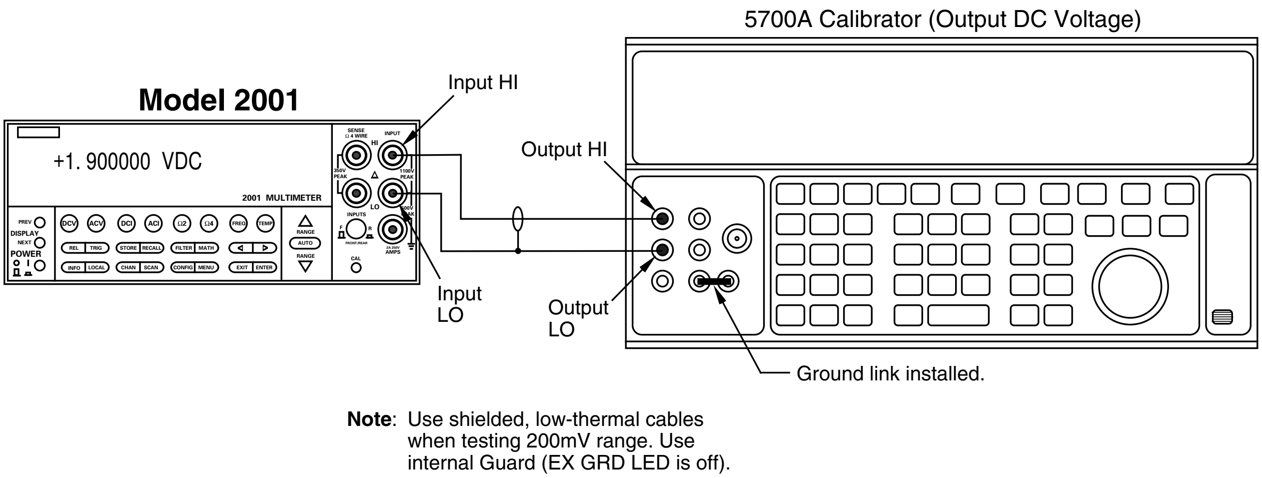


Figure 1-1
Connections for DC volts verification

Table 1-2
Limits for DC volts verification

2001 DCV range	Applied DC voltage	Reading limits (18° to 28°C, 1 year)
200mV	190.0000mV	189.9918mV to 190.0082mV
2V	1.900000V	1.899949V to 1.900052V
20V	19.00000V	18.99946V to 19.00054V
200V	190.0000V	189.9922V to 190.0078V
1000V	1000.000V	999.953V to 1000.047V

Notes:
1. Repeat procedure for negative voltages.
2. Reading limits shown do not include calibrator uncertainty.

1.8.2 AC volts verification

AC voltage accuracy is checked by applying accurate AC voltages at specific frequencies from an AC calibration source and then verifying that each Model 2001 AC voltage reading falls within the specified range. The three ACV verification procedures that follow include:

- Normal mode
- Low-frequency mode
- Peak ACV

CAUTION

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

Normal mode

1. Turn on the Model 2001, calibrator, and amplifier, and allow a one-hour warm-up period before making measurements.
2. Connect the Model 2001 to the calibrator, as shown in Figure 1-2. Be sure to connect the amplifier HI to Model 2001 INPUT HI, and amplifier LO to Model 2001 INPUT LO as shown. Connect the power amplifier to the calibrator using the appropriate connector on the rear of the calibrator.
3. Restore Model 2001 factory default conditions, as explained in paragraph 1.7.
4. Select the ACV function and the 200mV range on the Model 2001, and make sure that REL is disabled.

NOTE

Do not use REL to null offsets when performing AC volts tests.

5. Set the calibrator output to 190.000mVAC at a frequency of 20Hz, and allow the reading to settle.
6. Verify that the Model 2001 reading is within the limits summarized in Table 1-3.
7. Repeat steps 5 and 6 for 190mVAC at the remaining frequencies listed in Table 1-3 (except 2MHz).Verify that instrument readings fall within the required limits listed in the table.
8. Repeat steps 5 through 7 for the 2V, 20V, 200V, and 750VAC ranges, using the input voltages and limits stated in Table 1-3.
9. Connect the Model 2001 to the wideband calibrator output (Figure 1-3).

10. Set the calibrator output to 190.0000mV at a frequency of 2MHz.
11. Verify that the reading is within limits stated in Table 1-3.
12. Repeat steps 10 and 11 for 1.900V input on the 2V range.

Low-frequency mode

1. Turn on the Model 2001, calibrator, and amplifier, and allow a one-hour warm-up period before making measurements.
2. Connect the Model 2001 to the calibrator, as shown in Figure 1-2. Be sure to connect the amplifier HI to Model 2001 INPUT HI, and amplifier LO to Model 2001 INPUT LO as shown. Connect the power amplifier to the calibrator using the appropriate connector on the rear of the calibrator.
3. Restore Model 2001 factory default conditions, as explained in paragraph 1.7.
4. Select the ACV function and the 200mV range on the Model 2001, and make sure that REL is disabled.

NOTE

Do not use REL to null offsets when performing AC volts tests. Also, do not enable the filter.

5. Select the low-frequency mode as follows:
   - A. Press CONFIG ACV, select AC-TYPE, then press ENTER.
   - B. Select LOW-FREQ-RMS, then press ENTER.
   - C. Press EXIT as required to return to normal display.
6. Set the calibrator output to 190.000mVAC at a frequency of 10Hz, and allow the reading to settle.
7. Verify that the Model 2001 reading is within the limits summarized in Table 1-4.
8. Repeat steps 6 and 7 for 190mVAC at the remaining frequencies listed in the table.
9. Repeat steps 6 through 8 for the 2V, 20V, 200V, and 750VAC ranges, using the input voltages and limits stated in Table 1-4.

CAUTION

Do not apply more than 400V at 50kHz, 80V at 250kHz, 40V at 500kHz, or 20V at 1MHz, or instrument damage may occur.

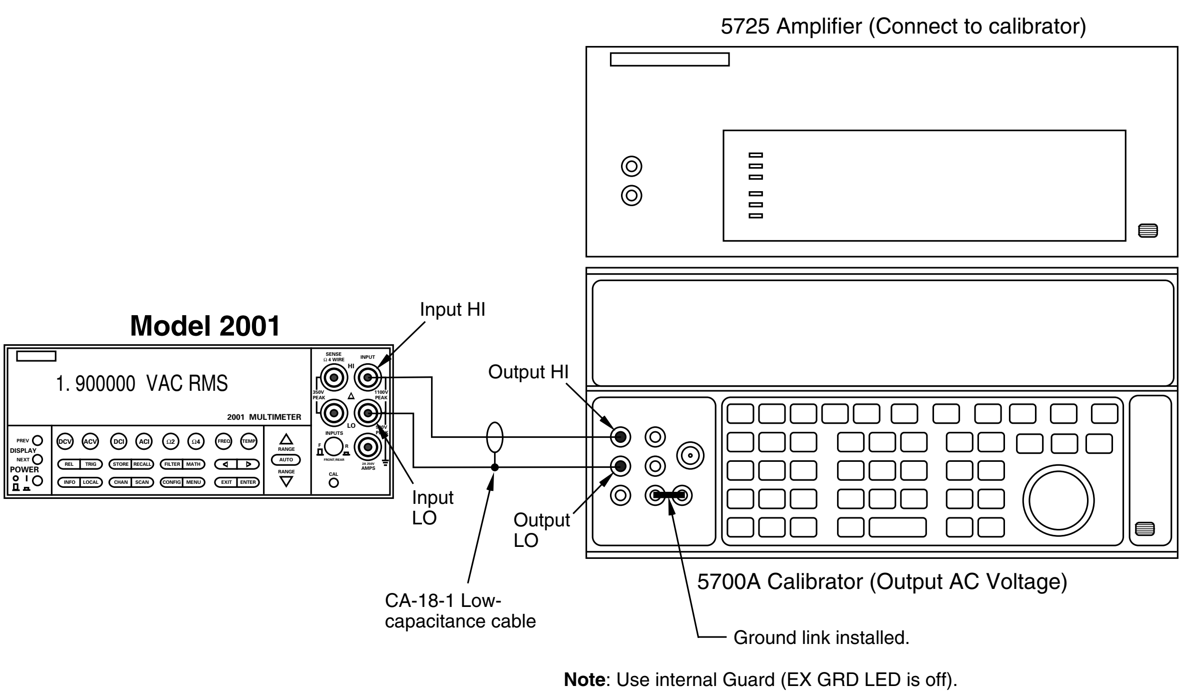


Figure 1-2
Connections for AC volts verification (all except 2MHz test)

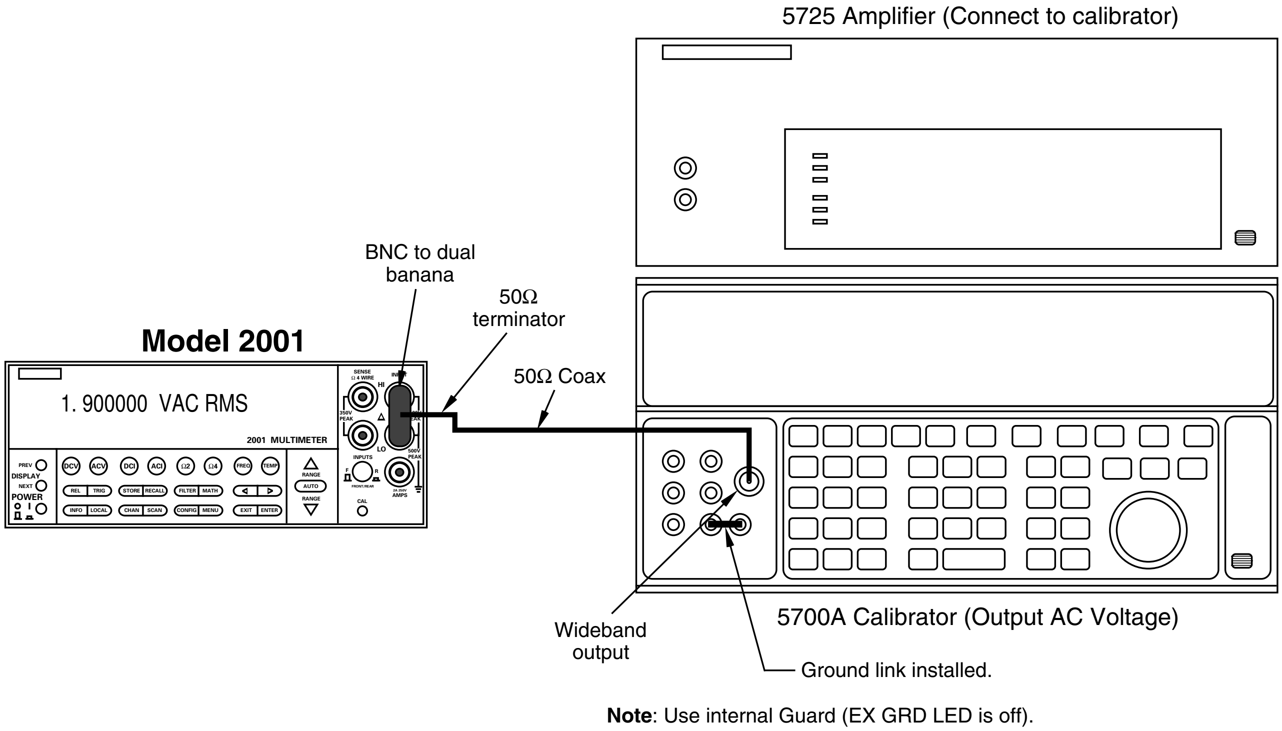


Figure 1-3
Connections for AC volts verification (2MHz frequency only)

Table 1-3
Limits for normal mode AC voltage verification

2001 ACV range	Applied voltage	Allowable readings (1 year, 18° to 28°C)									
		20Hz	50Hz	1kHz	5kHz	25kHz	50kHz	100kHz	200kHz	1MHz	2MHz**
200mV	190mV	188.716mV to 191.284mV	189.685mV to 190.315mV	189.875mV to 190.125mV	189.875mV to 190.125mV	189.875mV to 190.125mV	189.856mV to 190.144mV	189.647mV to 190.353mV	189.000mV to 191.000mV	186.000mV to 194.000mV	180.100mV to 199.900mV
2V	1.9V	1.88716V to 1.91284V	1.89685V to 1.90315V	1.89875V to 1.90125V	1.89875V to 1.90125V	1.89875V to 1.90125V	1.89856V to 1.90144V	1.89647V to 1.90353V	1.89000V to 1.91000V	1.86000V to 1.94000V	1.80100V to 1.99900V
20V	19V	18.8716V to 19.1284V	18.9685V to 19.0315V	18.9856V to 19.0144V	18.9809V to 19.0192V	18.9742V to 19.0258V	18.9723V to 19.0277V	18.9647V to 19.0353V	18.9000V to 19.1000V	18.2000V to 19.8000V	*
200V	190V	188.709V to 191.291V	189.678V to 190.322V	189.849V to 190.151V	189.802V to 190.198V	189.735V to 190.265V	189.716V to 190.284V	189.640V to 190.360V	*	*	*
750V	750V	—	748.12V to 751.88V	748.72V to 751.28V	748.49V to 751.51V	748.12V to 751.88V	*	*	*	*	*

***CAUTION: Do not exceed 2×10^7V•Hz input.**
**Use wideband option and connections when performing 2MHz tests.
NOTE: Limits shown do not include calibrator uncertainty. Reading limits do include the adder for AC Coupling of the input.

Table 1-4

Limits for low-frequency mode AC voltage verification

2001 ACV range	Applied voltage	Allowable readings (1 year, 18° to 28°C)		
		10Hz	50Hz	100Hz
200mV	190mV	189.837mV to 190.163mV	189.875mV to 190.125mV	189.875mV to 190.125mV
2V	1.9V	1.89837V to 1.90163V	1.89875V to 1.90125V	1.89875V to 1.90125V
20V	19V	18.9818V to 19.0182V	18.9856V to 19.0144V	18.9856V to 19.0144V
200V	190V	189.811V to 190.189V	189.849V to 190.151V	189.849V to 190.151V
750V	750V	—	748.72V to 751.28V	748.72V to 751.28V

NOTE: Specifications above 100Hz are the same as normal mode. Limits shown do not include calibrator uncertainty.

AC peak mode

1. Turn on the Model 2001, calibrator, and amplifier, and allow a one-hour warm-up period before making measurements.
2. Connect the Model 2001 to the calibrator, as shown in Figure 1-2. Be sure to connect the amplifier HI to Model 2001 INPUT HI, and amplifier LO to Model 2001 INPUT LO as shown. Connect the power amplifier to the calibrator using the appropriate connector on the rear of the calibrator.
3. Restore Model 2001 factory default conditions, as explained in paragraph 1.7.
4. Select the ACV function and the 200mV range on the Model 2001, and make sure that REL is disabled.

NOTE

Do not use REL to null offsets when performing AC volts tests. Use AC coupling for 5kHz-1MHz tests. Use AC+DC coupling for 20Hz tests. (Use CONFIG-ACV to set coupling.)

5. Select the AC peak and filter modes as follows:
   A. Press CONFIG then ACV, select AC-TYPE, then press ENTER.
   B. Select PEAK, then press ENTER.
   C. Select FILTER, then press ENTER.
   D. Select AVERAGING, then press ENTER.
   E. Using the cursor and range keys, set the averaging parameter to 10 readings, then press ENTER.
   F. Press EXIT as necessary to return to normal display.
   G. If the FLT annunciator is off, press FILTER to enable the filter.
6. Set the calibrator output to 100.000mVAC at a frequency of 5kHz, and allow the reading to settle.
7. Verify that the Model 2001 reading is within the limits summarized in Table 1-5.
8. Repeat steps 6 and 7 for 100mVAC at the remaining frequencies listed in the table.
9. Repeat steps 6 through 8 for the 2V, 20V, 200V, and 750VAC ranges, using the input voltages and limits stated in Table 1-5.

CAUTION

Do not apply more than 400V at 50kHz, 80V at 250kHz, 40V at 500kHz, or 20V at 1MHz, or instrument damage may occur.

10. Set input coupling to AC+DC, then repeat the procedure for a 20Hz input signal.

Table 1-5
Limits for AC peak voltage verification

2001 ACV range	Applied voltage*	20Hz†	5kHz	25kHz	50kHz	100kHz	250kHz	500kHz	750kHz	1MHz
		Allowable Readings (1 year, 18° to 28°C)								
200mV	100mV	139.9mV to 142.9mV	139.9mV to 142.9mV	139.9mV to 142.9mV	139.8mV to 143.0mV	139.6mV to 143.2mV	138.6mV to 144.2mV	136.5mV to 146.3mV	132.2mV to 150.6mV	127.3mV to 155.5mV
2V	1V	1.407V to 1.421V	1.407V to 1.421V	1.407V to 1.421V	1.406V to 1.422V	1.404V to 1.424V	1.394V to 1.434V	1.373V to 1.455V	1.330V to 1.498V	1.281V to 1.547V
20V	10V	13.99V to 14.29V	13.98V to 14.30V	13.98V to 14.30V	13.97V to 14.31V	13.96V to 14.32V	13.86V to 14.42V	13.65V to 14.63V	13.22V to 15.06V	12.73V to 15.55V
200V	190V	267.8V to 269.6V	267.8V to 269.6V	267.7V to 269.7V	267.6V to 269.8V	267.4V to 270.0V	**	**	**	**
750V	750V	—	1054V to 1067V	1053V to 1068V	**	**	**	**	**	**

*Calibrator voltage is given as an RMS value. Model 2001 reading limits are peak AC values.
**CAUTION: Do not apply more than 2×10^7V•Hz
†Use AC+DC input coupling for 20Hz tests only. (Use CONFIG-ACV to set coupling.)
NOTE: Limits shown do not include uncertainty calibrator.

1.8.3 DC current verification

DC current accuracy is checked by applying accurate DC currents from a calibrator to the instrument AMPS input and then verifying that the current readings fall within appropriate limits.

Follow the steps below to verify DCI measurement accuracy.

CAUTION

Do not apply more than 2A, 250V to the AMPS input, or the amps protection fuse will blow.

1. Turn on the Model 2001 and the calibrator, and allow a one-hour warm-up period before making measurements.
2. Connect the Model 2001 to the calibrator, as shown in Figure 1-4. Be sure to connect calibrator HI to the AMPS input, and connect calibrator LO to INPUT LO as shown.
3. Restore Model 2001 factory default conditions, as explained in paragraph 1.7.
4. Set digital filter averaging as follows:
   A. From normal display, press CONFIG then DCI.
   B. Select FILTER, then press ENTER.
   C. Select AVERAGING, then press ENTER.
   D. Using the cursor and range keys, set the averaging parameter to 10 readings, then press ENTER.
   E. Press EXIT as necessary to return to normal display.
   F. If the FILT annunciator is off, press FILTER to enable the filter.
5. Select the DC current function (DCI) and the 200µA range on the Model 2001.
6. Set the calibrator output to +190.0000µADC, and allow the reading to settle.
7. Verify that the Model 2001 reading is within the limits summarized in Table 1-6.
8. Repeat steps 6 and 7 for the remaining currents listed in Table 1-6.
9. Repeat the procedure for each of the ranges with negative currents of the same magnitude as those listed in Table 1-6.

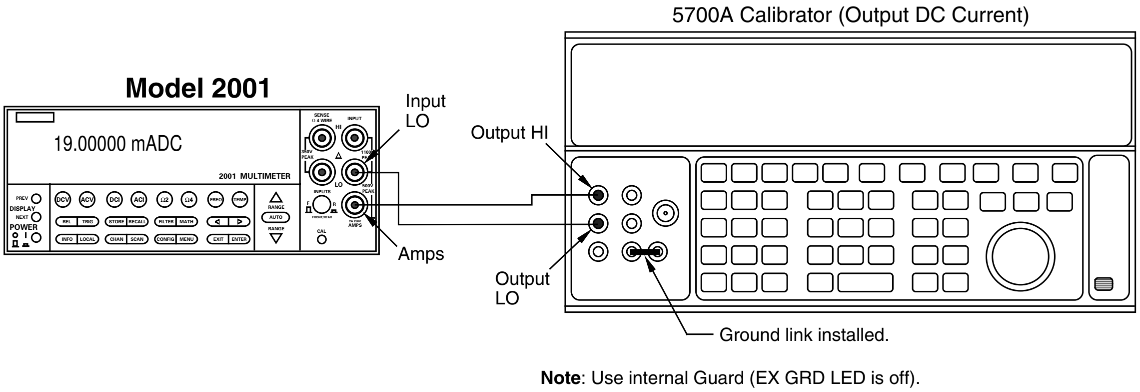


Figure 1-4
Connections for DC current verification

Table 1-6
Limits for DC current verification

2001 DCI range	Applied DC current	Reading limits (1 year, 18° to 28°C)
200µA	190.0000µA	189.9000µA to 190.1000µA
2mA	1.900000mA	1.899200mA to 1.900800mA
20mA	19.00000mA	18.99200mA to 19.00800mA
200mA	190.0000mA	189.9010mA to 190.0990mA
2A	1.900000A	1.898200A to 1.901800A

NOTES:
1. Repeat procedure for negative currents.
2. Reading limits shown do not include calibrator uncertainty.

1.8.4 AC current verification

AC current verification is performed by applying accurate AC currents at specific frequencies and then verifying that Model 2001 readings fall within specified limits.

Follow the steps below to verify ACI measurement accuracy.

CAUTION

Do not apply more than 2A, 250V to the AMPS input, or the current protection fuse will blow.

1. Turn on the Model 2001 and the calibrator, and allow a one-hour warm-up period before making measurements.
2. Connect the Model 2001 to the calibrator, as shown in Figure 1-5. Be sure to connect calibrator HI to the AMPS input, and connect calibrator LO to INPUT LO as shown.
3. Restore Model 2001 factory default conditions, as explained in paragraph 1.7.
4. Select the AC current function and the 200µA range on the Model 2001.
5. Set the calibrator output to 190.000µA AC at a frequency of 40Hz, and allow the reading to settle.
6. Verify that the Model 2001 reading is within the limits for the present current and frequency summarized in Table 1-7.
7. Repeat steps 4 and 5 for each frequency listed in Table 1-7.
8. Repeat steps 4 through 7 for the remaining ranges and frequencies listed in Table 1-7.

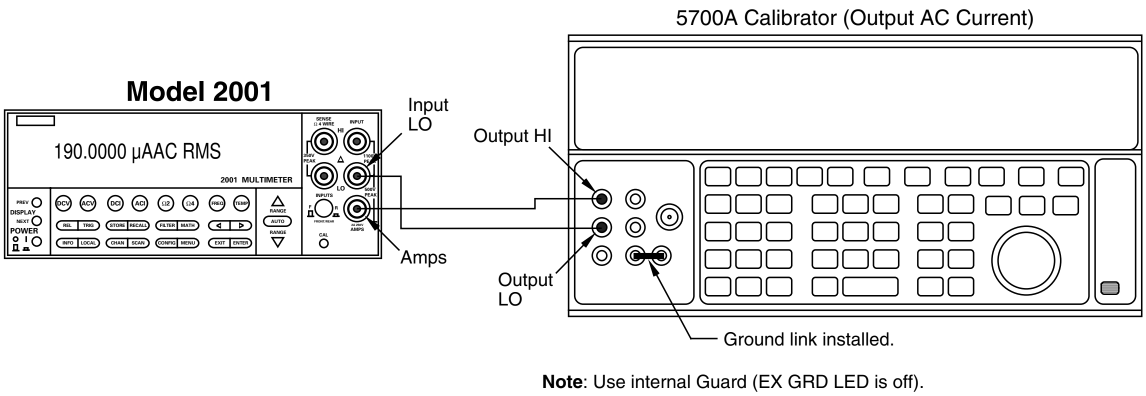


Figure 1-5
Connections for AC current verification

Table 1-7
Limits for AC current verification

2001 ACI range	Applied AC current	Reading limits (1 year, 18° to 28°C)			
		40Hz	**100Hz**	**1kHz**	**10kHz**
200µA	190.000µA	188.260µA to 191.740µA	189.560µA to 190.440µA	189.210µA to 190.790µA	189.020µA to 190.980µA
2mA	1.90000mA	1.88355mA to 1.91645mA	1.89657mA to 1.90344mA	1.89742mA to 1.90258mA	1.89742mA to 1.90258mA
20mA	19.0000mA	18.8355mA to 19.1645mA	18.9657mA to 19.0344mA	18.9742mA to 19.0258mA	18.9742mA to 19.0258mA
200mA	190.000mA	188.355mA to 191.645mA	189.657mA to 190.344mA	189.742mA to 190.258mA	189.685mA to 190.315mA
2A	1.90000A	1.88250A to 1.91750A	1.89556A to 1.90444A	1.89390A to 1.90610A	1.89105A to 1.90895A

Note: Reading limits shown do not include calibrator uncertainty.

1.8.5 Resistance verification

Resistance verification is performed by connecting accurate resistance values to the instrument and verifying that Model 2001 resistance readings are within stated limits.

Follow the steps below to verify resistance measurement accuracy.

CAUTION

Do not apply more than 1100V peak between INPUT HI and LO or more than 350V peak between SENSE HI and LO, or instrument damage may occur.

20¾ - 200k¾ range verification

1. Turn on the Model 2001 and the calibrator, and allow a one-hour warm-up period before making measurements.
2. Set the calibrator for 4-wire resistance (external sense on).
3. Using shielded 4-wire connections, connect the Model 2001 to the calibrator, as shown in Figure 1-6. Be sure to connect calibrator HI and LO terminals to the Model 2001 HI and LO terminals (including SENSE HI and LO) as shown.
4. Restore Model 2001 factory default conditions, as explained in paragraph 1.7.
5. Set operating modes as follows:
   A. From normal display, press CONFIG then ¾4.
   B. Select FILTER, then press ENTER.
   C. Select AVERAGING, then press ENTER.
   D. Using the cursor and range keys, set the averaging parameter to 10 readings, then press ENTER.
   E. Select OFFSETCOMP, then press ENTER.
   F. Select ON, then press ENTER.
   G. Press EXIT to return to normal display.
6. Set the calibrator to output 19.000¾, and allow the reading to settle. Verify that the reading is within the limits stated in Table 1-8.

NOTE

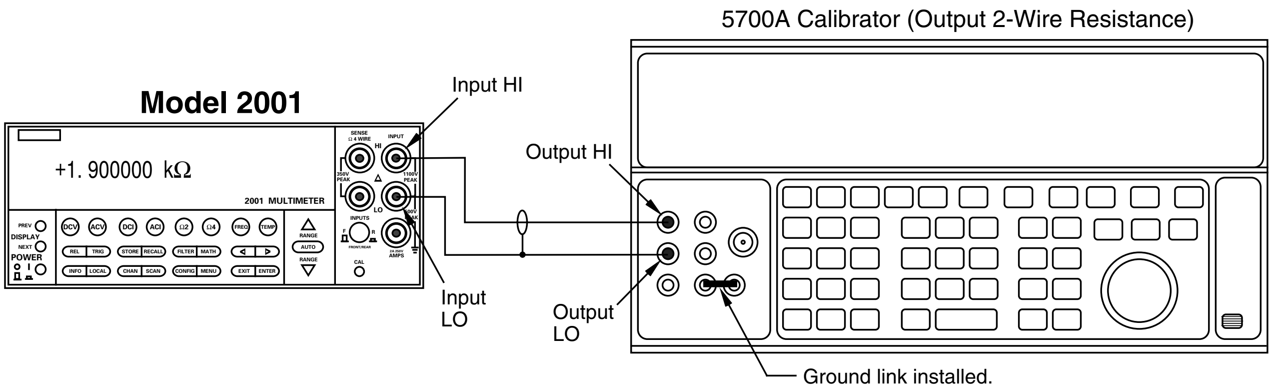
Resistance values available in the Model 5700A calibrator may be slightly different than the stated nominal resistance values. Calculated limits stated in Table 1-8 should be recalculated based on actual calibrator resistance values.

7. Set the calibrator output to 190.000¾, and allow the reading to settle.
8. Verify that the reading is within the limits stated in Table 1-8. (NOTE: Recalculate limits if calibrator resistance is not exactly as listed.)
9. Repeat steps 11 and 12 for the 2k¾ through 200k¾ ranges using the values listed in Table 1-8. NOTE: Turn offset compensation off when testing the 200k¾ range (see step 5).

Table 1-8
Limits for resistance verification (20¾-200M¾ ranges)

2001 ¾ range	Applied resistance	Reading limits (1 year, 18° to 28°C)
20¾	19.0000¾	18.99849¾ to 19.00151¾
200¾	190.000¾	189.9880¾ to 190.0120¾
2k¾	1.90000k¾	1.899897k¾ to 1.900103k¾
20k¾	19.0000k¾	18.99897k¾ to 19.00103k¾
200k¾	190.000k¾	189.9820k¾ to 190.0180k¾
2M¾	1.90000M¾	1.899687M¾ to 1.900313M¾
20M¾	19.0000M¾	18.98281M¾ to 19.01719M¾
200M¾	100.000M¾	97.9800M¾ to 102.0200M¾

NOTES:
1. Limits shown do not include calibrator uncertainty and are based on absolute calibration values shown. Recalculate limits using Model 2001 specifications if calibrator resistance values differ from nominal values shown.
2. Use 4-wire connections and function for 20¾-200k¾ ranges. Use 2-wire connections and function for 2M¾-200M¾ ranges.



Note: Use shielded cable to minimize noise.
Disable calibrator external sense mode.
Use internal Guard (EX GRD LED is off).

Figure 1-6
Connections for resistance verification (20¾-200k¾ ranges)

2M¾ – 200M¾ range verification

1. Connect the DC calibrator and Model 2001 using the 2-wire connections shown in Figure 1-7.
2. Set the calibrator to the 2-wire mode (external sense off).
3. Set operating modes as follows:
   A. From normal display, press CONFIG then ¾2.
   B. Select FILTER, then press ENTER.
   C. Select AVERAGING, then press ENTER.
   D. Using the cursor and range keys, set the averaging parameter to 10 readings, then press ENTER.
   E. Press EXIT to return to normal display.
   F. If the FILT annunciator is off, press FILTER to enable the filter.
4. Select the Model 2001 ¾2 function, and change to the 2M¾ range.
5. Set the calibrator to output 1.90000M¾, and allow the reading to settle.
6. Verify that the reading is within the limits for the 2M¾ range stated in Table 1-8. (NOTE: Recalculate limits if actual calibrator resistance differs from value shown.)
7. Repeat steps 4 through 6 for the 20M¾ (output 19.0000M¾) and 200M¾ (output 100.000M¾) ranges.

1G¾ range verification

1. Mount the 1G¾ resistor and the banana plugs to the test box, as shown in Figure 1-8. Be sure to mount the banana plugs with the correct spacing. The resistor should be completely enclosed in and shielded by the metal test box. The resistor LO lead should be electrically connected to the test box to provide adequate shielding.
2. Characterize the 1G¾ resistor to within ±10,000ppm or better using an accurate megohmmeter (see Table 1-1). Record the characterized value where indicated in Table 1-9. Also, compute the limits based on the value of R using the formula at the bottom of the table.

NOTE

The value of the 1G¾ resistor should not exceed 1.05G¾.

3. Set operating modes as follows:
   A. From normal display, press CONFIG then ¾2.
   B. Select FILTER, then press ENTER.
   C. Select AVERAGING, then press ENTER.
   D. Using the cursor and range keys, set the averaging parameter to 10 readings, then press ENTER.
   E. Press EXIT to return to normal display.
   F. If the FILT annunciator is off, press FILTER to enable the filter.
4. Select the 2-wire ohms function (¾2) and the 1G¾ range on the Model 2001.
5. Connect the 1G¾ resistor test box (from steps 1 and 2) to the INPUT HI and LO terminals of the Model 2001. Allow the reading to settle.
6. Verify that the Model 2001 reading is within the limits you calculated and recorded in Table 1-9.

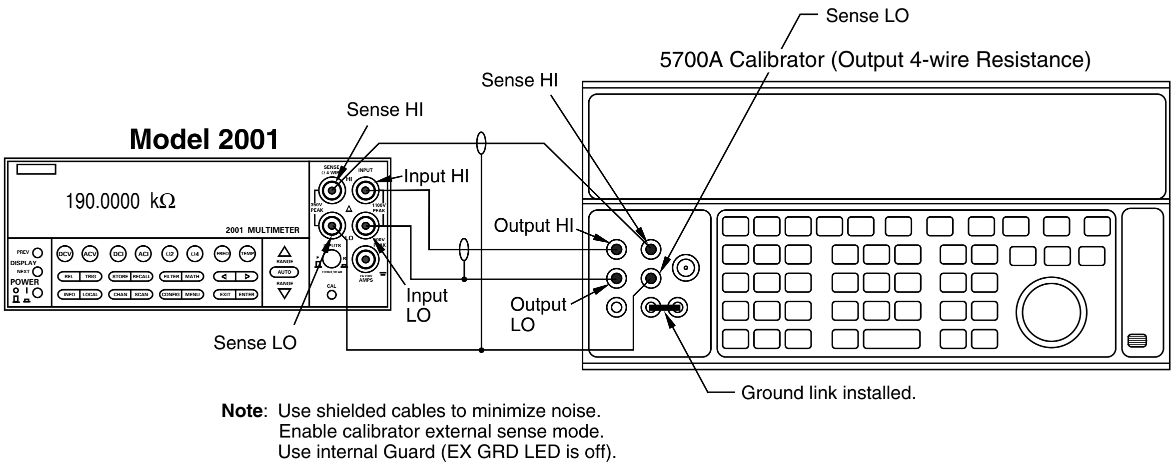


Figure 1-7
Connections for resistance verification (2M¾ - 200M¾ ranges)

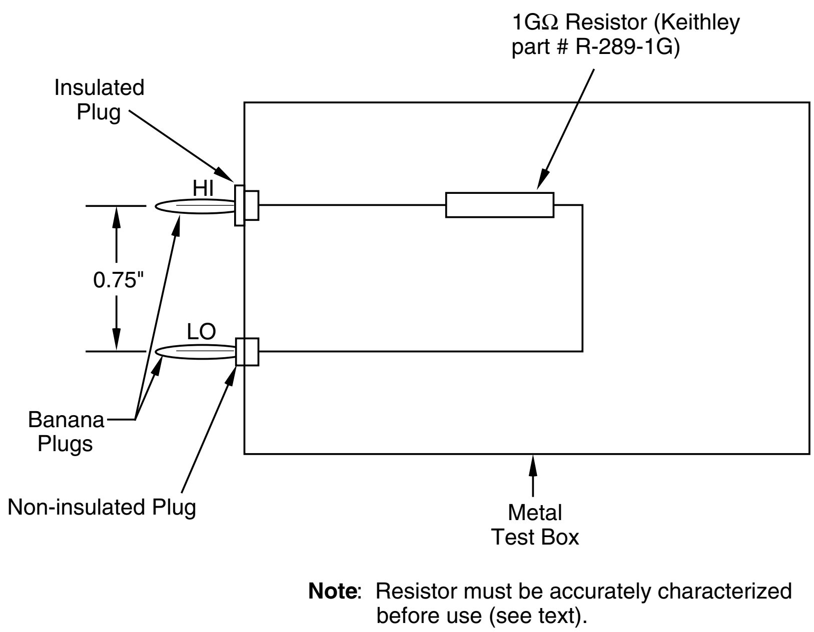


Figure 1-8
1G¾ resistor test box construction

Table 1-9
Limits for resistance verification (1G¾ range)

Characterized resistor (R)	Reading limit (1 year, 18° to 28°C)*
____________ G¾	_________G¾ to _________G¾

*1 Year limits = R ± (0.04R + 100,000)
Where R = characterized value of 1G¾ resistor.

1.8.6 Frequency accuracy verification

Frequency accuracy verification is performed by connecting an accurate frequency source to the Model 2001 inputs, and then verifying that the frequency readings are within stated limits.

Use the procedure below to verify the frequency measurement accuracy of the Model 2001.

1. Connect the frequency synthesizer to the Model 2001 INPUT terminals, as shown in Figure 1-9.
2. Turn on both instruments, and allow a one-hour warm-up period before measurement.
3. Set the synthesizer operating modes as follows:

   FREQ: 1Hz
   AMPTD: 5V p-p
   OFFSET: 0V
   MODE: CONT
   FCTN: sine wave

4. Restore Model 2001 factory defaults, as explained in paragraph 1.7.
5. Press FREQ to place the Model 2001 in the frequency measurement mode.
6. Set maximum signal level to 10V as follows:
   A. Press CONFIG then FREQ.
   B. Select MAX-SIGNAL-LEVEL, then press ENTER.
   C. Select VOLTAGE, then press ENTER.
   D. Select 10V, then press ENTER.
   E. Press EXIT to return to normal display.
7. Verify that the Model 2001 frequency reading is within the limits shown in the first line of Table 1-10.
8. Set the synthesizer to each of the frequencies listed in Table 1-10, and verify that the Model 2001 frequency reading is within the required limits.

Table 1-10
Frequency verification limits

Synthesizer frequency	Reading limits (1 year, 18° to 28°C)
1Hz	0.9997Hz to 1.0003Hz
10Hz	9.997Hz to 10.003Hz
100Hz	99.97Hz to 100.03Hz
1kHz	0.9997kHz to 1.0003kHz
10kHz	9.997kHz to 10.003kHz
100kHz	99.97kHz to 100.03kHz
1MHz	0.9997MHz to 1.0003MHz
10MHz	9.997MHz to 10.003MHz
15MHz	14.995MHz to 15.005MHz

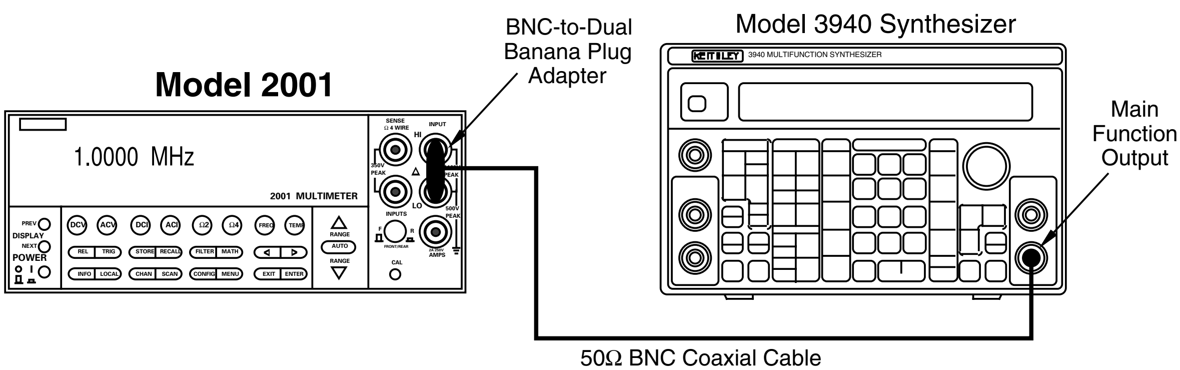


Figure 1-9
Connections for frequency accuracy verification

1.8.7 Temperature reading checks

When using thermocouples, the Model 2001 displays temperature by measuring the DC thermocouple voltage, and then calculating the corresponding temperature. Similarly, the instrument computes RTD temperature readings by measuring the resistance of the RTD probe and calculating temperature from the resistance value.

Since the instrument computes temperature from DCV and resistance measurements, verifying the accuracy of those DCV and resistance measurement functions guarantees the accuracy of corresponding temperature measurements. Thus, it is not necessary to perform a comprehensive temperature verification procedure if DCV and resistance verification procedures show the instrument meets its specifications in those areas. However, those who wish to verify that the Model 2001 does in fact properly display temperature can use the following procedure to do so.

Selecting the temperature sensor

Follow the steps below to select the type of temperature sensor:

1. From normal display, press CONFIG then TEMP.
2. Select SENSOR, then press ENTER.
3. Select 4-WIRE RTD or THERMOCOUPLE as desired, then press ENTER.
4. Select the type of RTD probe or thermocouple you wish to test, then return to the CONFIG TEMPERATURE menu.
5. Select UNITS, then press ENTER.
6. Select DEG-C, then press ENTER.
7. Press EXIT as necessary to return to normal display.
8. Press the TEMP key to place the Model 2001 in the temperature display mode. Refer to further information below on how to check thermocouple and RTD probe readings.

Thermocouple temperature reading checks

To check thermocouple readings, simply apply the appropriate DC voltage listed in Table 1-11 to the Model 2001 INPUT jacks using a precision DC voltage source (such as the one used to verify DC voltage accuracy in paragraph 1.8.1), and check the displayed temperature reading. Be sure to use low-thermal cables for connections between the DC calibrator and the Model 2001 when making these tests.

NOTE

The voltages shown are based on a 0°C reference junction temperature. Use CONFIG TEMP to set the default reference junction temperature to 0°C.

Table 1-11
Thermocouple temperature reading checks

Thermo-couple type	Applied DC voltage*	Displayed temperature (°C)
J	-4.215mV	-90.5 to -89.5
	0mV	-0.5 to +0.5
	1.277mV	24.5 to 25.5
	5.268mV	99.5 to 100.5
	42.283mV	749.5 to 750.5
K	-3.242mV	-90.5 to -89.5
	0mV	-0.5 to +0.5
	1.000mV	24.5 to 25.5
	4.095mV	99.5 to 100.5
	54.125mV	1349.5 to 1350.5
T	-3.089mV	-90.5 to -89.5
	0mV	-0.5 to +0.5
	0.992mV	24.5 to 25.5
	4.277mV	99.5 to 100.5
	20.252mV	389.5 to 390.5
E	-4.777mV	-90.6 to -89.4
	0mV	-0.6 to +0.6
	1.495mV	24.4 to 25.6
	6.317mV	99.4 to 100.6
	75.608mV	989.4 to 990.6
R	0.054mV	7 to 13
	0.647mV	97 to 103
	4.471mV	497 to 503
	20.878mV	1747 to 1753
S	0.055mV	7 to 13
	0.645mV	97 to 103
	4.234mV	497 to 503
	18.504mV	1747 to 1753
B	0.632mV	355 to 365
	1.241mV	495 to 505
	4.833mV	995 to 1005
	13.585mV	1795 to 1805

*Voltages shown are based on 0°C reference junction temperature. Use CONFIG-TEMP menu to set default reference junction to 0°C.

RTD Temperature reading checks

Use a precision decade resistance box (see Table 1-1) to simulate probe resistances at various temperatures (Table 1-12). Be sure to use 4-wire connections between the decade resistance box and the Model 2001.

Table 1-12
RTD probe temperature reading checks

RTD probe type	Applied resistance	Displayed temperature (°C)
PT385 (∝=0.00385055)	64.30¾	-90.08 to -89.92
	100¾	-0.08 to +0.08
	109.73¾	24.92 to 25.08
	138.51¾	99.92 to 100.08
	313.71¾	599.86 to 600.14
PT3916 (∝=0.00392)	63.68¾	-90.08 to -89.92
	100¾	-0.08 to +0.08
	109.90¾	24.92 to 25.08
	139.16¾	99.92 to 100.08
	266.94¾	449.86 to 450.14

2

Calibration

2.1 Introduction

This section gives detailed procedures for calibrating the Model 2001. There are three types of calibration procedures:

- Comprehensive calibration
- AC self-calibration
- Low-level calibration

Comprehensive calibration requires accurate calibration equipment to supply precise DC voltages and resistance values. AC self-calibration requires no external equipment and can be performed at any time by the operator. Low-level calibration is normally performed only at the factory where the instrument is manufactured and is not usually required in the field.

NOTE

Low-level calibration is required in the field only if the Model 2001 has been repaired, or if the other calibration procedures cannot bring the instrument within stated specifications.

Section 2 includes the following information:

2.2 Environmental conditions: States the temperature and humidity limits for calibration.

2.3 Warm-up period: Discusses the length of time the Model 2001 should be allowed to warm up before calibration.

2.4 Line power: States the power line voltage limits when calibrating the unit.

2.5 Calibration lock: Explains how to unlock calibration with the CAL switch.

2.6 IEEE-488 bus calibration commands and program: Summarizes bus commands used for calibration, lists a simple calibration program, and also discusses other important aspects of calibrating the instrument over the bus.

2.7 Calibration errors: Details front panel error messages that might occur during calibration and also explains how to check for errors over the bus.

2.8 Comprehensive calibration: Covers comprehensive (user) calibration from the front panel and over the IEEE-488 bus.

2.9 AC self-calibration: Discusses the AC user calibration process, both from the front panel and over the IEEE-488 bus.

2.10 Low-level calibration: Explains how to perform the low-level calibration procedure, which is normally required only at the factory.

2.2 Environmental conditions

Calibration procedures should be performed at an ambient temperature of 23°± 1°C, and at a relative humidity of less than 80% unless otherwise noted.

2.3 Warm-up period

The Model 2001 must be allowed to warm up for at least one hour before calibration. If the instrument has been subjected to temperature extremes (outside the range stated in paragraph 2.2), allow additional time for internal temperatures to stabilize. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

The calibration equipment should also be allowed to warm up for the minimum period specified by the manufacturer.

2.4 Line power

The Model 2001 should be calibrated while operating from a line voltage in the range of 90-134V or 180-250V at 50, 60, or 400Hz.

2.5 Calibration lock

Calibration can be unlocked by pressing in on the front panel CAL switch. Remove the sticker that covers the CAL switch access hole before calibration. Replace the sticker after completing calibration.

2.5.1 Comprehensive calibration lock

Before performing comprehensive calibration, you must first unlock calibration by momentarily pressing in on the recessed CAL switch. The instrument will display the following message:

```
CALIBRATION UNLOCKED
Comprehensive cal can now be performed
```

If you attempt comprehensive or low-level calibration without performing the unlocking procedure, the following message will be displayed:

```
CALIBRATION LOCKED
Press the CAL switch to unlock.
```

Note that it is not necessary to unlock calibration for the AC-only self-calibration procedure.

If the CAL switch is pressed with calibration already unlocked, the following message will be displayed:

```
CAL ALREADY UNLOCKED
Cycle Power to relock cal switch.
```

2.5.2 Low-level calibration lock

To unlock low-level calibration, press in and hold the CAL switch while turning on the power. Low-level calibration can then be performed.

NOTE

Do not unlock low-level calibration unless you have the appropriate equipment and intend to perform low-level calibration. See paragraph 2.10 for low-level calibration details.

2.5.3 IEEE-488 bus calibration lock status

You can determine the status of either calibration lock over the bus by using the appropriate query. To determine comprehensive calibration lock status, send the following query:

```
:CAL:PROT:SWIT?
```

The instrument will respond with the calibration lock status:

0: comprehensive calibration locked
1: comprehensive calibration unlocked

To determine the status of the low-level calibration lock, send the following query:

```
:CAL:PROT:LLEV:SWIT?
```

Responses to this lock query are:

0: low-level calibration locked
1: low-level calibration unlocked

Refer to paragraph 2.6.1 below and Section 3 for more details on calibration commands.

2.6 IEEE-488 bus calibration commands and program

2.6.1 Calibration commands

Table 2-1 summarizes calibration commands used to calibrate the instrument over the IEEE-488 bus (GPIB). For a complete description of calibration commands refer to Section 3.

Table 2-1
IEEE-488 bus calibration command summary

Command	Description
:CALibration	Calibration root command.
:PROTected	All commands in this subsystem are protected by the CAL switch.
:LOCK	Lock out calibration (opposite of enabling cal with CAL switch).
:SWITch?	Request comprehensive CAL switch state. (0 = locked; 1 = unlocked)
:SAVE	Save cal constants to EEPROM.
:DATA?	Download cal constants from 2001.
:DATE "<string>"	Send cal date to 2001.
:DATE?	Request cal date from 2001.
:NDUE "<string>"	Send next due cal date to 2001.
:NDUE?	Request next due cal date from 2001.
:LLEVel	Low-level calibration subsystem.
:SWITch?	Request low-level CAL switch state. (0 = locked; 1 = unlocked)
:STEP <Step #>	
1	20V AC at 1kHz step.
2	20V AC at 30kHz step.
3	200V AC at 1kHz step.
4	200V AC at 30kHz
5	1.5V AC at 1kHz step.
6	0.2V AC at 1kHz step.
7	5mV AC at 100kHz step.
8	0.5mV AC at 1kHz step.
9	+2V DC step.
10	-2V DC step.
11	0V DC step.
12	20mA AC at 1kHz step.
13	+0.2A DC step.
14	+2A DC step.
15	2V AC at 1Hz step.
:CALCulate	Calculate low-level cal constants.
:DC	User calibration subsystem.
:ZERO	Low-thermal short calibration step.
:LOW <value>	+2V DC calibration step.
:HIGH <value>	+20V DC calibration step.
:LOHM <value>	20k¾ calibration step.
:HOHM <value>	1M¾ calibration step.
:OPEN	Open circuit calibration step.
:CALCulate	Calculate DC cal constants.
:UNPRotected	All commands in this subsystem are not protected by CAL switch.
:ACCompensation	Perform user AC calibration (disconnect all cables)

NOTE: Upper case letters indicated short form of each command. For example, instead of sending ":CALibration:PROTected:LOCK", you can send ":CAL:PROT:LOCK".

2.6.2 Required order of command execution

When calibrating from the front panel, the Model 2001 will automatically prompt you in the correct order for various calibration steps. When calibrating over the IEEE-488 bus, however, the calibration sequence is determined by the order in which commands are received. Note that the Model 2001 must receive calibration commands in a specific order as covered below.

Comprehensive calibration

The following rules must be observed when sending bus commands to perform comprehensive calibration. These rules assume that comprehensive calibration has been enabled by pressing the CAL switch after instrument power is turned on.

1. The Model 2001 must execute all commands in the :CAL:PROT:DC subsystem before the :CAL:PROT:DC:CALC command will be executed. Commands in the :CAL:PROT:DC subsystem can be sent in any order with the exception of the CALC command.
2. The Model 2001 must execute the following commands before it will execute the :CAL:PROT:SAVE command:
   - All :CAL:PROT:DC subsystem commands.
   - The :CAL:PROT:DATE command.
   - The :CAL:PROT:NDUE command.

Low-level calibration

The following rules must be observed when sending commands to perform low-level calibration. These rules assume that low-level calibration has been enabled by pressing the CAL switch while turning on instrument power.

1. The Model 2001 must execute all commands in the :CAL:PROT:DC subsystem before the :CAL:PROT:DC:CALC command will be executed. Commands in the :CAL:PROT:DC subsystem can be executed in any order (except for CALC).
2. The Model 2001 must execute all commands in the :CAL:PROT:DC subsystem, and it must execute the :CAL:UNPR:AC command before it will execute any of the low-level commands.
3. There are a total of 15 low-level calibration steps, all of which must be executed before the :CAL:PROT:LLEV:CALC command will be executed. The 15 low-level calibration steps must be executed in order (step 1 through step 15).

   Step 1 is always a valid next step, which allows you to restart the low-level calibration procedure at any time. Similarly, the present step is always a valid next step, allowing you to repeat a calibration step if necessary. The next low-level step in numerical order is always valid.
4. The Model 2001 must execute the following commands before it will execute the :CAL:PROT:SAVE command:
   - All :CAL:PROT:DC subsystem commands.
   - The :CAL:UNPR:ACC command.
   - All :CAL:PROT:LLEV subsystem commands.
   - The :CAL:PROT:DATE command.
   - The :CAL:PROT:NDUE command.

2.6.3 Example calibration command program

Program 2-1 below will allow you to type in calibration commands and send them to the instrument. If the command is a query, the information will be requested from the instrument and displayed on the computer screen. The program uses the *OPC command to detect the end of each calibration step, as discussed in paragraph 3.6 in Section 3.

NOTE

See Appendix B for a summary of complete calibration programs.

Program requirements

In order to use this program, you will need the following:

- IBM PC, AT, or compatible computer.
- IOtech Personal488, CEC PC-488, or National Instruments PC-II or IIA IEEE-488 interface for the computer.
- Shielded IEEE-488 cable (Keithley Model 7007)
- MS-DOS or PC-DOS version 3.3 or later.
- Microsoft QuickBASIC, version 4.0 or later.
- IOtech Driver488 IEEE-488 bus driver, Rev. 2.3 or later. (NOTE: Later versions of Driver488 may not support other manufacturers' interface cards.)

Program instructions

1. With the power off, connect the Model 2001 to the IEEE-488 interface of the computer.
2. Turn on the computer and the Model 2001. Press in on the CAL switch to unlock calibration.
3. Make sure the Model 2001 is set for a primary address of 16. You can check or change the address as follows:
   A. Press MENU, select GPIB, then press ENTER.
   B. Select MODE, then press ENTER.
   C. Select ADDRESSABLE, and press ENTER.

D. If the address is set correctly, press EXIT as necessary to return to normal display.
E. To change the address, use the cursor and range keys to set the address to the desired value, then press ENTER. Press EXIT as necessary to return to normal display.

4. Make sure that the IEEE-488 bus driver software is properly initialized.
5. Enter the QuickBASIC editor, and type in the example program. After checking for errors, press <Shift> + <F5> to run it.
6. Type in the desired calibration command from the procedure (see paragraph 2.8.3), then press <Enter>.

2.7 Calibration errors

The Model 2001 checks for errors when calibration constants are calculated, minimizing the possibility that improper calibration may occur due to operator error. The following paragraphs summarize calibration error messages and discuss bus error reporting.

2.7.1 Front panel error message summary

Table 2-2 summarizes front panel calibration error messages that may occur because of improper connections or procedure.

NOTE

There are many more error messages that could occur because of internal hardware problems. Refer to Appendix C for a complete listing of all Model 2001 calibration error messages.

Table 2-2
Calibration error messages

Error ID code	Error message
-222	Parameter data out of range.
+438	Date of calibration not set.
+439	Next date of calibration not set.
+440	Calibration process not completed.

NOTE: This table lists only those errors that could occur because of some external problem such as improper connections or wrong procedure. See Appendix C for a complete listing of all error messages.

Program 2-1
Example Program to Send Calibration Commands

```
OPEN “\DEV\IEEEOUT” FOR OUTPUT AS #1     ‘  Open  IEEE-488  output
path.
OPEN “\DEV\IEEEIN” FOR INPUT AS #2       ‘  Open  IEEE-488  input
path.
IOCTL #1, “BREAK”                        ‘ Reset interface.
PRINT #1, “RESET”                        ‘ Warm start interface.
PRINT #1, “REMOTE 16”                    ‘ Put unit in remote.
PRINT #1, “TERM LF EOI”                  ‘ Set terminator.
PRINT #1, “OUTPUT 16;*RST;*ESE 1”        ‘ Initialize 2001.
CLS                                      ‘ Clear CRT.
Cmd: LINE INPUT “COMMAND? ”; A$
IF RIGHT$(A$, 1) = “?” THEN GOTO Query   ‘ Check for a query.
PRINT #1, “OUTPUT 16;*CLS”               ‘ Clear status registers.
PRINT #1, “OUTPUT 16;”; A$; “;*OPC”      ‘ Send command to unit.
Cal:
PRINT #1, “SPOLL 16”                     ‘ Check for completed cal.
INPUT #2, S
IF (S AND 32) = 0 THEN GOTO Cal:
GOTO Cmd
Query:
PRINT #1, “OUTPUT 16;”; A$               ‘ Send query to unit.
PRINT #1, “ENTER 16”                     ‘ Address unit to talk.
LINE INPUT #2, B$                        ‘  Input  response  from
unit.
PRINT B$
```

2.7.2 IEEE-488 bus error reporting

You can detect errors over the bus by testing the state of EAV (Error Available) bit (bit 2) in the status byte. (Use the *STB? query or serial polling to request the status byte.) If you wish to generate an SRQ (Service Request) on errors, send "*SRE 4" to the instrument to enable SRQ on errors.

You can query the instrument for the type of error by using the ":SYSTem:ERRor?" query. The Model 2001 will respond with the error number and a text message describing the nature of the error.

See paragraph 3.5 in Section 3 for more information on bus error reporting.

2.8 Comprehensive calibration

The comprehensive calibration procedure calibrates DCV, DCI (except for the 2A range), ¾2, and ¾4 functions. At the end of the DC calibration procedure, AC self-calibration is performed to complete the calibration process.

Comprehensive calibration should be performed at least once a year, or every 90 days to ensure the unit meets the corresponding specifications.

The comprehensive calibration procedure covered in this paragraph is normally the only calibration required in the field. However, if the unit has been repaired, you should perform the low-level calibration procedure explained in paragraph 2.10.

2.8.1 Recommended equipment for comprehensive calibration

Table 2-3 lists all test equipment recommended for comprehensive calibration. Alternate equipment (such as a DC transfer standard and characterized resistors) may be used as long as that equipment has specifications at least as good as those listed in the table. See Appendix D for a list of alternate calibration sources.

NOTE

Do not connect test equipment to the Model 2001 through a scanner.

2.8.2 Front panel comprehensive calibration

Follow the steps below to calibrate the Model 2001 from the front panel. Refer to paragraph 2.8.3 below for the procedure to calibrate the unit over the IEEE-488 bus. Table 2-4 summarizes the front panel calibration procedure.

Table 2-4
Front panel comprehensive calibration summary

Step	Description	Equipment/ connections
1	Warm-up, unlock calibration	None
2	DC zero calibration	Low-thermal short
3	+2VDC calibration	DC calibrator
4	+20VDC calibration	DC calibrator
5	20k¾ calibration	Ohms calibrator
6	1M¾ calibration	Ohms calibrator
7	Open-circuit calibration	Disconnect leads
8	AC self-calibration	Disconnect leads
9	Enter calibration dates	None
10	Save calibration constants	None

Table 2-3
Recommended equipment for comprehensive calibration

Mfg.	Model	Description	Specifications*
Fluke	5700A	Calibrator	±5ppm basic uncertainty. DC voltage: 2V: ±5ppm 20V: ±5ppm Resistance: 19k¾: ±11ppm 1M¾: ±18ppm
Keithley	8610	Low-thermal shorting plug	

* 90-day calibrator specifications shown include total uncertainty at specified output. The 2V output includes 0.5ppm transfer uncertainty. Use 20k¾ instead of 19k¾ if available with alternate resistance standard. See Appendix D for a list of alternate calibration sources.

Procedure

Step 1: Prepare the Model 2001 for calibration

1. Turn on the power, and allow the Model 2001 to warm up for at least one hour before performing calibration.
2. Unlock comprehensive calibration by briefly pressing in on the recessed front panel CAL switch, and verify that the following message is displayed:

   CALIBRATION UNLOCKED
   Comprehensive calibration can now be run

3. Enter the front panel calibration menu as follows:
   A. From normal display, press MENU.
   B. Select CALIBRATION, and press ENTER.
   C. Select COMPREHENSIVE, then press ENTER.
4. At this point, the instrument will display the following message:

   DC CALIBRATION PHASE

Step 2: DC zero calibration

1. Press ENTER. The instrument will display the following prompt.

   SHORT-CIRCUIT INPUTS

2. Connect the Model 8610 low-thermal short to the instrument INPUT and SENSE terminals, as shown in Figure 2-1. Wait at least three minutes before proceeding to allow for thermal equilibrium.

NOTE

Be sure to connect the low-thermal short properly to the HI, LO, and SENSE terminals. Keep drafts away from low-thermal connections to avoid thermal drift, which could affect calibration accuracy.

3. Press ENTER. The instrument will then begin DC zero calibration. While calibration is in progress, the following will be displayed:

   Performing Short-Ckt Calibration

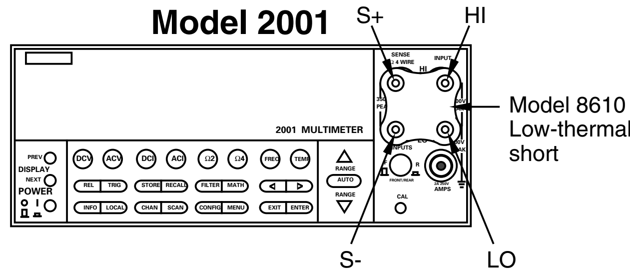


Figure 2-1
Low-thermal short connections

Step 3: +2V DC calibration

1. When the DC zero calibration step is completed, the following message will be displayed:

   CONNECT 2 VDC CAL

2. Disconnect the low-thermal short, and connect the DC calibrator to the INPUT jacks, as shown in Figure 2-2.

NOTE

Although 4-wire connections are shown, the sense leads are connected and disconnected at various points in the procedure by turning calibrator external sense on or off as appropriate. If your calibrator does not have provisions for turning external sense on and off, disconnect the sense leads when external sensing is to be turned off, and connect the sense leads when external sensing is to be turned on.

3. Set the calibrator output to +2.0000000V, and turn external sense off.
4. Press ENTER, and note that the Model 2001 displays the presently selected calibration voltage:

   VOLTAGE = 2.0000000

   (At this point, you can use the cursor and range keys to set the calibration voltage to a value from 0.98 to 2.1V if your calibrator cannot source 2V).

NOTE

For best results, it is recommended that you use the displayed calibration values throughout the procedure whenever possible.

5. Press ENTER. The instrument will display the following during calibration:

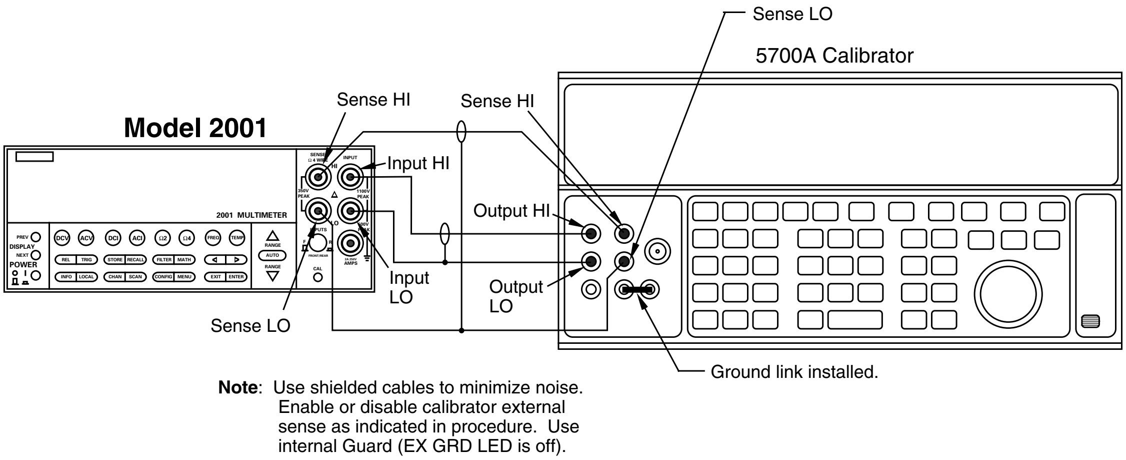


Figure 2-2
Connections for comprehensive calibration

Performing 2 VDC Calibration

Step 4: +20V DC calibration

1. After completing 2VDC calibration, the instrument will display the following:

   CONNECT 20 VDC CAL

2. Set the DC calibrator output to +20.000000V.
3. Press ENTER, and note that the instrument displays the calibration voltage:

   VOLTAGE = 20.0000000

   (At this point, you can use the cursor and range keys to set the calibration voltage to a value from 9.8 to 21V if your calibrator cannot source 20V).

4. Press ENTER. The instrument will display the following message to indicate it is performing 20V DC calibration:

   Performing 20 VDC Calibration

Step 5: 20k¾ calibration

1. After completing 20VDC calibration, the instrument will display the following:

   CONNECT 20kOHM RES

2. Set the calibrator output to 19.0000k¾, and turn external sense on.
3. Press ENTER, and note that the Model 2001 displays the resistance calibration value:

   OHMS = 20000.000

4. Using the cursor and range keys, set the resistance value displayed by the Model 2001 to the exact resistance value displayed by the calibrator. (The allowable range is from 9k¾ to 21k¾.)
5. Press ENTER, and note that the instrument displays the following during 20k¾ calibration:

   Performing 20 kOHM Calibration

Step 6: 1M¾ calibration

1. After completing 20k¾ calibration, the instrument will display the following:

   CONNECT 1.0 MOHM RES

2. Set the calibrator output to 1.00000M¾, and turn external sense off.
3. Press ENTER, and note that the Model 2001 displays the resistance calibration value:

   OHMS = 1000000.000

4. Using the cursor and range keys, set the resistance value displayed by the Model 2001 to the exact resistance value displayed by the calibrator. (The allowable range for this parameter is from 800k¾ to 2M¾.)
5. Press ENTER, and note that the instrument displays the following during 1M¾ calibration:

   Performing 1.0 MOHM Calibration

Step 7: Open-circuit calibration

1. At this point, the instrument will display the following message advising you to disconnect test leads:

   OPEN CIRCUIT INPUTS

2. Disconnect all test leads from the INPUT and SENSE jacks, then press ENTER. During this calibration phase, the instrument will display the following:

   Performing Open-Ckt Calibration

Step 8: AC self-calibration

1. After open circuit calibration, the instrument will display the following message:

   AC CALIBRATION PHASE

2. Make sure all test leads are still disconnected from the Model 2001 INPUT and SENSE jacks.
3. Press ENTER to perform AC calibration, which will take about six minutes to complete. During AC calibration, the instrument will display the following:

   Calibrating AC: Please wait

4. When AC calibration is finished, the instrument will display the following:

   AC CAL COMPLETE

Step 9: Enter calibration dates

1. Press ENTER, and note that the instrument prompts you to enter the present calibration date:

   CAL DATE: 01/01/92

2. Use the cursor and range keys to enter the current date as the calibration date, then press ENTER. Press ENTER again to confirm the date as being correct.
3. The instrument will then prompt you to enter the due date for next calibration:

   NEXT CAL: 01/01/93

4. Use the cursor and range keys to set the date as desired, then press ENTER. Press ENTER a second time to confirm your selection.

Step 10: Save calibration constants

1. At the end of a successful calibration cycle, the instrument will display the following:

   CALIBRATION SUCCESS

2. If you wish to save calibration constants from the procedure just completed, press ENTER.
3. If you do not want to save calibration constants from the procedure just completed and wish instead to restore previous constants, press EXIT.
4. Press EXIT to return to normal display after calibration.

NOTE

Comprehensive calibration will be automatically locked out after the calibration procedure has been completed.

2.8.3 IEEE-488 bus comprehensive calibration

Follow the procedure outlined below to perform comprehensive calibration over the IEEE-488 bus. Use the program listed in paragraph 2.6.3 or other similar program to send commands to the instrument. Table 2-5 summarizes the calibration procedure and bus commands.

Procedure

Step 1: Prepare the Model 2001 for calibration

1. Connect the Model 2001 to the IEEE-488 bus of the computer using a shielded IEEE-488 cable such as the Keithley Model 7007.
2. Turn on the power, and allow the Model 2001 to warm up for at least one hour before performing calibration.
3. Unlock calibration by briefly pressing in on the recessed front panel CAL switch, and verify that the following message is displayed:

   CALIBRATION UNLOCKED
   Comprehensive calibration can now be run

NOTE

You can query the instrument for the state of the comprehensive CAL switch by using the following query:

:CAL:PROT:SWIT?

A returned value of 1 indicates that calibration is locked, while a returned value of 0 shows that calibration is unlocked.

4. Make sure the primary address of the Model 2001 is the same as the address specified in the program you will be using to send commands (see paragraph 2.6.3).

Table 2-5
IEEE-488 bus comprehensive calibration summary

Step	Description	IEEE-488 bus command
1	Warm-up, unlock calibration	
2	DC zero calibration	:CAL:PROT:DC:ZERO
3	+2VDC calibration	:CAL:PROT:DC:LOW <value>
4	+20VDC calibration	:CAL:PROT:DC:HIGH <value>
5	20k¾ calibration	:CAL:PROT:DC:LOHM <value>
6	1M¾ calibration	:CAL:PROT:DC:HOHM <value>
7	Open-circuit calibration	:CAL:PROT:DC:OPEN
8	Calculate constants	:CAL:PROT:DC:CALC
9	Check for errors	:SYST:ERR?
10	Perform user AC cal	:CAL:UNPR:ACC
11	Check for errors	:SYST:ERR?
12	Save calibration dates	:CAL:PROT:DATE “<cal_date>” :CAL:PROT:NDUE “<due_date>”
13	Save calibration constants	:CAL:PROT:DC:SAVE
14	Lock out calibration	:CAL:PROT:LOCK

Step 2: DC zero calibration

1. Connect the Model 8610 low-thermal short to the instrument INPUT and SENSE terminals, as shown in Figure 2-1. Wait at least three minutes before proceeding to allow for thermal equilibrium.

NOTE

Be sure to properly connect HI, LO, and SENSE terminals. Keep drafts away from low-thermal connections to avoid thermal drift, which could affect calibration accuracy.

2. Send the following command over the bus:

   :CAL:PROT:DC:ZERO

3. Wait until the Model 2001 finishes this calibration step before proceeding. (You can use the *OPC or *OPC? commands to determine when calibration steps end, as discussed in paragraph 3.6.)

Step 3: +2V DC calibration

1. Disconnect the low-thermal short, and connect the DC calibrator to the INPUT jacks, as shown in Figure 2-2.

NOTE

Although 4-wire connections are shown, the sense leads are connected and disconnected at various points in the procedure by turning calibrator external sense on or off as appropriate. If your calibrator does not have provisions for turning external sense on and off, disconnect the sense leads when external sensing is to be turned off, and connect the sense leads when external sensing is to be turned on.

2. Set the DC calibrator output to +2.00000V, and turn external sense off.
3. Send the following command to the Model 2001 over the IEEE-488 bus:

   :CAL:PROT:DC:LOW 2.0

   (Be sure to use the exact calibration value if you are using a voltage other than 2V. The allowable range from is 0.98V to 2.1V).

NOTE

For best results, use the calibration values given in this procedure whenever possible.

4. Wait until the Model 2001 finishes this step before going on.

Step 4: +20V DC calibration

1. Set the DC calibrator output to +20.00000V.
2. Send the following command to the instrument:

   :CAL:PROT:DC:HIGH 20

   (Send the actual calibration value in the range of 9.8V to 21V if you are using a different voltage.)
3. Wait until the Model 2001 finishes this step before going on.

Step 5: 20k¾ calibration

1. Set the calibrator output to 19.0000k¾, and turn external sense on.

NOTE

> If your calibrator can source 20k¾, use that value instead of the 19k¾ value.

2. Send the following command to the Model 2001:

   :CAL:PROT:DC:LOHM <value>

   Here, <value> is the actual calibrator resistance value. For example, if the calibrator resistance is 18.9987k¾, the command would appear as follows:

   :CAL:PROT:DC:LOHM 18.9987E3

   (The allowable range for this parameter is from 9E3 to 20E3.)
3. Wait until the Model 2001 finishes 20k¾ calibration before continuing.

Step 6: 1M¾ calibration

1. Set the calibrator output to 1.0000M¾, and turn external sense off.
2. Send the following command to the Model 2001:

   :CAL:PROT:DC:HOHM <value>

   Here, <value> is the actual calibrator resistance value. For example, if the calibrator resistance is 1.00023M¾, the command would appear as follows:

   :CAL:PROT:DC:HOHM 1.00023E6

   (The allowable range for this parameter is from 800E3 to 2E6.)
3. Wait until the Model 2001 finishes 1M¾ calibration before continuing.

Step 7. Open-circuit calibration

1. Disconnect all test leads from the Model 2001 INPUT and SENSE jacks.
2. Send the following command to the instrument:

   :CAL:PROT:DC:OPEN
3. Wait until open-circuit calibration is complete before going on to the next step.

Step 8: Calculate DC calibration constants

To program the Model 2001 to calculate new DC calibration constants, send the following command over the bus:

:CAL:PROT:DC:CALC

Step 9: Check for DC calibration errors

You can check for DC calibration errors over the bus by sending the following query:

:SYST:ERR?

If no errors are reported, DC calibration is successful, and you can proceed to the next step.

Step 10: Perform AC user calibration

To perform user AC calibration, send the following command:

:CAL:UNPR:ACC

Note that AC calibration will take about six minutes to complete.

Step 11: Check for AC calibration errors

To check for AC calibration errors, send the following query:

SYST:ERR?

If the unit sends back a “No error” response, AC calibration was successful.

Step 12: Enter calibration dates

To set the calibration date and next due date, use following commands to do so:

:CAL:PROT:DATE ‘1/01/92’ (programs calibration date)

:CAL:PROT:NDUE ‘1/01/93’ (programs next calibration due date)

Step 13: Save calibration constants

Calibration is now complete, so you can store the calibration constants in EEROM by sending the following command:

:CAL:PROT:SAVE

Step 14: Lock out calibration

To lock out further calibration, send the following command after completing the calibration procedure:

:CAL:PROT:LOCK

2.9 AC self-calibration

The AC self-calibration procedure requires no external equipment and can be performed at any time by the user. As the name implies, this calibration procedure assures the accuracy of ACI and ACV measurements.

In general, AC calibration should be performed one-hour after power-on or at least once every 24 hours for optimum AC measurement accuracy.

NOTE

The AC calibration constants generated by this procedure are not permanently stored. Thus, AC calibration constants are in effect only until the power is turned off. In order to permanently store AC calibration constants, you must perform the comprehensive or low-level calibration procedure and then choose to save calibration constants at the end of that procedure. See paragraph 2.8 or 2.10 for details.

2.9.1 Front panel AC calibration

Procedure:

1. Disconnect all test leads or cables from the INPUT and SENSE jacks.
2. Press MENU. The instrument will display the following:

   MAIN MENU
   SAVESETUP GPIB CALIBRATION

3. Select CALIBRATION, then press ENTER. The Model 2001 will display the following:

   PERFORM CALIBRATION
   COMPREHENSIVE AC-ONLY-CAL

4. Select AC-ONLY-CAL, then press ENTER. The instrument will display the following message:

   AC CALIBRATION PHASE
   Open-circuit inputs, press ENTER

5. Press ENTER to begin AC calibration, which will take about six minutes to complete. During AC calibration, the instrument will display the following:

   Calibrating AC: Please wait

6. Once the process has been successfully completed, the message below will be displayed, and you can press ENTER or EXIT to return to normal display:

   AC CAL COMPLETE
   Press ENTER or EXIT to continue.

2.9.2 IEEE-488 bus AC self-calibration

Procedure:

1. Disconnect all test leads and cables from the INPUT and SENSE jacks.
2. Send the following command over the bus:

   :CAL:UNPR:ACC

3. Wait until calibration has been completed before sending any further commands.
4. Check for calibration errors by using the :SYST:ERR? query.

2.10 Low-level calibration

Low-level calibration is normally performed only at the factory when the instrument is manufactured and is not usually required in the field. The following paragraphs give detailed procedures for performing low-level calibration should it ever become necessary in the field.

NOTE

Low-level calibration is required in the field only if the Model 2001 has been repaired, or if the other calibration procedures cannot bring the instrument within stated specifications. The low-level calibration procedure includes the comprehensive calibration steps discussed in paragraph 2.8. Comprehensive calibration steps must be performed before performing the low-level calibration steps.

2.10.1 Recommended equipment for low-level calibration

Table 2-6 summarizes recommended equipment for low-level calibration. Alternate equipment may be used as long as corresponding specifications are at least as good as those listed in the table. See Appendix D for a list of alternate calibration sources.

2.10.2 Low-level calibration summary

Table 2-7 summarizes the steps necessary to complete the low-level calibration procedure. The procedure must be performed in the order shown in the table. Calibration commands shown are to be used when calibrating the unit over the IEEE-488 bus.

Table 2-6
Recommended equipment for low-level calibration

Mfg.	Model	Description	Specifications*
Fluke	5700A	Calibrator	±5ppm basic uncertainty. DC voltage: 0V: ±0.75µV -2V, +2V: ±5ppm 20V: ±5ppm DC current: 200mA: ±65ppm 2A: ±90ppm AC voltage: 0.5mV @ 1kHz: ±10000ppm 5mV @ 100kHz: ±2400ppm 200mV @ 1kHz: ±150ppm 1.5V @ 1kHz: ±80ppm 20V @ 1kHz: ±80ppm 20V @ 30kHz: ±140ppm 200V @ 1kHz: ±85ppm 200V @ 30kHz: ±240ppm AC current: 20mA @ 1kHz: ±160ppm Resistance: 19k¾: ±11ppm 1M¾: ±18ppm
Keithley	3930A	Synthesizer	2V rms @ 1Hz
Keithley	8610	Low-thermal shorting plug	

* 90-day calibrator specifications shown include total uncertainty at specified output. The ±2V outputs include 0.5ppm transfer uncertainty. See Appendix D for a list of alternate calibration sources.

Table 2-7
Low-level calibration summary

Calibration signal	Calibration command	Comments
Low-thermal short	:CAL:PROT:DC:ZERO	Comprehensive cal zero.
+2V DC	:CAL:PROT:DC:LOW <value>	Comprehensive cal 2V.
+20V DC	:CAL:PROT:DC:HIGH <value>	Comprehensive cal 20V.
20k¾	:CAL:PROT:DC:LOHM <value>	Comprehensive cal 20k¾.
1M¾	:CAL:PROT:DC:HOHM <value>	Comprehensive cal 1M¾.
Disconnect leads	:CAL:PROT:DC:OPEN	Comprehensive cal open.
None	:CAL:PROT:DC:CALC	Calculate constants.
None	:SYST:ERR?	Check for DC errors.
None	:CAL:UNPR:ACC	AC user calibration.
None	:SYST:ERR?	Check for AC errors.
20V AC @ 1kHz	:CAL:PROT:LLEV:STEP 1	Low-level Step 1.
20V AC @ 30kHz	:CAL:PROT:LLEV:STEP 2	Low-level Step 2.
200V AC @ 1kHz	:CAL:PROT:LLEV:STEP 3	Low-level Step 3.
200V AC @ 30kHz	:CAL:PROT:LLEV:STEP 4	Low-level Step 4.
1.5V AC @ 1kHz	:CAL:PROT:LLEV:STEP 5	Low-level Step 5.
200mV AC @ 1kHz	:CAL:PROT:LLEV:STEP 6	Low-level Step 6.
5mV AC @ 100kHz	:CAL:PROT:LLEV:STEP 7	Low-level Step 7.
0.5mV AC @ 1kHz	:CAL:PROT:LLEV:STEP 8	Low-level Step 8.
+2V DC	:CAL:PROT:LLEV:STEP 9	Low-level Step 9.
-2V DC	:CAL:PROT:LLEV:STEP 10	Low-level Step 10.
0V DC	:CAL:PROT:LLEV:STEP 11	Low-level Step 11.
20mA AC @ 1kHz	:CAL:PROT:LLEV:STEP 12	Low-level Step 12.
+200mA DC	:CAL:PROT:LLEV:STEP 13	Low-level Step 13.
+2A DC	:CAL:PROT:LLEV:STEP 14	Low-level Step 14.
2V rms @ 1Hz	:CAL:PROT:LLEV:STEP 15	Low-level Step 15.
None	:CAL:PROT:LLEV:CALC	Calculate constants.
None	:SYST:ERR?	Check for errors.
None	:CAL:PROT:DATE “<date>”	Program cal date
None	:CAL:PROT:NDUE “<due>”	Program cal due date.
None	:CAL:PROT:SAVE	Save constants.
None	:CAL:PROT:LOCK	Lock out calibration.

2.10.3 Front panel low-level calibration procedure

Follow the steps below to perform low-level calibration from the front panel.

Procedure

1. Turn off the power if the instrument is presently turned on.
2. While pressing in on the recessed CAL switch, turn on the power. The instrument will display the following to indicated it is ready for low-level calibration:

   MANUFACTURING CAL

3. Press ENTER. The instrument will display the following:

   DC CALIBRATION PHASE

4. Allow the Model 2001 to warm up for at least one hour before performing calibration.
5. Press ENTER. The instrument will display the following prompt.

   SHORT-CIRCUIT INPUTS

6. Connect the Model 8610 low-thermal short to the instrument INPUT and SENSE terminals, as shown in Figure 2-1. Wait three minutes before proceeding to allow for thermal equilibrium.

NOTE

Be sure to properly connect HI, LO, and SENSE terminals. Keep drafts away from low-thermal connections to avoid thermal drift, which could affect calibration accuracy.

7. Press ENTER. The instrument will then begin DC zero calibration. While calibration is in progress, the following will be displayed:

   Performing Short-Ckt Calibration

8. When the DC zero calibration step is completed, the following message will be displayed:

   CONNECT 2 VDC CAL

9. Disconnect the low-thermal short, and connect the DC calibrator to the INPUT jacks, as shown in Figure 2-2.
10. Set the DC calibrator output to +2.00000V, and make sure that external sense is turned **off**.
11. Press ENTER, and note that the Model 2001 displays the presently selected calibration voltage:

    VOLTAGE = 2.0000000

    (At this point, you can use the cursor and range keys to set the calibration voltage to a value from 0.98 to 2.1V if your calibrator cannot output 2V).

12. Press ENTER. The instrument will display the following during calibration:

    Performing 2 VDC Calibration

13. After completing 2VDC calibration, the instrument will display the following:

    CONNECT 20 VDC CAL

14. Set the DC calibrator output to +20.00000V.
15. Press ENTER, and note that the instrument displays the calibration voltage:

    VOLTAGE = 20.000000

    (At this point, you can use the cursor and range keys to set the calibration voltage to a value from 9.8 to 21V if your calibrator cannot output 20V).

16. Press ENTER. The instrument will display the following message to indicate it is performing 20V DC calibration:

    Performing 20 VDC Calibration

17. After completing 20VDC calibration, the instrument will display the following:

    CONNECT 20kOHM RES

18. Set the calibrator output to 19.0000k¾, and turn external sense on. (Allowable range is from 9k¾ to 20k¾.)
19. Press ENTER, and note that the Model 2001 displays the resistance calibration value:

    OHMS = 20000.000

20. Using the cursor and range keys, set the resistance value displayed by the Model 2001 to the exact resistance value displayed by the calibrator.
21. Press ENTER, and note that the instrument displays the following during 20k¾ calibration:

    Performing 20 kOHM Calibration

22. After completing 20k¾ calibration, the instrument will display the following:

    CONNECT 1.0 MOHM RES

23. Set the calibrator output to 1.00000M¾, and turn external sense off. (Allowable range is 800k¾ to 2M¾.)
24. Press ENTER, and note that the Model 2001 displays the resistance calibration value:

    OHMS = 1000000.00

25. Using the cursor keys, set the resistance value displayed by the Model 2001 to the **exact** resistance value displayed by the calibrator.

26. Press ENTER, and note that the instrument displays the following during 1M¾ calibration:

    Performing 1.0 MOhm Calibration

27. At this point, the instrument will display the following message advising you to disconnect test leads:

    OPEN CIRCUIT INPUTS

28. Disconnect all test leads from the INPUT and SENSE jacks, then press ENTER. During this calibration phase, the instrument will display the following:

    Performing Open-Ckt Calibration

29. After open circuit calibration, the instrument will display the following message:

    AC CALIBRATION PHASE

30. Make sure all test leads are still disconnected from the Model 2001 INPUT and SENSE jacks.
31. Press ENTER to perform AC calibration, which will take a while to complete. During AC calibration, the instrument will display the following:

    Calibrating AC: Please wait

32. After the AC calibration phase is completed, the instrument will display the following:

    AC CAL COMPLETE

33. Press ENTER. The instrument will display the following to indicate the start of the low-level calibration phase:

    LOW-LEVEL CAL PHASE

NOTE

Use the exact calibration values shown when performing the following steps.

34. Connect the calibrator to the INPUT terminals, as shown in Figure 2-3.
35. Press ENTER. The instrument will display the following:

    Connect 20V @ 1kHz

36. Set the calibrator to output 20V AC at a frequency of 1kHz, then press ENTER. The instrument will display the following:

    Low-Level Cal - Step 1 of 15

37. Next, the instrument will prompt for a new calibration signal:

    Connect 20V @ 30kHz

38. Program the calibrator for an output voltage of 20V AC at 30kHz, then press ENTER. The instrument will display the following while calibrating this step:

    Low-Level Cal - Step 2 of 15

39. The Model 2001 will then display:

    Connect 200V @ 1kHz

40. Set the calibrator output to 200V AC at a frequency of 1kHz, then press ENTER. The Model 2001 will display the following message:

    Low-Level Cal - Step 3 of 15

41. When finished with this step, the Model 2001 will display:

    Connect 200V @ 30kHz

42. Set the calibrator output to 200V AC at 30kHz, then press ENTER. The Model 2001 will display the following:

    Low-Level Cal - Step 4 of 15

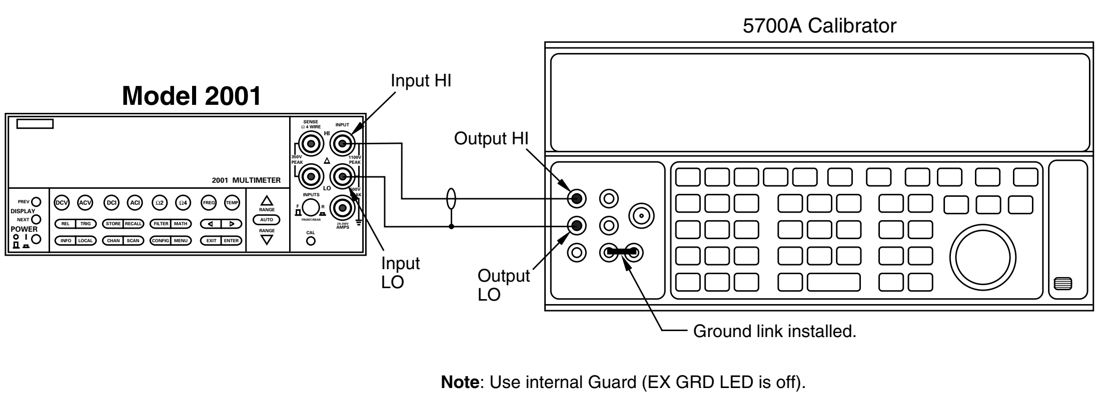


Figure 2-3
Calibration voltage connections

43. The unit will then prompt for the next calibration signal:

    Connect 1.5V @ 1kHz

44. Set the calibrator for 1.5V AC at a frequency of 1kHz, then press ENTER. The Model 2001 will display the following:

    Low-Level Cal - Step 5 of 15

45. After step 5, the unit will display the following:

    Connect 200mV @ 1kHz

46. Program the calibrator to output 200mV at a frequency of 1kHz, then press ENTER. The Model 2001 will then display the following:

    Low-Level Cal - Step 6 of 15

47. When finished with step 6, the unit will display the following:

    Connect 5mV @ 100kHz

48. Set the calibrator to output 5mV at a frequency of 100kHz, then press ENTER. The Model 2001 will then display the following while calibrating:

    Low-Level Cal - Step 7 of 15

49. Following step 7, the instrument will display the following message to prompt for the next calibration signal:

    Connect 0.5mV @ 1kHz

50. Program the calibrator to output 0.5mV at 1kHz, then press ENTER. The unit will display the following in-progress message:

    Low-Level Cal - Step 8 of 15

51. Next, the unit will prompt for the next calibration signal:

    Connect +2 VDC

52. Set the calibrator to output +2V DC, then press the ENTER key. The Model 2001 will advise you that the present step is in progress:

    Low-Level Cal - Step 9 of 15

53. After this step has been completed, the unit will display the following:

    Connect -2 VDC

54. Set the calibrator for an output voltage of -2V DC, then press ENTER. The Model 2001 will display the following message:

    Low-Level Cal - Step 10 of 15

55. The Model 2001 will then prompt for the next calibration signal:

    Set calibrator to 0V

56. Program the calibrator to output 0 VDC, then press the ENTER key. The Model 2001 will display the following:

    Low-Level Cal - Step 11 of 15

57. After completing step 11, the unit will display the following:

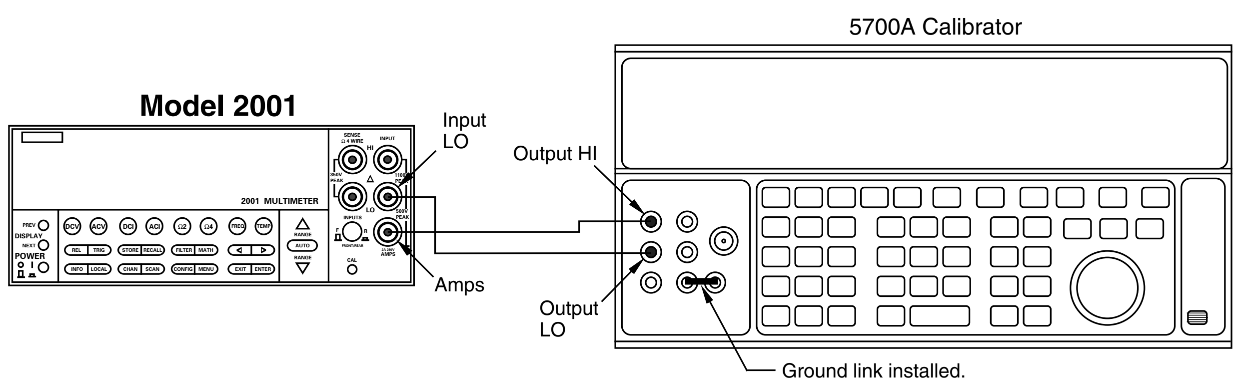
    Connect 20mA @ 1kHz

58. Connect the calibrator to the AMPS and INPUT LO jacks, as shown in Figure 2-4.
59. Set the calibrator output to 20mA AC at a frequency of 1kHz, then press the ENTER key. The Model 2001 will display the following while calibrating:

    Low-Level Cal - Step 12 of 15

60. The unit will then prompt for the next calibration signal:

    Connect +0.2ADC



Note: Be sure calibrator is set for normal current output.
Use internal Guard (EX GRD LED is off).

Figure 2-4
Current calibration connections

61. Program the calibrator to output +200mA DC, then press then ENTER key. The Model 2001 will display the following while calibrating:

    Low-Level Cal - Step 13 of 15

62. The Model 2001 will prompt for the next calibration signal:

    Connect +2 ADC

63. Program the calibrator to output +2A DC, then press the ENTER key. During calibration, the instrument will display the following:

    Low-Level Cal - Step 14 of 15

64. The unit will then prompt for the last calibration signal:

    Connect 2 V at 1 Hz

65. Put the calibrator in standby, then disconnect it from the Model 2001 INPUT and AMPS jacks; connect the synthesizer to INPUT HI and LO, as shown in Figure 2-5.
66. Set synthesizer operation modes as follows:

    FCTN: sine

    FREQ: 1Hz

    AMPTD: 2Vrms

    MODE: CONT

67. Press the Model 2001 ENTER key. The instrument will display the following while calibrating:

    Low-Level Cal - Step 15 of 15

68. After step 15 is completed, the instrument will display the following message to indicate that calibration has been completed:

    CALIBRATION COMPLETE

69. Press ENTER. The instrument will prompt you to enter the calibration date:

    CAL DATE: 01/01/92

70. Use the cursor and range keys to set the date as desired, then press ENTER. Press ENTER a second time to confirm your date selection.
71. The Model 2001 will then prompt you to enter the calibration due date:

    NEXT CAL: 01/01/92

72. Use the cursor keys to set the date as desired, then press ENTER. Press ENTER again to confirm your date.
73. The Model 2001 will then display the following message:

    CALIBRATION SUCCESS

74. If you wish to save the new calibration constants, press ENTER. If, on the other hand, you wish to restore previous calibration constants, press EXIT.
75. Press EXIT as necessary to return to normal display.

NOTE

Calibration will be locked out automatically when the calibration procedure is completed.

2.10.4 IEEE-488 bus low-level calibration procedure

Follow the steps below to perform low-level calibration over the IEEE-488 bus. Table 2-7 summarizes calibration commands for the procedure.

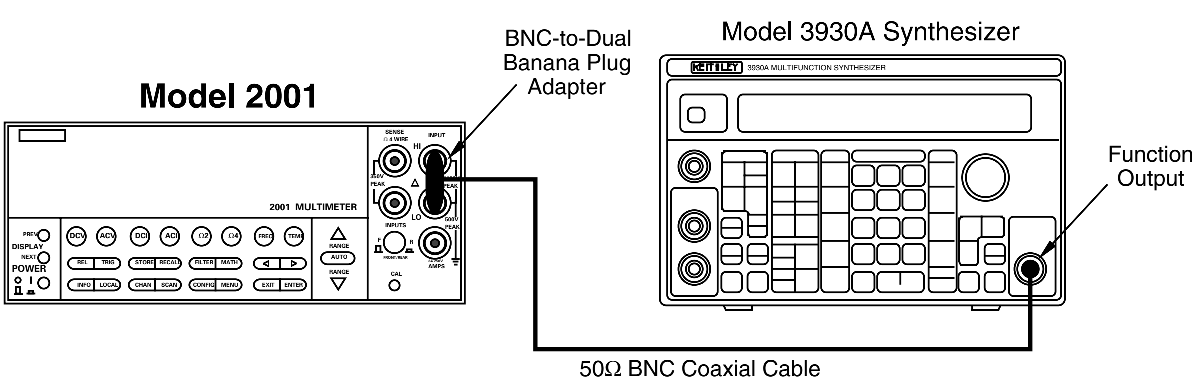


Figure 2-5
Synthesizer connections

Procedure

1. Connect the Model 2001 to the IEEE-488 bus of the computer using a shielded IEEE-488 cable such as the Keithley Model 7007.
2. Make sure the primary address of the Model 2001 is the same as the address specified in the program you will be using to send commands (see paragraph 2.6.3).
3. Turn off the power if the instrument is presently turned on.
4. Press and hold the recessed CAL switch while turning on the power. The instrument will display the following message to indicate it is ready for the low-level calibration procedure:

   MANUFACTURING CAL

5. Allow the Model 2001 to warm up for at least one hour before performing calibration.
6. Connect the Model 8610 low-thermal short to the instrument INPUT and SENSE terminals, as shown in Figure 2-1. Wait three minutes before proceeding to allow for thermal equilibrium.

NOTE

> Be sure to properly connect HI, LO, and SENSE terminals. Keep drafts away from low-thermal connections to avoid thermal drift, which could affect calibration accuracy.

7. Send the following command over the bus:

   :CAL:PROT:DC:ZERO

   Wait until the Model 2001 finishes this calibration step before proceeding. (You can use the *OPC or *OPC? commands to determine when calibration steps end, as discussed in paragraph 3.6.)

8. Disconnect the low-thermal short, and connect the DC calibrator to the INPUT jacks, as shown in Figure 2-2.
9. Set the DC calibrator output to +2.00000V, and turn external sense off. Send the following command to the Model 2001 over the IEEE-488 bus:

   :CAL:PROT:DC:LOW 2.0

   (Be sure to use the exact calibration value if you are using a voltage other than 2V. The allowable range is 0.98V to 2.1V).

NOTE

> For best results, use the calibration values given in this part of the procedure whenever possible.

   Wait until the Model 2001 finishes this step before going on.

10. Set the DC calibrator output to +20.00000V. Send the following command to the instrument:

    :CAL:PROT:DC:HIGH 20

    (Send the actual calibration value in the range of 9.8V to 21V if you are using a different voltage.) Wait until the Model 2001 finishes this step before going on.

11. Set the calibrator output to 19.0000k¾, and turn external sense on. Send the following command to the Model 2001:

    :CAL:PROT:DC:LOHM <value>

    Here, <value> is the actual calibrator resistance value. For example, if the calibrator resistance is 18.9987k¾, the command would appear as follows:

    :CAL:PROT:DC:LOHM 18.9987E3

    Wait until the Model 2001 finishes the 20k¾ calibration step before continuing.

NOTE

> If your calibrator can source 20k¾, use that value instead of the 19k¾ value used here.

12. Set the calibrator output to 1.0000M¾, and turn external sense off. Send the following command to the Model 2001:

    :CAL:PROT:DC:HOHM <value>

    Here, <value> is the actual calibrator resistance value. For example, if the calibrator resistance is 1.00023M¾, the command would appear as follows:

    :CAL:PROT:DC:HOHM 1.00023E6

    Wait until the Model 2001 finishes 1M¾ calibration before continuing.

13. Disconnect all test leads from the INPUT and SENSE jacks. Send the following command to the instrument:

    :CAL:PROT:DC:OPEN

    Wait until the open-circuit calibration is complete before going on to the next step.

14. To program the Model 2001 to calculate new calibration constants, send the following command over the bus:

    :CAL:PROT:DC:CALC

15. Check for DC calibration errors by sending the following query:

    :SYST:ERR?

16. Perform user AC calibration by sending the following command:

    :CAL:UNPR:ACC

    Note that the AC calibration phase will take about six minutes to complete.

17. Check for AC calibration errors by sending the following command:

    :SYST:ERR?

NOTE

The following steps perform the low-level part of the calibration procedure. Use only the indicated calibration values for these steps. Be sure the instrument completes each step before sending the next calibration command.

18. Connect the Model 2001 to the calibrator using 2-wire connections, as shown in Figure 2-3.
19. Program the calibrator to output 20V AC at a frequency of 1kHz, then send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 1

20. Program the calibrator to output 20V AC at a frequency of 30kHz, and send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 2

21. Set the calibrator output to 200V AC at 1kHz, then send the following command:

    :CAL:PROT:LLEV:STEP 3

22. Set the calibrator output to 200V AC at a frequency of 30kHz, then send the following command:

    :CAL:PROT:LLEV:STEP 4

23. Program the calibrator to output 1.5V AC at a frequency of 1kHz. Send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 5

24. Program the calibrator to output 200mV AC at a frequency of 1kHz, and send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 6

25. Set the calibrator output to 5mV AC at a frequency of 100kHz. Send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 7

26. Program the calibrator to output 0.5mV AC at a frequency of 1kHz. Send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 8

27. Set the calibrator output to +2V DC. Send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 9

28. Program the calibrator to output -2V DC, and send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 10

29. Set the calibrator output to 0V DC, and then send the following command:

    :CAL:PROT:LLEV:STEP 11

30. Connect the calibrator to the AMPS and INPUT LO terminals, as shown in Figure 2-4.
31. Program the calibrator to output 20mA AC at a frequency of 1kHz. Send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 12

32. Set the calibrator output to +200mA DC. Send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 13

33. Program the calibrator to output +2A DC, then send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 14

34. Connect the multifunction synthesizer to the Model 2001, as shown in Figure 2-5.
35. Set the synthesizer operating modes as follows:

    FCTN: sine

    FREQ: 1Hz

    AMPTD: 2Vrms

    MODE: CONT

36. Send the following command to the Model 2001:

    :CAL:PROT:LLEV:STEP 15

37. Calculate new calibration constants by sending the following command to the Model 2001:

    :CAL:PROT:LLEV:CALC

38. To check for calibration errors, send the following query:

    :SYST:ERR?

    If no errors are reported, calibration was successfully completed.

39. Update the calibration date and calibration due date by sending the following commands:

    :CAL:PROT:DATE ‘1/01/92’
    :CAL:PROT:NDUE ‘1/01/93’

40. Save calibration constants in EEPROM by sending the following command:

    :CAL:PROT:SAVE

41. Finally, lock out calibration by sending the following command:

    :CAL:PROT:LOCK

3

Calibration Command Reference

3.1 Introduction

This section contains detailed information on the various Model 2001 IEEE-488 bus calibration commands. Section 2 of this manual covers detailed calibration procedures, and Appendix B lists several calibration programs. For information on additional commands to control other instrument functions, refer to the Model 2001 Operator's Manual.

Information in this section includes:

3.2 **Command summary:** Summarizes all commands necessary to perform comprehensive, AC, and low-level calibration.

3.3 **CALibration:PROTected subsystem:** Gives detailed explanations of the various commands used for both comprehensive and low-level calibration.

3.4 **CALibration:UNPRotected subsystem:** Discusses the :ACC command, which is used to perform AC user calibration over the bus.

3.5 **Bus error reporting:** Summarizes bus calibration errors, and discusses how to obtain error information.

3.6 **Detecting calibration step completion:** Covers how to determine when each calibration step is completed by using the *OPC and *OPC? commands.

3.2 Command summary

Table 3-1 summarizes Model 2001 calibration commands along with the paragraph number where a detail description of each command is located.

Table 3-1
IEEE-488 bus calibration command summary

Command	Description	Paragraph
:CALibration	Calibration root command.	
:PROTected	All commands in this subsystem are protected by the CAL switch.	3.3
:LOCK	Lock out calibration (opposite of enabling cal with CAL switch).	3.3.1
:SWITch?	Request comprehensive CAL switch state. (0 = locked; 1 = unlocked)	3.3.2
:SAVE	Save cal constants to EEPROM.	3.3.3
:DATA?	Download cal constants from 2001.	3.3.4
:DATE “<string>”	Send cal date to 2001.	3.3.5
:DATE?	Request cal date from 2001.	3.3.6
:NDUE “<string>”	Send next due cal date to 2001.	3.3.7
:NDUE?	Request next due cal date from 2001.	3.3.8
:LLEVel	Low-level calibration subsystem.	3.3.9
:SWITch?	Request low-level CAL switch state. (0 = locked; 1 = unlocked)	
:STEP <Step #>		
1	20V AC at 1kHz step.	
2	20V AC at 30kHz step.	
3	200V AC at 1kHz step.	
4	200V AC at 30kHz step.	
5	1.5V AC at 1kHz step.	
6	0.2V AC at 1kHz step.	
7	5mV AC at 100kHz step.	
8	0.5mV AC at 1kHz step.	
9	+2V DC step.	
10	-2V DC step.	
11	0V DC step.	
12	20mA AC at 1kHz step.	
13	+0.2A DC step.	
14	+2A DC step.	
15	2V AC at 1Hz step.	
:STEP?	Request cal step number.	
:CALCulate	Calculate low-level cal constants.	
:DC	User calibration subsystem.	3.3.10
:ZERO	Low-thermal short calibration step.	
:LOW <value>	+2V DC calibration step.	
:HIGH <value>	+20V DC calibration step.	
:LOHM <value>	20k¾ calibration step.	
:HOHM <value>	1M¾ calibration step.	
:OPEN	Open circuit calibration step.	
:CALCulate	Calculate DC cal constants.	
:UNPRotected	All commands in this subsystem are not protected by CAL switch.	3.4
:ACCompensation	Perform user AC calibration (disconnect all cables)	3.4.1

NOTE: Upper case letters indicate short form of each command. For example, instead of sending “:CALIBRATION:PROTECTED:LOCK”, you can send “:CAL:PROT:LOCK”.

3.3 :CALibration:PROTected subsystem

The protected calibration subsystem commands perform all Model 2001 calibration except for AC-only calibration. All commands in this subsystem are protected by the calibration lock (CAL switch). The following paragraphs discuss these commands in detail.

3.3.1 :LOCK

(:CALibration:PROTected):LOCK

Purpose

To lock out comprehensive and low-level calibration commands once calibration has been completed.

Format

:cal:prot:lock

Parameters

None

Description

The :LOCK command allows you to lock out both comprehensive and low-level calibration after completing those procedures. Thus, :LOCK does just the opposite of pressing in on the front panel CAL switch to unlock calibration.

Programming note

To unlock comprehensive calibration, press in on the CAL switch with power turned on. To unlock low-level calibration, hold in the CAL switch while turning on the power.

Programming example

```
10   OUTPUT 716; ":CAL:PROT:LOCK"          ! Lock out calibration.
```

3.3.2 :SWITch?

(:CALibration:PROTected):SWITch?

Purpose

To read comprehensive calibration lock status.

Format

:cal:prot:swit?

Response

0 Comprehensive calibration locked.
1 Comprehensive calibration unlocked.

Description

The :SWITch? query requests status from the Model 2001 on calibration locked/unlocked state. Calibration must be unlocked by pressing in on the CAL switch while power is turned on before calibration can be performed.

Programming note

The :CAL:PROT:SWIT? query does not check the status of the low-level calibration lock, which can be checked by using the :CAL:PROT:LLEV:SWIT? query. (See paragraph 3.3.9.)

Programming example

```
10   OUTPUT 716; ":CAL:PROT:SWIT?"         ! Query for switch status.
20   ENTER 716; S                          ! Input response.
30   PRINT S                               ! Display response.
```

3.3.3 :SAVE

(:CALibration:PROTected):SAVE

Purpose To save calibration constants in EEPROM after the calibration procedure.

Format :cal:prot:save

Parameters None

Description The :SAVE command stores internally calculated calibration constants derived during calibration in EEPROM. EEPROM is non-volatile memory, and calibration constants will be retained indefinitely once saved. Generally, :SAVE is the last command sent during calibration.

Programming note Calibration will be only temporary unless the :SAVE command is sent to permanently store calibration constants.

Programming example

```
10   OUTPUT 716; ":CAL:PROT:SAVE"        ! Save constants.
```

3.3.4 :DATA?

(:CALibration:PROTected):DATA?

Purpose To download calibration constants from the Model 2001

Format :cal:prot:data?

Response <Cal 1>,<Cal 2>,...<Cal n>

Description :DATA? allows you to request the present calibration constants stored in EEPROM from the instrument. This command can be used to compare present constants with those from a previous calibration procedure to verify that calibration was performed properly. The returned values are 99 numbers using ASCII representation delimited by commas (,). See Appendix C for a listing of constants.

Programming note The :CAL:PROT:DATA? response is not affected by the FORMAT subsystem.

Programming example

```
10   DIM A$[2000]                        ! Dimension string.
20   OUTPUT 716; ":CAL:PROT:DATA?"       ! Request constants.
30   ENTER 716; A$                       ! Input constants.
40   PRINT A$                            ! Display constants.
```

3.3.5 :DATE

(:CALibration:PROTected):DATE

Purpose To send the calibration date to the instrument.

Format :cal:prot:date “<string>”?

Parameters <string> = date (mm/dd/yy)

Description The :DATE command allows you to store the calibration date in instrument memory for future reference. You can read back the date from the instrument over the bus by using the :DATE? query, or by using the CALIBRATION selection in the front panel menu.

Programming note The date <string> must be enclosed either in double or single quotes (“<string>” or ‘<string>’).

Programming example

```
10    OUTPUT 716; ":CAL:PROT:DATE '01/01/92'" ! Send date.
```

3.3.6 :DATE?

(:CALibration:PROTected):DATE?

Purpose To request the calibration date from the instrument.

Format :cal:prot:date?

Response <date> (mm/dd/yy)

Description The :DATE? query allows you to request from the instrument the previously stored calibration date. The instrument response is simply a string of ASCII characters representing the last stored date.

Programming example

```
10    OUTPUT 716; ":CAL:PROT:DATE?"        ! Query for date.
20    ENTER 716; A$                        ! Input date.
30    PRINT A$                             ! Display date.
```

3.3.7 :NDUE

(:CALibration:PROTected):NDUE

Purpose To send the next calibration due date to the instrument.

Format :cal:prot:ndue “<string>”

Parameters <string> = next due date (mm/dd/yy)

Description The :NDUE command allows you to store the date when calibration is next due in instrument memory. You can read back the next due date from the instrument over the bus by using the :NDUE? query, or by using the CALIBRATION-DATES selection in the front panel menu.

Programming note The next due date <string> must be enclosed either in single or double quotes (“<string>” or ‘<string>’).

Programming example

```
10    OUTPUT 716; ":CAL:PROT:NDUE '01/01/93'"     ! Send due date.
```

3.3.8 :NDUE?

(:CALibration:PROTected):NDUE?

Purpose To request the calibration due date from the instrument.

Format :cal:prot:ndue?

Response <date> (mm/dd/yy)

Description The :NDUE? query allows you to request from the instrument the previously stored calibration due date. The instrument response is a string of ASCII characters representing the last stored due date.

Programming example

```
10  OUTPUT 716; ":CAL:PROT:DATE?"     ! Query for due date.
20  ENTER 716; A$                     ! Input due date.
30  PRINT A$                          ! Display due date.
```

3.3.9 :LLEVel

(CALibration:PROTected):LLEVel

Low-level calibration commands are summarized in Table 3-2.

Table 3-2
Low-level calibration commands

Command	Description
:CALibration	
:PROTected	
:LLEVel	Low-level calibration subsystem.
:SWITch?	Request low-level CAL switch state. (0 = locked; 1 = unlocked)
:STEP <Step #>	
1	20V AC at 1kHz step.
2	20V AC at 30kHz step.
3	200V AC at 1kHz step.
4	200V AC at 30kHz step.
5	1.5V AC at 1kHz step.
6	0.2V AC at 1kHz step.
7	5mV AC at 100kHz step
8	0.5mV AC at 1kHz step.
9	+2V DC step.
10	-2V DC step.
11	0V DC step.
12	20mA AC at 1kHz step.
13	+0.2A DC step.
14	+2A DC step.
15	2V AC at 1Hz step.
:CALCulate	Calculate low-level cal constants.

:SWITch?

(CALibration:PROTected:LLEVel):SWITch?

Purpose

To request the state of the low-level calibration lock.

Format

:cal:prot:llev:swit?

Response

0 Low-level calibration locked.
1 Low-level calibration unlocked.

Description

:SWITch? query requests the status of the low-level calibration lock from the instrument. This :SWITch? query should not be confused with the :SWITch query that requests the status of the comprehensive calibration lock (see paragraph 3.3.1).

Programming note

To unlock low-level calibration, hold in the CAL switch while turning on instrument power.

Programming example

```
10   OUTPUT 716; ":CAL:PROT:LLEV:SWIT?"     ! Request switch status.
20   ENTER 716; S                           ! Input switch status.
30   PRINT S                                ! Display switch status.
```

:STEP

(CALibration:PROTected:LLEVel):STEP

Purpose

To program individual low-level calibration steps.

Format

:cal:prot:llev:step <n>

Parameters

1 20V AC @ 1kHz
2 20V AC @ 30kHz
3 200V AC @ 1kHz
4 200V AC @ 30kHz
5 1.5V AC @ 1kHz
6 200mV AC @ 1kHz
7 5mV AC @ 100kHz
8 0.5mV AC @ 1kHz
9 +2V DC
10 -2V DC
11 0V DC
12 20mA @ 1kHz
13 +200mA DC
14 +2A DC
15 2V AC @ 1Hz

Description

The :STEP command programs the 15 individual low-level calibration steps; <n> represents the calibration step number. The appropriate signal must be connected to the instrument when programming each step, as summarized in the parameters listed above (see Section 2 for details).

Programming example

```
10   OUTPUT 716; ":CAL:PROT:LLEV:STEP 1"    ! Low-level Step 1.
```

:STEP?

(CALibration:PROTected:LLEVel):STEP?

Purpose To request current low-level calibration step.

Format :cal:prot:llev:step?

Response

1	20V AC @ 1kHz
2	20V AC @ 30kHz
3	200V AC @ 1kHz
4	200V AC @ 30kHz
5	1.5V AC @ 1kHz
6	200mV AC @ 1kHz
7	5mV AC @ 100kHz
8	0.5mV AC @ 1kHz
9	+2V DC
10	-2V DC
11	0V DC
12	20mA @ 1kHz
13	+200mA DC
14	+2A DC
15	2V AC @ 1Hz

Description The :STEP? query requests the present low-level calibration step.

Programming example

```
10   OUTPUT 716; ":CAL:PROT:LLEV:STEP ?"    ! Request step.
20   ENTER 716;S                            ! Input step.
30   PRINT S                                ! Display step.
```

:CALCulate

(:CALibration:PROTected:LLEVel):CALCulate

Purpose To program the Model 2001 to calculate new low-level calibration constants.

Format :cal:prot:llev:calc

Parameters None

Description The :CALCulate command causes the Model 2001 to calculate new low-level calibration constants based on parameters determined during the calibration procedure. This command should be sent after completing all low-level calibration steps, but before saving calibration constants in EEPROM with the :SAVE command.

Programming example

```
10   OUTPUT 716; ":CAL:PROT:LLEV:CALC"      ! Calculate constants.
```

3.3.10 :DC

(CALibration:PROTected):DC

The :DC commands perform comprehensive (user) calibration. Table 3-3 summarizes these comprehensive calibration commands.

Table 3-3
Comprehensive calibration commands

Command	Description
:CALibration	
:PROTected	
:DC	User calibration subsystem.
:ZERO	Low-thermal short calibration step.
:LOW <value>	+2V DC calibration step.
:HIGH <value>	+20V DC calibration step.
:LOHM <value>	20k¾ calibration step.
:HOHM <value>	1M¾ calibration step.
:OPEN	Open circuit calibration step.
Calculate	DC cal constants.

:ZERO

(:CALibration:PROTected:DC):ZERO

Purpose To perform short-circuit comprehensive calibration.

Format :cal:prot:dc:zero

Parameters None

Description :ZERO performs the short-circuit calibration step in the comprehensive calibration procedure. A low-thermal short (Model 8610) must be connected to the input jacks before sending this command.

Programming example

```
10   OUTPUT 716; “CAL:PROT:DC:ZERO”          ! Do short-circuit cal.
```

:LOW

(:CALibration:PROTected:DC):LOW

Purpose To program the +2V DC comprehensive calibration step.

Format :cal:prot:dc:low <cal_voltage>

Parameters <Cal_voltage> = 1.0 to 2.0 [V]

Description :LOW programs the +2V DC comprehensive calibration step. The allowable range of the calibration voltage parameter is from 1.0 to 2.0V, but 2V is recommended for best results.

Programming example

```
10   OUTPUT 716; “:CAL:PROT:DC:LOW 2”        ! Program 2V step.
```

:HIGH

(:CALibration:PROTected:DC):HIGH

Purpose To program the +20V DC comprehensive calibration step.

Format :cal:prot:dc:high <cal_voltage>

Parameters <Cal_voltage> = 10 to 20 [V]

Description :HIGH programs the +20V DC comprehensive calibration step. The allowable range of the calibration voltage parameter is from 10 to 20V, but 20V is recommended for best results.

Programming example

```
10 OUTPUT 716; ":CAL:PROT:DC:HIGH 20"     ! Program 20V step.
```

:LOHM

(CALibration:PROTected:DC):LOHM

Purpose To program the 20k¾ comprehensive calibration step.

Format :cal:prot:dc:lohm <cal_resistance>

Parameters <Cal_resistance> = 9E3 to 20E3 [¾]

Description :LOHM programs the 20k¾ comprehensive calibration step. The allowable range of the calibration resistance parameter is from 9k¾ to 20k¾ (9E3 to 20E3). Use the 20k¾ value whenever possible, or the closest possible value (for example, 19k¾, which is the closest value available on many calibrators).

Programming example

```
10 OUTPUT 716; ":CAL:PROT:DC:LOHM 19E3" ! Program 19k¾.
```

:HOHM

(CALibration:PROTected:DC):HOHM

Purpose To program the 1M¾ comprehensive calibration step.

Format :cal:prot:dc:hohm <cal_resistance>

Parameters <Cal_resistance> = 800E3 to 2E6 [¾]

Description :LOHM programs the 1M¾ comprehensive calibration step. The resistance parameter can be programmed for any value from 800k¾ (800E3) to 2M¾ (2E6). Use the 1M¾ value whenever possible, or the closest possible value on your calibrator for best results.

Programming example

```
10 OUTPUT 716; ":CAL:PROT:DC:HOHM 1E6"  ! Program 1M¾ step.
```

:CALCulate

(:CALibration:PROTected:DC):CALCulate

Purpose To program the Model 2001 to calculate new comprehensive calibration DC constants.

Format :cal:prot:dc:calc

Parameters None

Description The :CALCulate command should be sent to the instrument after performing all other DC calibration steps to calculate new comprehensive calibration constants. All other comprehensive calibration steps must be completed before sending this command.

Programming example

```
10 OUTPUT 716; ":CAL:PROT:DC:CALC"        ! Calculate new constants.
```

3.4 :CALibration:UNPRotected Subsystem

3.3.11 :ACCompensation

(:CALibration:UNPRotected):ACCompensation

Purpose

To perform user AC calibration.

Format

:cal:unpr:acc

Parameters

None

Description

The :ACC command performs user AC calibration, which requires no calibration equipment. All test leads must be disconnected from the input jacks when performing user AC calibration.

Programming note

Calibration constants generated by using the :ACC command are not stored in EEPROM. Thus, AC calibration constants are in effect only until the instrument is turned off. In order to save AC calibration constants, perform the comprehensive calibration procedure, and use the :SAVE command.

Programming example

```
10   OUTPUT 716; ":CAL:UNPR:ACC:          ! Perform AC user cal.
```

3.5 Bus error reporting

3.5.1 Calibration error summary

Table 3-4 summarizes errors that may occur during bus calibration.

NOTE

See Appendix C for a complete listing of calibration error messages.

3.5.2 Detecting calibration errors

Several methods to detect calibration errors are discussed in the following paragraphs.

Error Queue

As with other Model 2001 errors, any calibration errors will be reported in the bus error queue. You can read this queue by using the :SYST:ERR? query. The Model 2001 will respond with the appropriate error message, as summarized in Table 3-4.

Status Byte EAV (Error Available) Bit

Whenever an error is available in the error queue, the EAV (Error Available) bit (bit 2) of the status byte will be set. Use the *STB? query or serial polling to obtain the status byte, then test bit 2 to see if it is set. If the EAV bit is set, an error has occurred, and you can use the :SYST:ERR? query to read the error and at the same time clear the EAV bit in the status byte.

Generating an SRQ on Error

To program the instrument to generate an SRQ when an error occurs, send the following command: *SRE 4. This command will enable SRQ when the EAV bit is set. You can then read the status byte and error queue as outlined above to check for errors and to determine the exact nature of the error.

3.6 Detecting calibration step completion

When sending calibration commands over the IEEE-488 bus, you must wait until the instrument completes the current operation before sending a command. You can use either *OPC? or *OPC to help determine when each calibration step is completed. (The example program in paragraph 2.6.2 uses the *OPC command to detect when each calibration step is completed.)

3.6.1 Using the *OPC? query

With the *OPC? (operation complete) query, the instrument will place an ASCII 1 in the output queue when it has completed each step. In order to determine when the OPC response is ready, do the following:

1. Repeatedly test the MAV (Message Available) bit (bit 4) in the status byte and wait until it is set. (You can request the status byte by using the *STB? query or serial polling.)
2. When MAV is set, a message is available in the output queue, and you can read the output queue and test for an ASCII 1.

Table 3-4
Calibration error summary

Error	Description
0, “No Error”	No error present in error queue.
-102, “Syntax error”	Calibration command syntax error.
-113, “Command header error”	Invalid calibration command header.
-200, “Execution error”	Cal commands sent out of sequence.
-221, “Settings conflict”	Cal command sent with calibration locked.
-222, “Parameter data out of range”	Calibration parameter invalid.
+438, “Date of calibration not set”	No calibration date sent.
+439, “Next date of calibration not set”	No next calibration date sent.
+440, “Calibration process not completed”	Incomplete calibration procedure.

NOTE: This table lists only those errors that could occur because of some external problem such as improper connections or wrong procedure. See Appendix C for a complete listing of all error messages.

3. After reading the output queue, repeatedly test MAV again until it clears. At this point, the calibration step is completed.

3.6.2 Using the *OPC command

The *OPC (operation complete) command can also be used to detect the completion of each calibration step. In order to use OPC to detect the end of each calibration step, you must do the following:

1. Enable operation complete by sending *ESE 1. The command sets the OPC (operation complete bit) in the standard event enable register, allowing operation complete status from the standard event status register to set the ESB (event summary bit) in the status byte when operation complete is detected.
2. Send the *OPC command immediately following each calibration command. For example:

   `:CAL:PROT:DC:ZERO;*OPC`

   Note that you must include the semicolon (;) to separate the two commands.
3. After sending a calibration command, repeatedly test the ESB (Event Summary) bit (bit 5) in the status byte until it is set. (Use either the *STB? query or serial polling to request the status byte.)
4. Once operation complete has been detected, clear OPC status using one of two methods: (1) Use the *ESR? query then read the response to clear the standard event status register, or (2) Send the *CLS command to clear the status registers. Note that sending *CLS will also clear the error queue and operation complete status.

A
Model 2001 Specifications

Model 2001 Specifications

The following pages contain the complete specifications for the 2001. Every effort has been made to make these specifications complete by characterizing its performance under the variety of conditions often encountered in production, engineering and research.

The 2001 provides 5-minute, 1-hour, 24-hour, 90-day, 1-year, and 2-year specifications, with full specifications for the 90-day, 1-year and 2-year specifications. This allows the user to utilize 90-day, 1-year, or 2-year recommended calibration intervals, depending upon the level of accuracy desired. As a general rule, the 2001's 2-year performance exceeds a 5½-digit DMM's 90-day, 180-day or 1-year specifications. 6½- or 7½-digit performance is assured using 90-day or 1-year specifications.

ABSOLUTE ACCURACY

To minimize confusion, *all 90-day, 1-year and 2-year 2001 specifications are absolute accuracy*, traceable to NIST based on factory calibration. Higher accuracies are possible, based on your calibration sources. For example, calibrating with a 10V primary standard rather than a 20V calibrator will reduce calibration uncertainty, and can thereby improve total 2001 accuracy for measurements up to 50% of range. Refer to the 2001 calibration procedure for details.

TYPICAL ACCURACIES

Accuracy can be specified as typical or warranted. All specifications shown are warranted unless specifically noted.

Almost 99% of the 2001's specifications are warranted specifications. In some cases it is not possible to obtain sources to maintain traceability on the performance of every unit in production on some measurements (e.g., high-voltage, high-frequency signal sources with sufficient accuracy do not exist). Since these values cannot be verified in production, the values are listed as typical.

2001 SPECIFIED CALIBRATION INTERVALS

MEASUREMENT FUNCTION	24 HOUR[1]	90 DAY[2]	1 YEAR[2]	2 YEAR[2]
DC Volts	•	•	•	•
DC Volts Peak Spikes		•[3]	•	•
AC Volts rms		•[3]	•	•
AC Volts Peak		•[3]	•	•
AC Volts Average		•[3]	•	•
AC Volts Crest Factor		•[3]	•	•
Ohms	•	•	•	•
DC Current	•	•	•	•
DC In-Circuit Current		•	•	•
AC Current		•[3]	•	•
Frequency		•	•	•
Temperature (Thermocouple)		•	•	•
Temperature (RTD)		•	•	•

[1] For T_{CAL} ±1°C.
[2] For T_{CAL} ±5°C.
[3] For ±2°C of last AC self cal.

DC VOLTS

DCV INPUT CHARACTERISTICS AND ACCURACY

RANGE	FULL SCALE	RESO-LUTION	DEFAULT RESO-LUTION	INPUT RESISTANCE	ACCURACY[1] ± (ppm of reading + ppm of range) 5 Minutes[12]	24 Hours[2]	90 Days[3]	1 Year[3]	2 Years[3]	TEMPERATURE COEFFICIENT ± (ppm of reading + ppm of range)/°C Outside T_{CAL} ± 5°C
200 mV [4]	±210.00000	10 nV	100 nV	>10 GΩ	3 + 3	10 + 6	25 + 6	37 + 6	50 + 6	3.3 +1.5
2 V	±2.1000000	100 nV	1 µV	>10 GΩ	2 + 1.5	7 + 2	18 + 2	25 + 2	32 + 2	2.6 +0.15
20 V	±21.000000	1 µV	10 µV	>10 GΩ	2 + 1.5	7 + 4	18 + 4	24 + 4	32 + 4	2.6 +0.7
200 V	±210.00000	10 µV	100 µV	10 MΩ ±1%	2 + 1.5	13 + 3	27 + 3	38 + 3	52 + 3	4.3 +1
1000 V	±1100.0000	100 µV	1 mV	10 MΩ ±1%	10 + 1.5	17 + 6	31 + 6	41 + 6	55 + 6	4.1 +1

DC VOLTAGE UNCERTAINTY = ±[(ppm of reading)×(measured value) + (ppm of range)×(range used)] / 1,000,000.
% ACCURACY = (ppm accuracy) / 10,000.
1 PPM OF RANGE = 2 counts for ranges up to 200V, 1 count on 1000V range at 6½ digits.

SPEED AND ACCURACY[5] 90 Days

RANGE	ACCURACY ± (ppm of reading + ppm of range + ppm of range rms noise[10]) 1 PLC DFILT On, 10 Readings	1 PLC DFILT Off	0.1 PLC DFILT Off	0.01 PLC[11] DFILT Off
200 mV [4]	25+6+0	25+6+0.6	25+30+10	100+200+15
2 V	18+2+0	18+2+0.2	18+25+1	130+200+3
20 V	18+4+0	18+4+0.3	18+20+0.5	130+200+3
200 V	27+3+0	27+5+0.3	27+20+0.8	130+200+3
1000 V	31+6+0	31+6+0.1	31+21+0.5	90+200+2

PLC = power line cycle; DFILT = digital filter

NOISE REJECTION (dB)

SPEED (Number of Power Line Cycles)	AC and DC CMRR[6] Line Sync On[7]	Internal Trigger[8]	Line Sync On[7] 25-Reading DFILT On	AC NMRR Line Sync On[7] DFILT Off	Internal Trigger[8] DFILT Off
NPLC = 10	140	120	90	80	60
NPLC ≥ 1	140	120	90	80	60
NPLC < 1	60	50	30	20	0

Effective noise is reduced by a factor of 10 for every 20dB of noise rejection (140dB reduces effective noise by 10,000,000:1).

CMRR is rejection of undesirable AC or DC signal between LO and earth. NMRR is rejection of undesirable AC signal between HI and LO.

DCV READING RATES[9,10]

200mV, 2V, 200V Ranges

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS/SECOND TO MEMORY Auto Zero Off	Auto Zero On	READINGS/SECOND TO IEEE-488 Auto Zero Off	Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	Auto Zero On
10	167 ms (200 ms)	28	7½	6 (5.1)	2 (1.7)	6	2 (1.6)	6 (4.1)	2 (1.6)
2	33.4 ms (40 ms)	26	7½	30 (25)	9 (7.6)	28 (23)	9 (7.3)	27 (22)	8 (7.2)
1	16.7 ms (20 ms)	25	6½	58 (48)	44 (34)	54 (45)	41 (32)	49 (41)	37 (30)
0.2	3.34 ms (4 ms)	22	6½	214 (186)	127 (112)	183 (162)	104 (101)	140 (126)	88 (85)
0.1	1.67 ms (2 ms)	21	5½	272 (272)	150 (148)	228 (225)	129 (123)	156 (153)	100 (96)
0.02	334 µs (400 µs)	19	5½	284 (287)	156 (155)	230 (230)	136 (134)	158 (156)	104 (103)
0.01	167 µs (167 µs)	16	4½	417 (417)	157 (157)	317 (317)	137 (134)	198 (198)	105 (103)
0.01[11]	167 µs (167 µs)	16	4½	2000 (2000)		2000 (2000)			

20V, 1000V Ranges

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS/SECOND TO MEMORY Auto Zero Off	Auto Zero On	READINGS/SECOND TO IEEE-488 Auto Zero Off	Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	Auto Zero On
10	167 ms (200 ms)	28	7½	6 (5.1)	2 (1.7)	6	2 (1.6)	6	2 (1.6)
2	33.4 ms (40 ms)	26	7½	30 (25)	9 (8.2)	28 (23)	9 (7.8)	27 (22)	9 (7.7)
1	16.7 ms (20 ms)	25	6½	57 (48)	42 (38)	54 (45)	43 (35)	48 (41)	39 (32)
0.2	3.34 ms (4 ms)	22	6½	201 (186)	102 (113)	173 (162)	102 (99)	129 (127)	84 (83)
0.1	1.67 ms (2 ms)	21	5½	201 (201)	126 (116)	175 (173)	105 (105)	129 (128)	86 (86)
0.02	334 µs (400 µs)	19	5½	227 (227)	129 (129)	178 (178)	114 (114)	138 (138)	90 (90)
0.01	167 µs (167 µs)	16	4½	422 (422)	130 (130)	333 (333)	117 (117)	199 (199)	95 (95)
0.01[11]	167 µs (167 µs)	16	4½	2000 (2000)		2000 (2000)			

SETTLING CHARACTERISTICS: <500µs to 10ppm of step size. Reading settling times are affected by source impedance and cable dielectric absorption characteristics. Add 10ppm of range for first reading after range change.

ZERO STABILITY: Typical variation in zero reading, 1 hour, T_{REF} ±1°C, 6½-digit default resolution, 10-reading digital filter:

Range	ZERO STABILITY 1 Power Line Cycle Integration	10 Power Line Cycle Integration
2V – 1000V	±3 counts	±2 counts
200 mV	±5 counts	±3 counts

ISOLATED POLARITY REVERSAL ERROR: This is the portion of the instrument error that is seen when high and low are reversed when driven by an isolated source. This is not an additional error—it is included in the overall instrument accuracy spec. **Reversal Error:** <2 counts at 10V input at 6½ digits, 10 power line cycles, 10-reading digital filter.

INPUT BIAS CURRENT: <100pA at 25°C.

LINEARITY: <1ppm of range typical, <2ppm maximum.

AUTORANGING: Autoranges up at 105% of range, down at 10% of range.

DC VOLTS NOTES

1. Specifications are for 1 power line cycle, Auto Zero on, 10-reading digital filter, except as noted.
2. For T_{CAL} ±1°C, following 55-minute warm-up. T_{CAL} is ambient temperature at calibration, which is 23°C from factory.
3. For T_{CAL} ±5°C, following 55-minute warm-up. Specifications include factory traceability to US NIST.
4. When properly zeroed using REL function.
5. For T_{CAL} ±5°C, 90-day accuracy. 1-year or 2-year accuracy can be found by applying the same speed accuracy ppm changes to the 1-year or 2-year base accuracy.
6. Applies for 1kΩ imbalance in the LO lead. For 400Hz operation, subtract 10dB.
7. For noise synchronous to the line frequency.
8. For line frequency ±0.1%.
9. See Operating Speed section for additional detail. For DELAY=0, internal trigger, digital filter off, display off (or display in “hold” mode). Aperture is reciprocal of line frequency. These rates are for 60Hz and (50Hz).
10. Typical values.
11. In burst mode, display off. Burst mode requires Auto Zero refresh (by changing resolution or measurement function) once every 24 hours.
12. DCV Transfer Stability typical applications are standard cell comparisons and relative accuracy measurements. Specs apply for 10 power line cycles, 20-reading digital filter, autozero on with type synchronous, fixed range following 2-hour warm-up at full scale to 10% of full scale, at T_{REF} ± 1°C (T_{REF} is the initial ambient temperature). Specifications on the 1000V range are for measurements within 5% of the initial measurement value and following measurement settling.

DCV PEAK SPIKES MEASUREMENT

REPETITIVE SPIKES ACCURACY[1] **90 Days, ± 2°C from last AC self-cal** **± (% of reading+% of range)**

RANGE	0–1kHz[4]	1kHz–10kHz	10kHz–30kHz	30kHz–50kHz	50kHz–100kHz	100kHz–300kHz	300kHz–500kHz	500kHz–750kHz	750kHz–1MHz	TEMPERATURE COEFFICIENT ± (% of reading+% of range)/°C Outside T_{CAL} ± 2°C
200 mV	0.08+0.7	0.08+0.7	0.1 +0.7	0.15+0.7	0.25+0.7	1.0+ 0.7	2.5+ 0.7	5.5+ 0.7	9+ 0.7	0.002+0.03
2 V	0.08+0.3	0.08+0.3	0.1 +0.3	0.15+0.3	0.25+0.3	1.0+0.3	2.5+0.3	5.5+0.3	9+0.3	0.002+0.03
20 V	0.09+0.7	0.1 +0.7	0.12+0.7	0.17+0.7	0.25+0.7	1.0+0.7	2.5+0.7	5.5+0.7	9+0.7	0.004+0.03
200 V[3]	0.09+0.3	0.1 +0.3	0.12+0.3	0.17+0.3	0.25+0.3	1.0+0.3[2]	2.5+0.3[2]	5.5+0.3[2]	9+0.3[2]	0.004+0.03
1000 V[3]	0.1 +0.6	0.13+0.6	0.16+0.6	0.25+0.6[2]	0.5 +0.6[2]					0.01 +0.02
Max. % of Range	±125%	±125%	±125%	±125%	±125%	±125%	±125%	±100%	±75%	

REPETITIVE SPIKES ACCURACY[1] **1 or 2 Years, T_{CAL} ± 5°C** **± (% of reading+% of range)**

RANGE	0–1kHz[4]	1kHz–10kHz	10kHz–30kHz	30kHz–50kHz	50kHz–100kHz	100kHz–300kHz	300kHz–500kHz	500kHz–750kHz	750kHz–1MHz	TEMPERATURE COEFFICIENT ± (% of reading+% of range)/°C Outside T_{CAL} ± 5°C
200 mV	0.08+0.7	0.09+0.7	0.1 +0.7	0.15+0.7	0.25+0.7	1.0+0.7	2.5+0.7	5.5+0.7	9+0.7	0.002+0.03
2 V	0.08+0.3	0.09+0.3	0.1 +0.3	0.15+0.3	0.25+0.3	1.0+0.3	2.5+0.3	5.5+0.3	9+0.3	0.002+0.03
20 V	0.1 +0.7	0.11+0.7	0.14+0.7	0.19+0.7	0.25+0.7	1.0+0.7	2.5+0.7	5.5+0.7	9+0.7	0.004+0.03
200 V[3]	0.1 +0.3	0.11+0.3	0.14+0.3	0.19+0.3	0.25+0.3	1.0+0.3[2]	2.5+0.3[2]	5.5+0.3[2]	9+0.3[2]	0.004+0.03
1000 V[3]	0.12+0.6	0.16+0.6	0.2 +0.6	0.25+0.6[2]	0.5 +0.6[2]					0.01 +0.02
Max. % of Range	±125%	±125%	±125%	±125%	±125%	±125%	±125%	±100%	±75%	

DEFAULT MEASUREMENT RESOLUTION: 3½ digits.

MAXIMUM INPUT: ±1100V peak value, $2{\times}10^7$V•Hz (for inputs above 20V).

NON-REPETITIVE SPIKES: 10% of range per µs typical slew rate.

SPIKE WIDTH: Specifications apply for spikes ≥1µs.

RANGE CONTROL: In Multiple Display mode, voltage range is the same as DCV range.

SPIKES MEASUREMENT WINDOW: Default is 100ms per reading (settable from 0.1 to 9.9s in Primary Display mode).

INPUT CHARACTERISTICS: Same as ACV input characteristics.

SPIKES DISPLAY: Access as multiple display on DC Volts. First option presents positive peak spikes and highest spike since reset. Second option presents negative spikes and lowest spike. Highest and lowest spike can be reset by pressing DCV function button. Third option displays the maximum and minimum levels of the input signal. Spikes displays are also available through CONFIG-ACV-ACTYPE as primary displays.

DCV PEAK SPIKES NOTES

1. Specifications apply for 10-reading digital filter. If no filter is used, add 0.25% of range typical uncertainty.
2. Typical values.
3. Add 0.001% of reading × $(V_{IN}/100V)^2$ additional uncertainty for inputs above 100V.
4. Specifications assume AC+DC coupling for frequencies below 200Hz. Below 20Hz add 0.1% of reading additional uncertainty.

AC VOLTS

AC magnitude: RMS or Average. Peak and Crest Factor measurements also available.

ACV INPUT CHARACTERISTICS

RMS RANGE	PEAK INPUT	FULL SCALE RMS	RESOLUTION	DEFAULT RESOLUTION	INPUT IMPEDANCE	TEMPERATURE COEFFICIENT[2] ± (% of reading + % of range) / °C Outside T_{CAL} ± 5°C
200 mV	1 V	210.0000	100 nV	1 µV	1MΩ ±2% with <140pF	0.004 + 0.001
2 V	8V	2.100000	1 µV	10 µV	1MΩ ±2% with <140pF	0.004 + 0.001
20 V	100 V	21.00000	10 µV	100 µV	1MΩ ±2% with <140pF	0.006 + 0.001
200 V	800 V	210.0000	100 µV	1 mV	1MΩ ±2% with <140pF	0.006 + 0.001
750 V	1100 V	775.000	1 mV	10 mV	1MΩ ±2% with <140pF	0.012 + 0.001

AC VOLTAGE UNCERTAINTY = ±[(% of reading) × (measured value) + (% of range) × (range used)] / 100.

PPM ACCURACY = (% accuracy) × 10,000.

0.015% OF RANGE = 30 counts for ranges up to 200V and 113 counts on 750V range at 5½ digits.

LOW FREQUENCY MODE RMS[1] 90 Days, ± 2°C from last AC self-cal, for 1% to 100% of range[3] ± (% of reading + % of range)

RANGE	1–10Hz[5]	10–50Hz	50–100Hz	0.1–2kHz	2–10kHz	10–30kHz	30–50kHz	50–100kHz	100–200kHz	0.2–1MHz	1–2MHz
200 mV	0.09+0.015	0.04+0.015	0.03+0.015	0.03+0.015	0.03+0.015	0.035+0.015	0.05+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
2 V	0.09+0.015	0.04+0.015	0.03+0.015	0.03+0.015	0.03+0.015	0.035+0.015	0.05+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
20 V	0.1 +0.015	0.05+0.015	0.04+0.015	0.04+0.015	0.06+0.015	0.08 +0.015	0.1 +0.015	0.17+0.015	0.5+0.025	4+0.2	7+0.2[5]
200 V[4]	0.1 +0.015	0.05+0.015	0.04+0.015	0.04+0.015	0.06+0.015	0.08 +0.015	0.1 +0.015	0.17+0.015	0.5+0.025[5]	4+0.2[5]	
750 V[4]	0.13+0.015	0.09+0.015	0.08+0.015	0.08+0.015	0.09+0.015	0.12 +0.015	0.15+0.015[5]	0.5 +0.015[5]			

LOW FREQUENCY MODE RMS[1] 1 or 2 Years, T_{CAL} ± 5°C for 1% to 100% of range[3] ± (% of reading + % of range)

RANGE	1–10Hz[5]	10–50Hz	50–100Hz	0.1–2kHz	2–10kHz	10–30kHz	30–50kHz	50–100kHz	100–200kHz	0.2–1MHz	1–2MHz
200 mV	0.11+0.015	0.06+0.015	0.05+0.015	0.05+0.015	0.05 +0.015	0.05+0.015	0.06+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
2 V	0.11+0.015	0.06+0.015	0.05+0.015	0.05+0.015	0.05 +0.015	0.05+0.015	0.06+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
20 V	0.12+0.015	0.07+0.015	0.06+0.015	0.06+0.015	0.085+0.015	0.12+0.015	0.13+0.015	0.17+0.015	0.5+0.025	4+0.2	7+0.2[5]
200 V[4]	0.12+0.015	0.07+0.015	0.06+0.015	0.06+0.015	0.085+0.015	0.12+0.015	0.13+0.015	0.17+0.015	0.5+0.025[5]	4+0.2[5]	
750 V[4]	0.15+0.015	0.11+0.015	0.1 +0.015	0.1 +0.015	0.13 +0.015	0.18+0.015	0.22+0.015[5]	0.5 +0.015[5]			

AC VOLTS (cont'd)

NORMAL MODE RMS[1]

90 Days, ± 2°C from last AC self-cal for 1% to 100% of range[3] ± (% of reading + % of range)

RANGE	20–50Hz	50–100Hz	0.1–2kHz	2–10kHz	10–30kHz	30–50kHz	50–100kHz	100–200kHz	0.2–1MHz	1–2MHz
200 mV	0.25+0.015	0.07+0.015	0.03+0.015	0.03+0.015	0.035+0.015	0.05+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
2 V	0.25+0.015	0.07+0.015	0.03+0.015	0.03+0.015	0.035+0.015	0.05+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
20 V	0.25+0.015	0.07+0.015	0.04+0.015	0.06+0.015	0.08 +0.015	0.1 +0.015	0.17+0.015	0.5+0.025	4+0.2	7+0.2[5]
200 V[4]	0.25+0.015	0.07+0.015	0.04+0.015	0.06+0.015	0.08 +0.015	0.1 +0.015	0.17+0.015	0.5+0.025[5]	4+0.2[5]	
750 V[4]	0.25+0.015	0.1 +0.015	0.08+0.015	0.09+0.015	0.12 +0.015	0.15+0.015[5]	0.5 +0.015[5]			

NORMAL MODE RMS[1]

1 or 2 Years, T_{CAL} ± 5°C for 1% to 100% of range[3] ± (% of reading + % of range)

RANGE	20–50Hz	50–100Hz	0.1–2kHz	2–10kHz	10–30kHz	30–50kHz	50–100kHz	100–200kHz	0.2–1MHz	1–2MHz
200 mV	0.25+0.015	0.08+0.015	0.05+0.015	0.05 +0.015	0.05+0.015	0.06+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
2 V	0.25+0.015	0.08+0.015	0.05+0.015	0.05 +0.015	0.05+0.015	0.06+0.015	0.17+0.015	0.5+0.025	2+0.1	5+0.2
20 V	0.25+0.015	0.08+0.015	0.06+0.015	0.085+0.015	0.12+0.015	0.13+0.015	0.17+0.015	0.5+0.025	4+0.2	7+0.2[5]
200 V[4]	0.25+0.015	0.08+0.015	0.06+0.015	0.085+0.015	0.12+0.015	0.13+0.015	0.17+0.015	0.5+0.025[5]	4+0.2[5]	
750 V[4]	0.27+0.015	0.11+0.015	0.1 +0.015	0.13 +0.015	0.18+0.015	0.22+0.015[5]	0.5 +0.015[5]			

dB ACCURACY RMS

± dB, 90 Days, 1 or 2 Years, T_{CAL} ± 5°C, Reference=1V, Autoranging, Low Frequency Mode, AC+DC Coupling

INPUT	1–100Hz	0.1–30kHz	30–100kHz	100–200kHz	0.2–1MHz	1–2MHz
–54 to –40 dB (2 mV to 10 mV)	0.230	0.225	0.236	0.355		
–40 to –34 dB (10 mV to 20 mV)	0.036	0.031	0.041	0.088		
–34 to 6 dB (20 mV to 2 V)	0.023	0.018	0.028	0.066	0.265	0.630
6 to 26 dB (2 V to 20 V)	0.024	0.024	0.028	0.066	0.538	0.820[5]
26 to 46 dB (20 V to 200 V)	0.024	0.024	0.028	0.066[5]	0.538[5]	
46 to 57.8 dB (200 V to 775 V)	0.018	0.021	0.049[5]			

ACV READING RATES[5,6]

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS/SECOND TO MEMORY Auto Zero Off	READINGS/SECOND TO MEMORY Auto Zero On	READINGS/SECOND TO IEEE-488 Auto Zero Off	READINGS/SECOND TO IEEE-488 Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero On
10	167 ms (200 ms)	28	6½	6 (5.1)	2 (1.7)	2	2 (1.6)	2	2 (1.5)
2	33.4 ms (40 ms)	26	5½	30 (24)	9 (7.9)	28 (23)	9 (7.6)	27 (22)	9 (7.5)
1	16.7 ms (20 ms)	25	5½	57 (48)	38 (35)	53 (45)	36 (33)	48 (41)	34 (30)
0.1	1.67 ms (2 ms)	21	5½	136 (136)	70 (70)	122 (122)	64 (64)	98 (98)	56 (56)
0.01	167 µs (167 µs)	16	4½	140 (140)	71 (71)	127 (127)	66 (66)	99 (99)	58 (58)
0.01[8]	167 µs (167 µs)	16	4½	2000 (2000)		2000 (2000)			

AC COUPLING:

For AC only coupling, add the following % of reading:

	1–10Hz	10–20Hz	20–50Hz	50–100Hz	100–200Hz
Normal Mode (rms, average)	—	—	0.41	0.07	0.015
Low Frequency Mode (rms)	0.1	0.01	0	0	0

For low frequency mode below 200Hz, specifications apply for sine wave inputs only.

AC+DC COUPLING: For DC>20% of AC rms voltage, apply the following additional uncertainty, multiplied by the ratio (DC/AC rms). Applies to rms and average measurements.

RANGE	% of Reading	% of Range
200mV, 20V	0.05	0.1
2V, 200V, 750V	0.07	0.01

ACV CREST FACTOR MEASUREMENT[11]

CREST FACTOR = Peak AC / rms AC.

CREST FACTOR RESOLUTION: 3 digits.

CREST FACTOR ACCURACY: Peak AC uncertainty + AC normal mode rms uncertainty.

MEASUREMENT TIME: 100ms plus rms measurement time.

INPUT CHARACTERISTICS: Same as ACV input.

CREST FACTOR FREQUENCY RANGE: 20Hz – 1MHz.

CREST FACTOR DISPLAY: Access as multiple display on AC volts.

AVERAGE ACV MEASUREMENT

Normal mode rms specifications apply from 10% to 100% of range, for 20Hz–1MHz. Add 0.025% of range for 50kHz–100kHz, 0.05% of range for 100kHz–200kHz, and 0.5% of range for 200kHz–1MHz.

HIGH CREST FACTOR ADDITIONAL ERROR ± (% of reading)

Applies to rms measurements.

CREST FACTOR:	1 – 2	2 – 3	3 – 4	4 – 5
ADDITIONAL ERROR:	0	0.1	0.2	0.4

ACV PEAK VALUE MEASUREMENT[10]

REPETITIVE PEAK ACCURACY, ± (% of reading+% of range), 90 Days, 1 Year or 2 Years, T_{CAL} ± 5°C

RANGE	20Hz–1kHz[9]	1kHz–10kHz	10kHz–30kHz	30kHz–50kHz	50kHz–100kHz	100kHz–300kHz	300kHz–500kHz	500kHz–750kHz	750kHz–1MHz	TEMPERATURE COEFFICIENT ± (% of reading+% of range)/°C Outside T_{CAL} ± 5°C
200 mV	0.08+0.7	0.09+0.7	0.1 +0.7	0.15+0.7	0.25+0.7	1.0+0.7	2.5+0.7	5.5+0.7	9+0.7	0.002 + 0.03
2 V	0.08+0.3	0.09+0.3	0.1 +0.3	0.15+0.3	0.25+0.3	1.0+0.3	2.5+0.3	5.5+0.3	9+0.3	0.002 + 0.03
20 V	0.1 +0.7	0.11+0.7	0.14+0.7	0.19+0.7	0.25+0.7	1.0+0.7	2.5+0.7	5.5+0.7	9+0.7	0.004 + 0.03
200 V[4]	0.1 +0.3	0.11+0.3	0.14+0.3	0.19+0.3	0.25+0.3	1.0+0.3[5]	2.5+0.3[5]	5.5+0.3[5]	9+0.3[5]	0.004 + 0.03
750 V[4]	0.12+0.6	0.16+0.6	0.2 +0.6	0.25+0.6[5]	0.5 +0.6[5]					0.01 + 0.02
Valid % of Range[7]	10–400%	10–400%	10–400%	10–350%	10–350%	10–250%	10–150%	10–100%	7.5–75%	

DEFAULT MEASUREMENT RESOLUTION: 4 digits.

NON-REPETITIVE PEAK: 10% of range per µs typical slew rate for single spikes.

PEAK WIDTH: Specifications apply for all peaks ≥1µs.

PEAK MEASUREMENT WINDOW: 100ms per reading.

MAXIMUM INPUT: ±1100V peak, 2×10^7V•Hz (for inputs above 20V).

AC VOLTS (cont'd)

SETTLING CHARACTERISTICS:

Normal Mode (rms, avg.)	<300ms to 1% of step change <450ms to 0.1% of step change <500ms to 0.01% of step change
Low Frequency Mode (rms)	<5s to 0.1% of final value

COMMON MODE REJECTION: For 1kΩ imbalance in either lead: >60dB for line frequency ±0.1%.

MAXIMUM VOLT•Hz PRODUCT: 2×10^7V•Hz (for inputs above 20V).

AUTORANGING: Autoranges up at 105% of range, down at 10% of range.

AC VOLTS NOTES

1. Specifications apply for sinewave input, AC + DC coupling, 1 power line cycle, digital filter off, following 55 minute warm-up.
2. Temperature coefficient applies to rms or average readings. For frequencies above 100kHz, add 0.01% of reading/°C to temperature coefficient.
3. For 1% to 5% of range below 750V range, and for 1% to 7% of 750V range, add 0.01% to range uncertainty. For inputs from 200kHz to 2MHz, specifications apply above 10% of range.
4. Add 0.001% of reading × $(V_{IN}/100V)^2$ additional uncertainty above 100V rms.
5. Typical values.
6. For DELAY=0, digital filter off, display off (or display in "hold" mode). Internal Trigger, Normal mode. See Operating Speed section for additional detail. Aperture is reciprocal of line frequency. These rates are for 60Hz and (50Hz). Applies for rms and average mode. Low frequency mode rate is typically 0.2 readings per second.
7. For overrange readings 200–300% of range, add 0.1% of reading. For 300–400% of range, add 0.2% of reading.
8. In burst mode, display off. Burst mode requires Auto Zero refresh (by changing resolution or measurement function) once every 24 hours.
9. AC peak specifications assume AC + DC coupling for frequencies below 200Hz.
10. Specifications apply for 10 reading digital filter. If no filter is used, add 0.25% of range typical uncertainty.
11. Subject to peak input voltage specification.

OHMS

TWO-WIRE AND FOUR-WIRE OHMS (2W and 4W Ohms Functions)

RANGE	FULL SCALE	RESOLUTION	DEFAULT RESOLUTION	CURRENT[1] SOURCE	OPEN CIRCUIT[12]	MAXIMUM LEAD RESISTANCE[2]	MAXIMUM OFFSET COMPENSATION[3]	TEMPERATURE COEFFICIENT ± (ppm of reading + ppm of range)/°C Outside T_{CAL} ± 5°
20 Ω	21.000000	1 µΩ	10 µΩ	9.2 mA	5 V	1.7 Ω	±0.2 V	8 + 1.5
200 Ω	210.00000	10 µΩ	100 µΩ	0.98 mA	5 V	12 Ω	±0.2 V	4 + 1.5
2 kΩ	2100.0000	100 µΩ	1 mΩ	0.98 mA	5 V	100 Ω	–0.2 V to +2 V	2.5 + 0.2
20 kΩ	21.000000	1 mΩ	10 mΩ	89 µA	5 V	1.5 kΩ	–0.2 V to +2 V	4 + 0.2
200 kΩ	210.00000	10 mΩ	100 mΩ	7 µA	5 V	1.5 kΩ		11 + 0.2
2 MΩ [4]	2.1000000	100 mΩ	1 Ω	770 nA	5 V	1.5 kΩ		25 + 0.2
20 MΩ [4]	21.000000	1 Ω	10 Ω	70 nA	5 V	1.5 kΩ		250 + 0.2
200 MΩ [4]	210.00000	10 Ω	100 Ω	4.4 nA	5 V	1.5 kΩ		4000 + 10
1 GΩ [4]	1.0500000	100 Ω	1 kΩ	4.4 nA	5 V	1.5 kΩ		4000 + 10

RESISTANCE ACCURACY[5] ± (ppm of reading + ppm of range)

RANGE	24 Hours[6]	90 Days[7]	1 Year[7]	2 Years[7]
20 Ω	29 + 7	52 + 7	72 + 7	110 + 7
200 Ω	24 + 7	36 + 7	56 + 7	90 + 7
2 kΩ	22 + 4	33 + 4	50 + 4	80 + 4.5
20 kΩ	19 + 4	32 + 4	50 + 4	80 + 4.5
200 kΩ	20 + 4.5	72 + 4.5	90 + 4.5	130 + 5
2 MΩ [4]	50 + 4.5	110 + 4.5	160 + 4.5	230 + 5
20 MΩ [4]	160 + 4.5	560 + 4.5	900 + 4.5	1100 + 5
200 MΩ [4]	3000 + 100	10000 + 100	20000 + 100	30000 + 100
1 GΩ [4]	9000 + 100	20000 + 100	40000 + 100	60000 + 100

RESISTANCE UNCERTAINTY = ± [(ppm of reading) × (measured value) + (ppm of range) × (range used)] / 1,000,000.

% ACCURACY = (ppm accuracy) / 10,000.

1PPM OF RANGE = 2 counts for ranges up to 200MΩ and 1 count on 1GΩ range at 6½ digits.

SPEED AND ACCURACY[9] 90 Days

RANGE	ACCURACY ± (ppm of reading+ppm of range+ppm of range rms noise[12]) 1PLC DFILT Off	0.1PLC[11] DFILT Off	0.01PLC[8,11] DFILT Off
20 Ω	52+ 7+0.6	52+ 30+10	110+200+ 35
200 Ω	36+ 7+0.6	36+ 30+10	110+200+ 35
2 kΩ	33+ 4+0.2	33+ 24+ 1	130+230+ 5
20 kΩ	32+ 4+0.2	32+ 24+ 2	130+230+ 5
200 kΩ	72+ 4.5+0.5	72+ 25+ 4	150+300+ 10
2 MΩ [4]	110+ 4.5+ 2	110+ 25+15	150+300+150
20 MΩ [4]	560+ 4.5+ 5	560+ 30+20	560+300+150
200 MΩ [4]	10,000+100+ 40	10,000+120+80	10,000+700+250
1 GΩ [4]	20,000+100+ 40	20,000+120+80	20,000+700+250

PLC = Power Line Cycles. DFILT = Digital Filter.

2-WIRE ACCURACY[7] ± (ppm of range)

RANGE	20 Ω	200 Ω	2 kΩ
ADDITIONAL UNCERTAINTY (inside T_{CAL} ± 5°C)	300 ppm	30 ppm	3 ppm
TEMPERATURE COEFFICIENT (outside T_{CAL} ± 5°C)	70ppm/°C	7ppm/°C	0.7ppm/°C

SETTLING CHARACTERISTICS: For first reading following step change, add the total 90-day measurement error for the present range. Pre-programmed settling delay times are for <200pF external circuit capacitance. For 200MΩ and 1GΩ ranges, add total 1 year errors for first reading following step change. Reading settling times are affected by source impedance and cable dielectric absorption characteristics.

OHMS MEASUREMENT METHOD: Constant current.

OFFSET COMPENSATION: Available on 20Ω – 20kΩ ranges.

OHMS VOLTAGE DROP MEASUREMENT: Available as a multiple display.

AUTORANGING: Autoranges up at 105% of range, down at 10% of range.

OHMS (cont'd)

2-WIRE RESISTANCE READING RATES[10,12] 20Ω, 200Ω, 2kΩ, and 20kΩ Ranges

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS/SECOND TO MEMORY Auto Zero Off	READINGS/SECOND TO MEMORY Auto Zero On	READINGS/SECOND TO IEEE-488 Auto Zero Off	READINGS/SECOND TO IEEE-488 Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero On
10	167 ms (200 ms)	28	7½	6 (5.1)	2 (1.7)	5 (4)	2 (1.6)	5 (4)	2 (1.6)
2	33.4 ms (40 ms)	26	7½	30 (25)	8 (7.1)	28 (23)	8 (6.8)	27 (22)	8 (6.7)
1	16.7 ms (20 ms)	25	6½	58 (48)	40 (34)	53 (45)	37 (32)	49 (41)	35 (31)
0.2[11]	3.34 ms (4 ms)	22	6½	219 (189)	109 (97)	197 (162)	97 (87)	140 (129)	79 (74)
0.1[11]	1.67 ms (2 ms)	21	5½	300 (300)	126 (118)	248 (245)	112 (108)	164 (163)	89 (88)
0.02[11]	334 µs (400 µs)	19	5½	300 (300)	130 (130)	249 (249)	114 (114)	165 (165)	91 (91)
0.01[11]	167 µs (167 µs)	16	4½	421 (421)	135 (135)	306 (306)	114 (114)	189 (189)	92 (92)
0.01[8,11]	167 µs (167 µs)	16	4½	2000 (2000)		2000(2000)			

2-WIRE RESISTANCE READING RATES[10,12] 20MΩ Range

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS/SECOND TO MEMORY Auto Zero Off	READINGS/SECOND TO MEMORY Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero On
10	167 ms (200 ms)	28	7½	6 (5.1)	1 (0.8)	2 (1.8)	1 (0.8)
2	33.4 ms (40 ms)	26	7½	30 (25)	1 (0.8)	16(14.5)	1 (0.8)
1	16.7 ms (20 ms)	25	6½	58 (48)	4 (3.8)	25 (22)	4 (3.5)
0.1[11]	1.67 ms (2 ms)	21	5½	300 (296)	5 (5)	43 (39)	5 (4.7)
0.02[11]	334 µs (400 µs)	19	5½	300 (300)	5 (5)	43 (43)	5 (5)
0.01[11]	167 µs (167 µs)	16	4½	412 (412)	5 (5)	43 (43)	5 (5)

4-WIRE RESISTANCE READING RATES[10,12] Any Range

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS or READINGS WITH TIME STAMP/SECOND TO MEMORY or IEEE-488, AUTO ZERO ON Offset Comp. Off	READINGS or READINGS WITH TIME STAMP/SECOND TO MEMORY or IEEE-488, AUTO ZERO ON Offset Comp. On
10	167 ms (200 ms)	28	7½	2 (1.6)	0.6 (0.5)
2	33.4 ms (40 ms)	26	7½	7 (6.1)	2 (1.6)
1	16.7 ms (20 ms)	25	6½	12 (11.6)	3 (3.7)
0.1[11]	1.67 ms (2 ms)	21	5½	20 (20)	6 (6)
0.01[11]	167 µs (167 µs)	16	4½	21 (21)	7 (7)

OHMS NOTES

1. Current source is typically ±9% absolute accuracy.
2. Total of measured value and lead resistance cannot exceed full scale.
3. Maximum offset compensation plus source current times measured resistance must be less than source current times resistance range selected.
4. For 2-wire mode.
5. Specifications are for 1 power line cycle, 10 reading digital filter, Auto Zero on, 4-wire mode, offset compensation on (for 20Ω to 20kΩ ranges).
6. For T_{CAL} ±1°C, following 55 minute warm-up. T_{CAL} is ambient temperature at calibration (23°C at the factory).
7. For T_{CAL} ±5°C, following 55-minute warm-up. Specifications include traceability to US NIST.
8. In burst mode, display off. Burst mode requires Auto Zero refresh (by changing resolution or measurement function) once every 24 hours.
9. For T_{CAL} ±5°C, 90-day accuracy. 1-year and 2-year accuracy can be found by applying the same speed accuracy ppm changes to the 1-year or 2-year base accuracy.
10. For DELAY=0, digital filter off, internal trigger, display off. Aperture is reciprocal of line frequency. These rates are for 60Hz and (50Hz). Speed for 200kΩ range is typically 10% slower than 20kΩ range; speed for 2MΩ range is typically 3 times faster than 20MΩ range; speed for 1GΩ range is typically 30%–50% as fast as 20MΩ range. See Operating Speed section for additional detail.
11. Ohms measurements at rates lower than 1 power line cycle are subject to potential noise pickup. Care must be taken to provide adequate shielding.
12. Typical values.

DC AMPS

DCI INPUT CHARACTERISTICS AND ACCURACY[4]

RANGE	FULL SCALE	RESOLUTION	DEFAULT RESOLUTION	MAXIMUM BURDEN VOLTAGE[6]	ACCURACY[1] ± (ppm of reading + ppm of range) 24 Hours[2]	90 Days[3]	1 Year[3]	2 Years[3]	TEMPERATURE COEFFICIENT ± (ppm of reading + ppm of range)/°C Outside T_{CAL} ± 5°C
200 µA	210.00000	10 pA	100 pA	0.25 V	63 + 25	300 + 25	500 + 25	1350 + 25	58 + 7
2 mA	2.1000000	100 pA	1 nA	0.31 V	64 + 20	300 + 20	400 + 20	750 + 20	58 + 5
20 mA	21.000000	1 nA	10 nA	0.4 V	65 + 20	300 + 20	400 + 20	750 + 20	58 + 5
200 mA	210.00000	10 nA	100 nA	0.5 V	96 + 20	300 + 20	500 + 20	750 + 20	58 + 5
2 A	2.1000000	100 nA	1 µA	1.5 V	500 + 20	600 + 20	900 + 20	1350 + 20	58 + 5

DC CURRENT UNCERTAINTY = ±[(ppm reading)×(measured value) + (ppm of range)×(range used)] / 1,000,000.

% ACCURACY = (ppm accuracy) / 10,000.

10PPM OF RANGE = 20 counts at 6½ digits.

DCI READING RATES[5,9]

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS/SECOND TO MEMORY Auto Zero Off	READINGS/SECOND TO MEMORY Auto Zero On	READINGS/SECOND TO IEEE-488 Auto Zero Off	READINGS/SECOND TO IEEE-488 Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero On
10	167 ms (200 ms)	28	7½	6 (5.1)	2 (1.7)	6 (4.8)	2 (1.6)	6 (4.8)	2 (1.6)
2	33.4 ms (40 ms)	26	7½	30 (24)	10 (8.2)	28 (23)	9 (7.8)	27 (22)	9 (7.7)
1	16.7 ms (20 ms)	25	6½	57 (48)	45 (38)	53 (45)	41 (35)	48 (41)	40 (32)
0.2	3.34 ms (4 ms)	22	6½	217 (195)	122 (111)	186 (168)	109 (98)	135 (125)	88 (85)
0.1	1.67 ms (2 ms)	21	5½	279 (279)	144 (144)	234 (229)	123 (123)	158 (156)	99 (98)
0.02	334 µs (400 µs)	19	5½	279 (279)	148 (148)	234 (234)	130 (130)	158 (158)	101 (101)
0.01	167 µs (167 µs)	16	4½	298 (298)	150 (150)	245 (245)	132 (132)	164 (164)	102 (102)
0.01[7]	167 µs (167 µs)	16	4½	2000 (2000)		2000 (2000)			

DC AMPS (cont'd)

SPEED AND ACCURACY[8] 90 Days

RANGE	ACCURACY ± (ppm of reading+ppm of range+ppm of range rms noise[9]) 1PLC DFILT Off	0.1PLC DFILT Off	0.01PLC[7] DFILT Off
200 µA	300+25+0.3	300+50+8	300+200+80
2 mA	300+20+0.3	300+45+8	300+200+80
20 mA	300+20+0.3	300+45+8	300+200+80
200 mA	300+20+0.3	300+45+8	300+200+80
2 A	600+20+0.3	600+45+8	600+200+80

PLC = Power Line Cycle. DFILT = Digital Filter.

SETTLING CHARACTERISTICS: <500µs to 50ppm of step size. Reading settling times are affected by source impedance and cable dielectric absorption characteristics. Add 50ppm of range for first reading after range change.

MAXIMUM ALLOWABLE INPUT: 2.1A, 250V.

OVERLOAD PROTECTION: 2A fuse (250V), accessible from front (for front input) and rear (for rear input).

AUTORANGING: Autoranges up at 105% of range, down at 10% of range.

DC AMPS NOTES

1. Specifications are for 1 power line cycle, Auto Zero on, 10 reading digital filter.
2. For T_{CAL} ± 1°C, following 55 minute warm-up.
3. For T_{CAL} ± 5°C, following 55 minute warm-up. Specifications include traceability to US NIST.
4. Add 50 ppm of range for current above 0.5A for self heating.
5. For DELAY=0, digital filter off, display off. Internal trigger. Aperture is reciprocal of line frequency. These rates are for 60Hz and (50Hz). See Operating Speed section for additional detail.
6. Actual maximum voltage burden = (maximum voltage burden) × ($I_{MEASURED}/I_{FULL\ SCALE}$).
7. In burst mode, display off. Burst mode requires Auto Zero refresh (by changing resolution or measurement function) once every 24 hours.
8. For T_{CAL} ±5°C, 90-day accuracy. 1-year and 2-year accuracy can be found by applying the same speed accuracy ppm changes to the 1-year or 2-year base accuracy.
9. Typical values.

DC IN-CIRCUIT CURRENT

The DC in-circuit current measurement function allows a user to measure the current through a wire or a circuit board trace without breaking the circuit.

When the In-Circuit Current Measurement function is selected, the 2001 will first perform a 4-wire resistance measurement, then a voltage measurement, and will display the calculated current.

TYPICAL RANGES:

Current: 100µA to 12A.

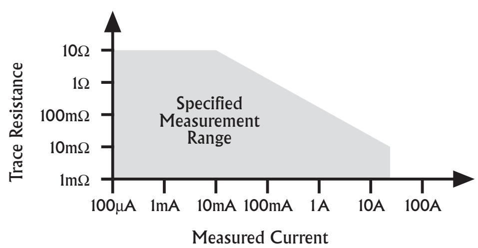
Trace Resistance: 1mΩ to 10Ω typical.

Voltage: ±200mV max. across trace.

Speed: 4 measurements/second at 1 power line cycle.

Accuracy: ±(5% + 2 counts). For 1 power line cycle, Auto Zero on, 10 reading digital filter, T_{CAL} ±5°C, after being properly zeroed. 90 days, 1 year or 2 years.

MEASUREMENT RANGE CHART



AC AMPS

AC magnitude: RMS or Average.

ACI INPUT CHARACTERISTICS

RMS RANGE	PEAK INPUT	FULL SCALE RMS	RESOLUTION	DEFAULT RESOLUTION	MAXIMUM BURDEN VOLTAGE[5]	TEMPERATURE COEFFICIENT ± (% of reading + % of range)/°C Outside T_{CAL} ± 5°C
200 µA	1 mA	210.0000	100 pA	1 nA	0.25 V	0.01 + 0.001
2 mA	10 mA	2.100000	1 nA	10 nA	0.31 V	0.01 + 0.001
20 mA	100 mA	21.00000	10 nA	100 nA	0.4 V	0.01 + 0.001
200 mA	1 A	210.0000	100 nA	1 µA	0.5 V	0.01 + 0.001
2 A	2 A	2.100000	1 µA	10 µA	1.5 V	0.01 + 0.001

ACI ACCURACY[1,2] 90 Days, 1 Year or 2 Years, T_{CAL} ± 5°C, for 5% to 100% of range, ± (% of reading + % of range)

RANGE	20Hz–50Hz	50Hz–200Hz	200Hz–1kHz	1kHz–10kHz	10kHz–30kHz[3]	30kHz–50kHz[3]	50kHz–100kHz[3]
200 µA	0.35 + 0.015	0.2 + 0.015	0.4 + 0.015	0.5 + 0.015			
2 mA	0.3 + 0.015	0.15 + 0.015	0.12 + 0.015	0.12 + 0.015	0.25 + 0.015	0.3 + 0.015	0.5 + 0.015
20 mA	0.3 + 0.015	0.15 + 0.015	0.12 + 0.015	0.12 + 0.015	0.25 + 0.015	0.3 + 0.015	0.5 + 0.015
200 mA	0.3 + 0.015	0.15 + 0.015	0.12 + 0.015	0.15 + 0.015	0.5 + 0.015	1 + 0.015	3 + 0.015
2 A	0.35 + 0.015	0.2 + 0.015	0.3 + 0.015	0.45 + 0.015	1.5 + 0.015	4 + 0.015	

AC CURRENT UNCERTAINTY = ±[(% of reading) × (measured value) + (% of range) × (range used)] / 100.

PPM ACCURACY = (% accuracy) × 10,000.

0.015% OF RANGE = 30 counts at 5½ digits.

AC COUPLING: For AC only coupling, add the following % of reading:

	20–50Hz	50–100Hz	100–200Hz
rms, Average	0.55	0.09	0.015

AC+DC COUPLING: For DC>20% of AC rms voltage, apply the following additional uncertainty, multiplied by the ratio (DC/AC rms).

	% of Reading	% of Range
rms, Average	0.05	0.1

AC AMPS (cont'd)

ACI READING RATES[3,4]

NPLC	MEASUREMENT APERTURE	BITS	DEFAULT DIGITS	READINGS/SECOND TO MEMORY Auto Zero Off	READINGS/SECOND TO MEMORY Auto Zero On	READINGS/SECOND TO IEEE-488 Auto Zero Off	READINGS/SECOND TO IEEE-488 Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero On
10	167 ms (200 ms)	28	6½	6 (5.1)	2 (1.7)	6 (4.9)	2 (1.6)	6 (4.8)	2 (1.6)
2	33.4 ms (40 ms)	26	5½	30 (25)	9 (7.9)	28 (23)	9 (7.6)	27 (22)	9 (7.5)
1	16.7 ms (20 ms)	25	5½	57 (48)	39 (35)	53 (45)	37 (33)	49 (41)	34 (30)
0.1	1.67 ms (2 ms)	21	5½	157 (136)	70 (70)	123 (123)	62 (62)	107 (107)	56 (53)
0.01	167 µs (167 µs)	16	4½	156 (136)	70 (70)	140 (140)	63 (63)	113 (113)	56 (56)
0.01[6]	167 µs (167 µs)	16	4½	2000 (2000)		2000 (2000)			

SETTLING CHARACTERISTICS: <300ms to 1% of step change
<450ms to 0.1% of step change
<500ms to 0.01% of step change

AUTORANGING: Autoranges up at 105% of range, down at 10% of range.

HIGH CREST FACTOR ADDITIONAL ERROR ± (% of reading)

Applies to rms measurements.

CREST FACTOR	1 – 2	2 – 3	3 – 4	4 – 5
ADDITIONAL ERROR	0	0.1	0.2	0.4

AVERAGE ACI MEASUREMENT

Rms specifications apply for 10% to 100% of range.

AC AMPS NOTES

1. Specifications apply for sinewave input, AC+DC coupling, 1 power line cycle, digital filter off, following 55 minute warm-up.
2. Add 0.005% of range uncertainty for current above 0.5A rms for self-heating.
3. Typical values.
4. For DELAY=0, digital filter off, display off, internal trigger. Aperture is reciprocal of line frequency. These rates are for 60Hz and (50Hz).
5. Actual maximum voltage burden = (maximum voltage burden) × ($I_{MEASURED}/I_{FULL\ SCALE}$).
6. In burst mode, display off. Burst mode requires Auto Zero refresh (by changing resolution or measurement function) once every 24 hours.

FREQUENCY COUNTER

FREQUENCY/PERIOD INPUT CHARACTERISTICS AND ACCURACY — 90 Days, 1 Year, or 2 Years

	FREQUENCY RANGE[1]	PERIOD RANGE	DEFAULT RESOLUTION	MINIMUM SIGNAL LEVEL 1Hz–1MHz	MINIMUM SIGNAL LEVEL 1–5MHz	MINIMUM SIGNAL LEVEL 5–15MHz	MAXIMUM INPUT	TRIGGER LEVEL	ACCURACY ± (% of reading)
AC Voltage Input	1Hz–15 MHz	67 ns – 1 s	5 digits	60 mV	60 mV	350 mV	1100 V pk[1]	0–600V	0.03
AC Current Input	1Hz– 1 MHz	1 µs – 1 s	5 digits	150 µA			1 A pk	0–600mA	0.03

MEASUREMENT TECHNIQUE: Unique pulse count/time count at overflow.

TIME BASE: 7.68MHz ± 0.01%, 0°C to 55°C.

READING TIME: 420ms maximum.

TRIGGER LEVEL ADJUSTMENT: Trigger level is adjustable in 0.5% of range steps to ±60% of range in real-time using the up and down range buttons.

FREQUENCY RANGING: Autoranging from Hz to MHz.

FREQUENCY COUPLING: AC + DC or AC only.

FREQUENCY NOTES

1. Subject to 2×10^7V•Hz product (for inputs above 20V).

TEMPERATURE (RTD)

RANGE	RESOLUTION	4-WIRE ACCURACY[3] 1 Hour[2]	90 Days	1 Year	2 Years
–100° to +100°C	0.001°C	±0.005°C	±0.05°C	±0.08°C	±0.12°C
–200° to +630°C	0.001°C	±0.005°C	±0.12°C	±0.14°C	±0.18°C
–212° to +180°F	0.001°F	±0.009°F	±0.09°F	±0.15°F	±0.22°F
–360° to +1102°F	0.001°F	±0.009°F	±0.15°F	±0.18°F	±0.33°F

RTD TYPE: 100Ω platinum; DIN 43 760 or IPTS-68, alpha 0.00385, 0.00390, 0.003916, or 0.00392, 4-wire.

MAXIMUM LEAD RESISTANCE (each lead): 12Ω (to achieve rated accuracy).

SENSOR CURRENT: 1mA (pulsed).

COMMON MODE REJECTION: <0.005°C/V at DC, 50Hz, 60Hz and 400Hz, (100Ω imbalance, LO driven).

TEMPERATURE COEFFICIENT: ±(0.0013% + 0.005°C)/°C or ±(0.0013% + 0.01°F)/°C outside T_{CAL} ±5°C.

RTD TEMPERATURE READING RATES[1] (2- or 4-Wire)

NPLC	READINGS or READINGS WITH TIME STAMP/SECOND TO MEMORY or IEEE-488 Auto Zero Off	Auto Zero On
10	1 (1)	1 (1)
2	5 (4.3)	4 (3.6)
1	7 (6.5)	6 (5.5)
0.1	12 (10.8)	9 (9)
0.01	12 (12)	10 (10)

TEMPERATURE (Thermocouple)

THERMOCOUPLE TYPE	RANGE	DEFAULT RESOLUTION	ACCURACY[4]
J	–200° to + 760°C	0.1°C	±0.5°C
K	–200° to +1372°C	0.1°C	±0.5°C
T	–200° to + 400°C	0.1°C	±0.5°C
E	–200° to +1000°C	0.1°C	±0.6°C
R	0° to +1768°C	1 °C	±3 °C
S	0° to +1768°C	1 °C	±3 °C
B	+350° to +1820°C	1 °C	±5 °C

TC TEMPERATURE READING RATES[1]

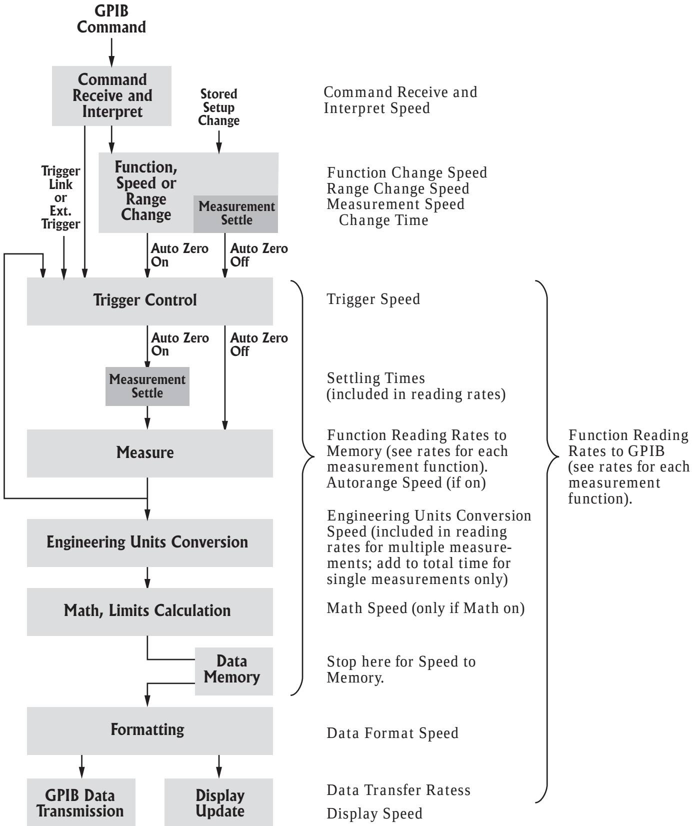
NPLC	READINGS/SECOND TO MEMORY Auto Zero Off	Auto Zero On	READINGS/SECOND TO IEEE-488 Auto Zero Off	Auto Zero On	READINGS/SECOND WITH TIME STAMP TO IEEE-488 Auto Zero Off	Auto Zero On
10	6 (5.1)	2 (1.7)	4 (3.4)	2 (1.4)	4 (3.4)	2 (1.4)
2	30 (25)	9 (7.6)	28 (23)	9 (7.3)	27 (22)	8 (7.2)
1	57 (48)	43 (37)	53 (45)	40 (32)	49 (41)	37 (30)
0.1	139 (139)	95 (95)	126 (123)	85 (84)	99 (99)	72 (72)
0.01	177 (177)	98 (98)	156 (156)	87 (87)	119 (119)	73 (73)

TEMPERATURE NOTES

1. Typical speeds for Auto Zero on. For DELAY=0, digital filter off, display off, internal trigger. Rates are for 60Hz and (50Hz).
2. For ambient temperature ±1°C, measured temperature ±10°C, 10-reading digital filter.
3. Excluding probe errors. T_{CAL} ±5°C.
4. Relative to external 0°C reference junction; exclusive of thermocouple errors. Junction temperature may be external. Applies for 90 days, 1 year or 2 years, T_{CAL} ±5°C.

OPERATING SPEED

The following diagram illustrates the factors that determine a DMM's reading rate.



COMMAND RECEIVE AND INTERPRET SPEED

	FASTEST	TYPICAL	SLOWEST
Time per character	0.16 ms	0.28 ms	0.66 ms
Characters per second	6250	3751	1515

TYPICAL COMMAND TIMES Command	Receive and Interpret Time	Rate (per second)
SENSE1:VOLTAGE:AC: RESOLUTION MAXIMUM	9.4 ms	106
VOLT:AC:RES:MAX	4.1 ms	243
SENSE1:FUNC 'VOLT:AC"	6.3 ms	158
RESISTANCE:RANGE:UPPER 1E9	9.0 ms	111
STATUS:QUEUE:CLEAR	5.1 ms	196
STAT:QUE:CLE	3.1 ms	322
*TRG	1.2 ms	833

MEASUREMENT SPEED CHANGE TIMES[1,2]

Typical delay before first reading after making a speed change.

FUNCTION	From	To	AUTO ZERO OFF Time	AUTO ZERO ON Time
DCV, DCI, ACI	Any	≤ 0.1 PLC	66 ms	44 ms
	Any	1 PLC	190 ms	140 ms
	Any	10 PLC	1540 ms	1195 ms
ACV	Any	≤ 0.1 PLC	120 ms	100 ms
	Any	1 PLC	250 ms	197 ms
	Any	10 PLC	1600 ms	1250 ms
Ohms (2-wire)	Any	≤ 0.1 PLC	69 ms	57 ms
	Any	1 PLC	195 ms	170 ms
	Any	10 PLC	1540 ms	1370 ms
Ohms (4-wire)	Any	≤ 0.1 PLC	110 ms	46 ms
	Any	1 PLC	240 ms	165 ms
	Any	10 PLC	1590 ms	1370 ms
TC Temperature	Any	≤ 0.1 PLC	80 ms	55 ms
	Any	1 PLC	195 ms	170 ms
	Any	10 PLC	1545 ms	1370 ms

FUNCTION CHANGE SPEED[1]

FROM Function	TO Function	Range(s)	AUTO ZERO OFF TIME	AUTO ZERO OFF RATE (per second)	AUTO ZERO ON TIME	AUTO ZERO ON RATE (per second)
Any	DCV	200mV, 2V	8.1 ms	120	36 ms	27
		20V	8.1 ms	120	8.6 ms	110
		200V	24 ms	40	52 ms	19
		1000V	11 ms	160	10.2 ms	190
Any	ACV	Any	563 ms	1.8	563 ms	1.8
Any except ACI	DCI	200µA, 2mA, 20mA	4.5 ms	220	5.1 ms	190
		200mA, 2A	6.0 ms	160	6.6 ms	150
ACI		Any	21.1 ms	45	22 ms	45
Any	ACI	Any	521 ms	1.9	521 ms	1.9
Any	Ohms (2-wire)	20Ω, 200Ω, 2kΩ, 20kΩ	6.0 ms	165	34 ms	29
		200kΩ	26 ms	38	61 ms	16
		2MΩ	95 ms	10.5	425 ms	2.4
		20MΩ	265 ms	4	690 ms	1.4
		200MΩ, 1GΩ	366 ms	3	5.5 ms	180
Any	Ohms (4-wire)	20Ω, 200Ω, 2kΩ, 20kΩ	12 ms	140	34.1 ms	29
		200kΩ	26 ms	38	60 ms	16
Any except ACI and Ohms	Frequency[8]	Any	61 ms	16	60 ms	17
ACI, Ohms (4-wire)		Any	79 ms	12	75 ms	13
Ohms (2-wire)		Any	418 ms	2	416 ms	2
Any	RTD Temp. (2-wire)	Any	6.0 ms	165	33 ms	30
	RTD Temp. (4-wire)	Any	11.5 ms	150	37 ms	27
	TC Temp.	Any	8.0 ms	125	35 ms	28

OPERATING SPEED (cont'd)

RANGE CHANGE SPEED[1]

FUNCTION	From	To	AUTO ZERO OFF TIME	AUTO ZERO OFF RATE (per second)	AUTO ZERO ON TIME	AUTO ZERO ON RATE (per second)
DCV	200mV, 2V	20V	4.5 ms	220	3.1 ms	190
	200V, 1000V	20V	8.0 ms	120	8.6 ms	110
	200mV, 2V, 20V	200mV, 2V, 20V	4.5 ms	220	36 ms	27
	200V, 1000V	200mV, 2V	8.0 ms	120	38 ms	26
	200mV, 2V, 20V	200V	24 ms	41	52 ms	19
	1000V	200V	9 ms	110	37 ms	27
	Any	1000V	11 ms	165	10.1 ms	190
ACV	Any	Any	563 ms	1.8	563 ms	1.8
DCI	Any	200µA, 2mA, 20mA	4.5 ms	220	5.2 ms	190
		200mA, 2A	6.0 ms	160	6.6 ms	150
ACI	Any	Any	525 ms	1.9	525 ms	1.9
Ohms (2-wire)	Any	20Ω, 200Ω, 2kΩ, 20kΩ	6.0 ms	160	34 ms	29
	Any	200kΩ	26 ms	38	66 ms	15
	Any	2MΩ	95 ms	10	420 ms	2.3
	Any	20MΩ	265 ms	3.7	690 ms	1.4
	Any	200MΩ, 1GΩ	366 ms	2.7	5.5 ms	180
Ohms (4-wire)	Any	20Ω, 200Ω, 2kΩ, 20kΩ	8 ms	160	34 ms	29
	Any	200kΩ	26 ms	38	66 ms	16

TRIGGER SPEED (External Trigger or Trigger-Link)

	Auto Zero On	Auto Zero Off
Trigger Latency:	1.2 ms typical	2 µs
Trigger Jitter:		±0.5 µs

ENGINEERING UNIT CONVERSION SPEED

Included in reading times for multiple measurements; add to total time for single measurements only.

CONFIGURATION	TIME	RATE (per second)
DCV	2.4 ms	416
DCV, Filter on	2.4 ms	416
DCV, Relative on	2.5 ms	400
DCV, Ratio on	3.7 ms	270
ACV	5.3 ms	188
ACV, Relative on	5.3 ms	188
ACV, Filter on	6.8 ms	147
ACV, dB	9.4 ms	106
ACV, dBm	17.3 ms	57

DISPLAY SPEED

Display updated at up to 20 times per second. Display update can be suspended by holding the display (press ENTER) or setting Display Enable Off from GPIB.

MATH AND LIMITS CALCULATION SPEED[1]

CALCULATION	NOMINAL TIME	NOMINAL RATE (per second)	MAXIMUM TIME
mX + b	0.35 ms	2850	0.44 ms
Percent	0.60 ms	1660	0.64 ms
Limits[6]	0.35 ms	2850	0.37 ms
None	0.07 ms		0.08 ms

GPIB DATA FORMATTING TRANSMISSION TIME[3]

FORMAT	READINGS ONLY Time	READINGS ONLY Rdg./s	READINGS WITH TIME STAMP Time	READINGS WITH TIME STAMP Rdg./s
DREAL (Double precision real)	0.30 ms	3330	2.0 ms	500
SREAL (Single precision real)	0.37 ms	2710	2.1 ms	475
ASCII	3.9 ms	255	8.2 ms	120

SINGLE FUNCTION SCAN SPEED[4] (Internal Scanner)

TYPE	DCV (20V)[7] Time per Chan.	DCV (20V)[7] Rate (Chan./second)	2-Wire Ohms (2kΩ)[7] Time per Chan.	2-Wire Ohms (2kΩ)[7] Rate (Chan./second)	4-Wire Ohms (2kΩ)[7] Time per Chan.	4-Wire Ohms (2kΩ)[7] Rate (Chan./second)	ACV Time per Chan.	ACV Rate (Chan./second)	Frequency Time per Chan.	Frequency Rate (Chan./second)	TC Temperature Time per Chan.	TC Temperature Rate (Chan./second)	RTD Temperature (2-Wire) Time per Chan.	RTD Temperature (2-Wire) Rate (Chan./second)
Ratio or Delta[5] (2 channels)	4 ms	250	4.4 ms	230	18.5 ms	54								
Fast Scan (using solid state channels)	5.5 ms	181	7 ms	140			520 ms	1.9	958 ms	1	13.8 ms	72		
Normal Scan	10.3 ms	97	12.1 ms	80	21 ms	47	532 ms	1.8	974 ms	1	18 ms	55	95 ms	10

MIXED FUNCTION SCAN SPEED[1] (Internal Scanner)

SCAN CONFIGURATION (Channels)	Average Time/ Channel	Average Rate (Channel/s)
5 chan. DCV, 5 chan. 2wΩ	20 ms	50
3 DCV, 3 2wΩ, 4 TC	22 ms	45
5 2wRTD, 5 TC	60 ms	17
5 2wΩ, 5 2wRTD	60 ms	17
9 DCV, 1 ACV	73 ms	13
2 DCV, 1 ACV, 2 2wΩ, 1 4wΩ	122 ms	8
5 DCV, 5 Freq.	490 ms	2
3 DCV, 3 ACV, 2 4wΩ	220 ms	5

OPERATING SPEED NOTES

1. With Display off, 1 power line cycle, autorange off, filter off, triggers halted. Display on may impact time by 3% worst case. To eliminate this impact press ENTER (hold) to lock out display from front panel.
2. Based on using 20V, 2kΩ, 200mA ranges.
3. Auto Zero off, using 386SX/16 computer, average time for 1000 readings, byte order swapped, front panel disabled.
4. Typical times for 0.01 power line cycle, autorange off, Delay=0, 100 measurements into buffer.
5. Ratio and delta functions output one value for each pair of measurements.
6. Time to measure, evaluate limits, and set digital outputs are found by summing measurement time with limits calculation time.
7. Auto Zero off.
8. Based on 100kHz input frequency.

DELAY AND TIMER

TIME STAMP

Resolution: 1µs.
Accuracy: ±0.01% ±1µs.
Maximum: 2,100,000.000 000 seconds (24 days, 20 hours).

DELAY TIME (Trigger edge to reading initiation)

Maximum: 999,999.999 seconds (11 days, 12 hours).
Resolution: 1ms.
Jitter: ±1ms.

TIMER (Reading initiation to reading initiation)

Maximum: 999,999.999 seconds (11 days, 12 hours).
Resolution: 1ms.
Jitter: ±1ms.

NOTE: To find measurement speed, see each measurement section.

MAXIMUM INPUT LEVELS

	RATED INPUT[1]		OVERLOAD RECOVERY TIME
HI to LO	±1100V pk		< 900 ms
HI Sense to LO	± 350V pk	250V rms	< 900 ms
LO Sense to LO	± 350V pk	250V rms	< 900 ms
I Input to LO	2A, ± 250V	(fused)	—
HI to Earth	±1600V		< 900 ms
LO to Earth	± 500V		

1. For voltages between other terminals, these ratings can be algebraically added.

IEEE-488 BUS IMPLEMENTATION

IMPLEMENTATION: IEEE-488.2, SCPI-1991.0.

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE COMMANDS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

DIGITAL I/O

CONNECTOR TYPE: 8 pin "D" subminiature.

INPUT: One pin, TTL compatible.

OUTPUTS: Four pins. Open collector, 30V maximum pull-up voltage, 100mA maximum sink current, 10Ω output impedance.

CONTROL: Direct control by output or set real-time with limits.

GENERAL SPECIFICATIONS AND STANDARDS COMPLIANCE

POWER

Voltage: 90–134V and 180–250V, universal self-selecting.

Frequency: 50Hz, 60Hz, or 400Hz self-identifying.

Consumption: <55VA.

ENVIRONMENTAL

Operating Temperature: 0°C to 50 °C.

Storage Temperature: –40 °C to 70 °C.

Humidity: 80% R.H., 0°C to 35°C, per MIL-T-28800E[1] Para 4.5.5.1.2.

NORMAL CALIBRATION

Type: Software. No manual adjustments required.

Sources: 2 DC voltages (2V, 20V) and 2 resistances (19k and 1M). Different calibration source values are allowed. All other functions calibrated (adjusted) from these sources and a short circuit. No AC calibrator required for adjustment.

PHYSICAL

Case Dimensions: 90mm high × 214mm wide × 369mm deep (3½ in. × 8½ in. × 14½ in.).

Working Dimensions: From front of case to rear including power cord and IEEE-488 connector: 15.0 inches.

Net Weight: <4.2kg (<9.2 lbs.).

Shipping Weight: <9.1kg (<20lbs.).

STANDARDS

EMI/RFI: Conforms to VDE 0871B (per Vfg 1046/1984), IEC 801-2. Meets FCC part 15 Class B, CISPR-22 (EN55022).

Safety: Conforms to IEC348, CAN/CSA-C22.2. No. 231, MIL-T-28800E[1]. Designed to UL1244.

Reliability: MIL-T-28800E[1].

Maintainability: MIL-T-28800E[1].

MTTR: <90 minutes (includes disassembly and assembly, excludes recalibration). MTTR is Mean Time To Repair.

MTBF, Estimated: >75,000 hours (Bellcore method). MTBF is Mean Time Between Failure.

MTTC: <20 minutes for normal calibration. <6 minutes for AC self-calibration. MTTC is Mean Time To Calibrate.

Process: MIL-STD 45662A and BS5750.

ACCESSORIES SUPPLIED

The unit is shipped with line cord, high performance modular test leads, user's manual, option slot cover, and full calibration data. A personal computer startup package is available free.

Note 1: For MIL-T-28800E, applies to Type III, Class 5, Style E.

EXTENDED MEMORY / NON-VOLATILE MEMORY OPTIONS

		DATA STORAGE			SETUP STORAGE	
MODEL	SIZE (Bytes)	4½-Digit	6½-Digit w/Time Stamp	Type	Number	Type
2001	8k	850	250	volatile	1	non-volatile
2001/MEM1	32k	7,000	1,400	non-volatile	5	non-volatile
2001/MEM2	128k	30,000	6,000	non-volatile	10	non-volatile

Specifications subject to change without notice.

B

Calibration Programs

Introduction

This appendix includes programs written in QuickBASIC and Turbo C to aid you in calibrating the Model 2001. Programs include:

- Comprehensive calibration programs for use with any suitable calibrator.
- Comprehensive calibration programs for use with the Fluke 5700A Calibrator.
- Low-level calibration programs for use with the Fluke 5700A Calibrator.

Refer to Section 2 for more details on calibration procedures.

QuickBASIC program requirements

In order to use the QuickBASIC programs, you will need the following:

- IBM PC, AT, or compatible computer.
- IOtech Personal488, CEC PC-488, or National Instruments PC-II or IIA IEEE-488 interface for the computer.
- Shielded IEEE-488 cable(s) (Keithley Model 7007).
- MS-DOS or PC-DOS version 3.3 or later.
- Microsoft QuickBASIC version 4.0 or later.
- IOtech Driver488 IEEE-488 bus driver, Rev. 2.3 or later. (NOTE: recent versions of Driver488 may not support other manufacturers' interface cards).

Turbo C program requirements

In order to use the Turbo C programs, you will need the following:

- IBM PC, AT, or compatible computer.
- IOtech Personal488, CEC PC-488, or National Instruments PC-II or IIA IEEE-488 interface for the computer.
- Shielded IEEE-488 cable(s) (Keithley Model 7007).
- MS-DOS or PC-DOS version 3.3 or later.
- Borland Turbo C version 2.0 or later.
- IOtech Driver488 IEEE-488 bus driver, Rev. 2.3 or later. (NOTE: recent versions of Driver488 may not support other manufacturers' interface cards).

Calibration equipment

Table B-1 summarizes recommended comprehensive calibration equipment, and Table B-1 summarizes test equipment required for low-level calibration.

Table B-1
Recommended equipment for comprehensive calibration

Mfg.	**Model**	**Description**	**Specifications***
Fluke	5700A	Calibrator	±5ppm basic uncertainty. DC voltage: 2V: ±5ppm 20V: ±5ppm Resistance: 19k¾: ±11ppm 1M¾: ±18ppm
Keithley	8610	Low-thermal Shorting Plug	

* 90-day calibrator specifications shown include total uncertainty at specified output. The 2V output includes 0.5ppm transfer uncertainty.

Table B-1
Recommended equipment for low-level calibration

Mfg.	**Model**	**Description**	**Specifications***
Fluke	5700A	Calibrator	±5ppm basic uncertainty. DC voltage: 0V: ±0.75µV -2V, +2V: ±5ppm 20V: ±5ppm DC current: 200mA: ±65ppm 2A: ±90ppm AC voltage: 0.5mV @ 1kHz: ±10000ppm 5mV @ 100kHz: ±2400ppm 200mV @ 1kHz: ±150ppm 1.5V @ 1kHz: ±80ppm 20V @ 1kHz: ±80ppm 20V @ 30kHz: ±140ppm 200V @ 1kHz: ±85ppm 200V @ 30kHz: ±240ppm AC current: 20mA @ 1kHz: ±160ppm Resistance: 19k¾: ±11ppm 1M¾: ±18ppm
Keithley	3930A	Synthesizer	2V rms @ 1Hz
Keithley	8610	Low-thermal Shorting Plug	

* 90-day calibrator specifications shown include total uncertainty at specified output. The ±2V output includes 0.5ppm transfer uncertainty.

General program instructions

1. With the power off, connect the Model 2001 to the IEEE-488 interface of the computer. If you are using one of the programs that controls the Fluke 5700A calibrator, connect the calibrator to the IEEE-488 bus as well. Be sure to use shielded IEEE-488 cables for bus connections.
2. Turn on the computer, the Model 2001, and the calibrator. Allow the Model 2001 to warm up for at least one hour before performing calibration.
3. Make sure the Model 2001 is set for a primary address of 16. You can check or change the address as follows:
   A. Press MENU, select GPIB, then press ENTER.
   B. Select MODE, then press ENTER.
   C. Select ADDRESSABLE, and press ENTER.
   D. If the address is set correctly, press EXIT as necessary to return to normal display.
   E. To change the address, use the cursor keys to set the address to the desired value, then press ENTER. Press EXIT as necessary to return to normal display.
4. If you are using the Fluke 5700A calibrator over the bus (Program B-3 through Program B-6), make sure that the calibrator primary address is at its factory default setting of 4.
5. Make sure that the computer bus driver software is properly initialized.
6. Enter the QuickBASIC or Turbo C editor, and type in the desired program. Check thoroughly for errors, then save it using a convenient filename.
7. Compile and run the program, and follow the prompts on the screen to perform calibration.

Unlocking calibration

In order to unlock comprehensive calibration, briefly press in on the CAL switch with the power turned on. To unlock low-level calibration, press in and hold the CAL switch while turning on the power.

Comprehensive calibration

Programs B-1 and B-2 will perform semi-automatic comprehensive calibration of the Model 2001 using any suitable calibrator (see Table B-1 for required calibrator specifications). Programs B-3 and B-4 will perform comprehensive calibration almost fully automatically using the Fluke 5700A calibrator.

Figure B-1 shows low-thermal short connections, while Figure B-2 shows calibrator connections.

Low-level calibration

Programs B-5 and B-6 perform low-level calibration using the Fluke 5700A calibrator. Refer to Figure B-1 and B-3 for low-thermal short and calibrator voltage connections. Figure B-4 shows calibrator current connections. Figure B-5 shows synthesizer connections necessary to supply the 2V AC @ 1Hz signal.

NOTE

Low-level calibration is not normally required in the field unless the Model 2001 has been repaired.

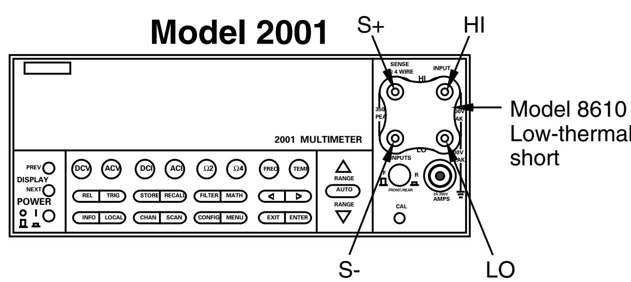


Figure B-1
Low-thermal short connections

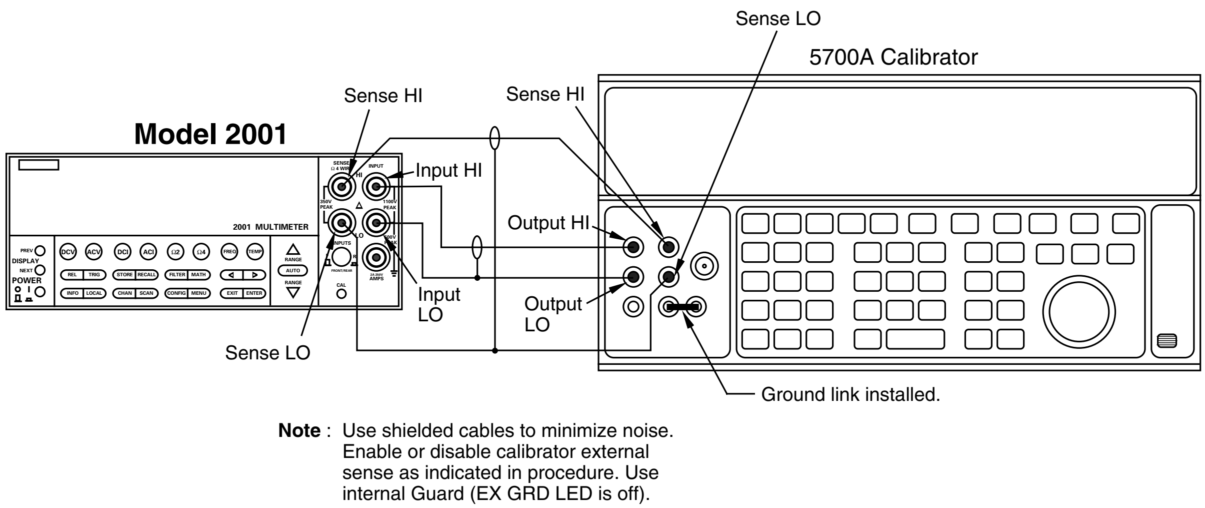


Figure B-2
Calibration connection for comprehensive calibration

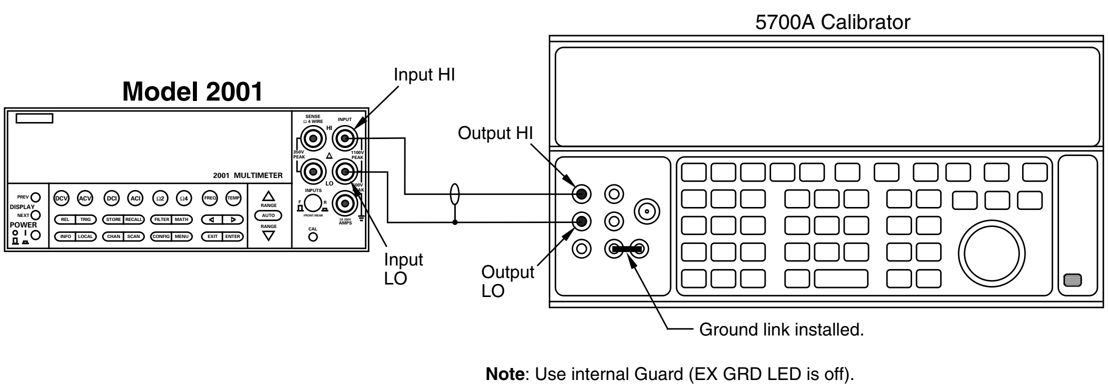


Figure B-3
Calibration voltage connections

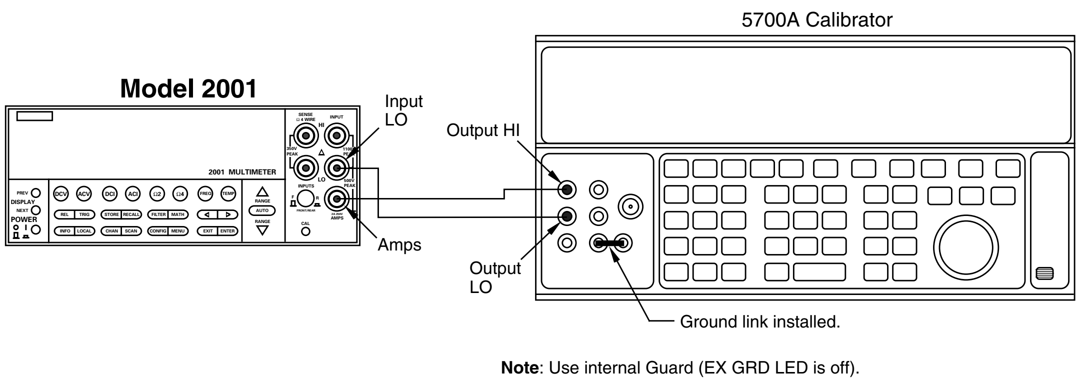


Figure B-4
Calibration current connections

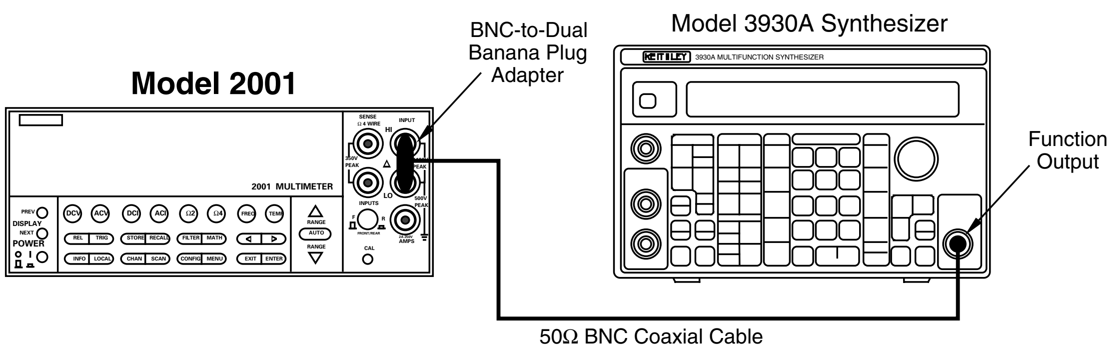


Figure B-5
Synthesizer connections

Program B-1

Comprehensive calibration program for use with any suitable calibrator (QuickBASIC Version).

```
' Model 2001 comprehensive calibration program
' for use with any suitable calibrator.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1    ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2      ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                       ' Reset interface.
PRINT #1, "RESET"                       ' Warm start interface
PRINT #1, "CLEAR"                       ' Send DCL.
PRINT #1, "REMOTE 16"                   ' Put unit in remote.
PRINT #1, "TERM LF EOI"                 ' Set terminator to LF + EOI.
PRINT #1, "OUTPUT 16;*RST;*CLS"         ' Initialize 2001.
PRINT #1, "OUTPUT 16;*ESE 1;*SRE 32"    ' Enable OPC and SRQ.
C$ = ":CAL:PROT:"                       ' 2001 partial command header.
CLS                                     ' Clear CRT.
'
PRINT "Model 2001 Multimeter Comprehensive Calibration Program"
GOSUB KeyCheck
GOSUB CheckSwitch                       ' Check CAL switch status.
RESTORE CmdList
'
FOR I = 1 TO 8                          ' Loop for all cal points.
READ Msg$, Cmd$                         ' Read message, cal strings.
PRINT Msg$
IF I < 7 THEN GOSUB KeyCheck
IF I = 8 THEN C$ = ":CAL:"
PRINT #1, "OUTPUT 16;"; C$; Cmd$; ";*OPC"' Send cal command.
GOSUB CalEnd                            ' Wait until cal step ends.
IF I = 7 OR I = 8 THEN GOSUB ErrCheck
NEXT I
'
INPUT "Enter calibration date (mm/dd/yy)"; D$ ' Program cal dates.
PRINT #1, "OUTPUT 16;:CAL:PROT:DATE '"; D$; "'"
INPUT "Enter calibration due date (mm/dd/yy)"; D$
PRINT #1, "OUTPUT 16;:CAL:PROT:NDUE '"; D$; "'"
PRINT #1, "OUTPUT 16;:CAL:PROT:SAVE"    ' Save calibration constants.
PRINT #1, "OUTPUT 16;:CAL:PROT:LOCK"    ' Lock out calibration.
PRINT "Calibration completed."
END
'
KeyCheck:                               ' Check for key press routine.
PRINT "Press any key to continue (ESC to abort program)."
Wai: I$ = INKEY$: IF I$ = "" THEN GOTO Wai
IF I$ = CHR$(27) THEN                   ' Abort if ESC is pressed.
        CLOSE 1: CLOSE 2
        PRINT "Program halted."
        END
END IF
RETURN
```

Program B-1 (continued)

Comprehensive calibration program for use with any suitable calibrator (QuickBASIC Version).

```
CalEnd:                                         ' Check for cal step completion.
PRINT "Waiting for calibration step"; I; "completion..."
Stat: PRINT #1, "STATUS"                        ' Request bus status.
INPUT #2, ST$                                   ' Read bus status.
IF MID$(ST$, 11, 2) = "S0" THEN GOTO Stat' Wait for operation complete.
PRINT #1, "OUTPUT 16;*ESR?"                     ' Clear OPC.
PRINT #1, "ENTER 16"
INPUT #2, S
PRINT #1, "SPOLL 16"                            ' Serial poll 2001.
INPUT #2, S
RETURN
'
ErrCheck:                                       ' Error check routine.
PRINT #1, "OUTPUT 16;:SYST:ERR?"                ' Query error queue.
PRINT #1, "ENTER 16"
INPUT #2, E, Err$
IF E <> 0 THEN
        PRINT                                   ' If error is detected, error
        PRINT Err$                              ' is displayed, and program
        PRINT "Calibration aborted."            ' is halted.
        BEEP
        CLOSE 1: CLOSE 2
        END
END IF
RETURN
'
CheckSwitch:                                    ' Check CAL switch status.
PRINT #1, "OUTPUT 16;:CAL:PROT:SWIT?"
PRINT #1, "ENTER 16"
INPUT #2, SW
IF SW = 1 THEN RETURN
BEEP
PRINT "Press CAL switch to unlock calibration."
PRINT #1, "LOCAL 16"
GOSUB KeyCheck
GOTO CheckSwitch
'
CmdList:
DATA "Connect low-thermal short to inputs, wait 3 minutes.","DC:ZERO"
DATA" Apply +2.0000V to INPUT jacks","DC:LOW 2.0"
DATA "Apply +20.0000V to INPUT jacks","DC:HIGH 20.0"
DATA "Connect 20k ohms to INPUT and SENSE jacks (4-wire connections)."
DATA "DC:LOHM 20E3"
DATA "Connect 1M Ohms to INPUT jacks (2-wire connections)"
DATA "DC:HOHM 1E6
DATA "Disconnect test leads from input jacks.","DC:OPEN"
DATA "Calculating new DC constants. ","DC:CALC"
DATA "Performing AC calibration, please wait...","UNPR:ACC"
```

Program B-2

Comprehensive calibration program for use with any suitable calibrator (Turbo C Version).

```
/* Model 2001 comprehensive calibration program for use
   with any suitable calibrator. */

#include "ieeeio.h"
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>

main()
{
        static char *msg[] = {
                "Connect low-thermal short, wait 3 minutes",
                "Apply +2.0000V to INPUT jacks",
                "Apply +20.000V to INPUT jacks",
                "Connect 20k ohms to INPUT and SENSE jacks",
                "Connect 1M ohms to INPUT jacks",
                "Disconnect test leads from INPUT jacks",
                "Calculating new DC constants",
                "Performing AC calibration"
        };
        static char *cmd[] = {
                ":cal:prot:dc:zero",":cal:prot:dc:low 2.0",
                ":cal:prot:dc:high 20.0",":cal:prot:dc:lohm 20E3",
                ":cal:prot:dc:hohm 1E6",":cal:prot:dc:open",
                ":cal:prot:dc:calc",":cal:unpr:acc"
        };
        void keypress(),errcheck(),chkswit();
        char date[10];
        int i,calend();
        if (ieeeinit()==-1){
                printf("Cannot initialize interface.\n");
                exit(1);
        }
        ieeewt("clear\n");              /* Send DCL. */
        ieeewt("remote 16\n");          /* Put 2001 in remote. */
        ieeewt("term lf eoi\n");        /* Set terminator. */
        ieeewt("output 16;*rst;*cls\n");/* Initialize 2001. */
        ieeewt("output 16;*ese 1;*sre 32\n"); /* Enable OPC, SRQ. */
        clrscr();                       /* Clear CRT. */

        printf("Model 2001 Comprehensive Calibration program\n");
        chkswit();                      /* Check cal switch. */
        for(i=0;i<=7;i++) {             /* Loop for cal points. */
                printf("%s\n",msg[i]);
                if (i<6) keypress();
                ieeeprtf("output 16;%s;*opc\n",cmd[i]);
                calend(i);
                if (i==6 || i==7) errcheck();
        }
```

Program B-2 (continued)

Comprehensive calibration program for use with any suitable calibrator (Turbo C Version).

```
        printf("Enter calibration date (mm/dd/yy): ");
        scanf("%s",date);
        ieeeprtf("output 16;:cal:prot:date '%s'\n",date);
        printf("Enter calibration due date (mm/dd/yy): ");
        scanf("%s",date);
        ieeeprtf("output 16;:cal:prot:ndue '%s'\n",date);
        ieeewt("output 16;:cal:prot:save\n");
        ieeewt("output 16;:cal:prot:lock\n");
        printf("Calibration completed.\n");
}
void keypress()                         /* Wait for keypress. */
{
        printf("Press any key to continue.\n");
        while(kbhit()==0);
        getch();
}
int calend(n)                           /* Check for cal end. */
int n;
{
        char status [40];
        int stat;
        printf("Waiting for cal step %d completion.\n",n+1);
        do {
                ieeewt("status\n");
                ieeerd(status);
        }
        while (status[11]=='0');
        ieeewt("output 16;*esr?\n");
        ieeewt("enter 16\n");
        ieeescnf("%d",&stat);
        ieeewt("spoll 16\n");
        ieeescnf("%d",&stat);
}
void errcheck()                         /* Check for error. */
{
        char errbuf[100];
        ieeewt("output 16;:syst:err?\n");
        ieeewt("enter 16\n");
        ieeerd(errbuf);
        if (atoi(errbuf) !=0){
                printf("%s\n",errbuf);
                printf("Calibration aborted.\n");
                exit (1);
        }
}
```

Program B-2 (continued)

Comprehensive calibration program for use with any suitable calibrator (Turbo C Version).

```
void chkswit()                              /* Check cal switch. */
{
        int swit=0;
        while (swit==0){
                ieeewt("output 16;:cal:prot:swit?\n");
                ieeewt("enter 16\n");
                ieeescnf("%d",&swit);
                if (swit==0){
                        printf("Press CAL switch to unlock"
                                " calibration.\n");
                        ieeewt("local 16\n");
                        keypress();
                }
        }
}
```

Program B-3

Comprehensive calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

```
' Model 2001 comprehensive calibration program
' for use only with the Fluke 5700A calibrator.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1    ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2      ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                       ' Reset interface.
PRINT #1, "RESET"                       ' Warm start interface
PRINT #1, "CLEAR"                       ' Send DCL.
PRINT #1, "REMOTE 16"                   ' Put 2001 in remote.
PRINT #1, "REMOTE 04"                   ' Put 5700A in remote.
PRINT #1, "TERM LF EOI"                 ' Set terminator to LF + EOI.
PRINT #1, "OUTPUT 16;*RST;*CLS"         ' Initialize 2001.
PRINT #1, "OUTPUT 16;*ESE 1;*SRE 32"    ' Enable OPC and SRQ
PRINT #1, "OUTPUT 04;*RST;*CLS"         ' Reset 5700A calibrator.
C$ = ":CAL:PROT:"                       ' 2001 partial command header.
'
CLS                                     ' Clear CRT.
PRINT "Model 2001 Multimeter Comprehensive Calibration Program"
PRINT "This program controls the Fluke 5700A Calibrator."
SwMsg: PRINT "Press Model 2001 CAL switch to unlock calibration."
GOSUB KeyCheck
GOSUB CheckSwitch
RESTORE CmdList
'
FOR I = 1 TO 8                          ' Loop for all cal points.
READ Msg$, Cmd$                         ' Read message, cal strings.
SELECT CASE I                           ' Select cal sequence.
        CASE 1
                PRINT Msg$
                GOSUB KeyCheck
        CASE 2
                PRINT "Connect calibrator to INPUT and SENSE jacks"
                GOSUB KeyCheck
                PRINT #1, "OUTPUT 04;OPER"
                PRINT #1, "OUTPUT 04;EXTSENSE OFF"
                PRINT #1, "OUTPUT 04;"; Msg$
        CASE 3
                PRINT #1, "OUTPUT 04;"; Msg$
        CASE 4, 5
                PRINT #1, "OUTPUT 04;"; Msg$
                PRINT #1, "OUTPUT 04;OPER"
                S$ = "ON": IF I = 5 THEN S$ = "OFF"
                PRINT #1, "OUTPUT 04;EXTSENSE "; S$
                PRINT #1, "OUTPUT 04;OUT?"
                PRINT #1, "ENTER 04"
                INPUT #2, R, R$, S
                Cmd$ = Cmd$ + " " + STR$(R)
        CASE 6
                PRINT #1, "OUTPUT 04;STBY"
                PRINT Msg$
                GOSUB KeyCheck
```

Program B-3 (continued)

Comprehensive calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

```
        CASE 7
                PRINT Msg$
        CASE 8
                C$ = ":CAL:"
                PRINT Msg$
END SELECT
GOSUB Dly                                   ' Settling time.
PRINT #1, "OUTPUT 16;"; C$; Cmd$; ";*OPC" ' Send cal command to 2001.
GOSUB CalEnd                                ' Wait until cal step ends.
IF I = 7 OR I = 8 THEN GOSUB ErrCheck       ' Check for cal error.
NEXT I
'
INPUT "Enter calibration date (mm/dd/yy)"; D$
PRINT #1, "OUTPUT 16;:CAL:PROT:DATE '"; D$; "'"
INPUT "Enter calibration due date (mm/dd/yy)"; D$
PRINT #1, "OUTPUT 16;:CAL:PROT:NDUE '"; D$; "'"
PRINT #1, "OUTPUT 16;:CAL:PROT:SAVE"        ' Save calibration constants.
PRINT #1, "OUTPUT 16;:CAL:PROT:LOCK"        ' Lock out calibration.
PRINT "Calibration completed."
END
'
KeyCheck:                                   ' Check for key press routine.
PRINT
PRINT "Press any key to continue (ESC to abort program)."
Wai: I$ = INKEY$: IF I$ = "" THEN GOTO Wai
IF I$ = CHR$(27) THEN                       ' Abort if ESC is pressed.
        PRINT #1, "OUTPUT 04;STBY"
        CLOSE 1: CLOSE 2
        PRINT "Program halted."
        END
END IF
RETURN
'
CalEnd:                                     ' Check for cal step completion.
PRINT "Waiting for calibration step"; I; "completion..."
Stat: PRINT #1, "STATUS"                    ' Request bus status.
INPUT #2, ST$                               ' Input status byte.
IF MID$(ST$, 11, 2) = "S0" THEN GOTO Stat' Wait for operation complete.
PRINT #1, "OUTPUT 16;*ESR?"                 ' Clear OPC.
PRINT #1, "ENTER 16"
INPUT #2, S
PRINT #1, "SPOLL 16"
INPUT #2, S
RETURN
```

Program B-3 (continued)

Comprehensive calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

```
ErrCheck:                                   ' Error check routine.
PRINT #1, "OUTPUT 16;:SYST:ERR?"            ' Query error queue.
PRINT #1, "ENTER 16"
INPUT #2, E, Err$
IF E <> 0 THEN
        PRINT                               ' If error is detected, error
        PRINT Err$                          ' is displayed, and program
        PRINT "Calibration aborted."        ' is halted.
        BEEP
        CLOSE 1: CLOSE 2
        END
END IF
RETURN
'
CheckSwitch:                                ' Check CAL switch status.
PRINT #1, "OUTPUT 16;:CAL:PROT:SWIT?"
PRINT #1, "ENTER 16"
INPUT #2, SW
IF SW = 1 THEN RETURN
PRINT "Press CAL switch to unlock calibration."
BEEP
PRINT #1, "LOCAL 16"
GOSUB KeyCheck
GOTO CheckSwitch
'
Dly:                                        ' Delay routine.
T = TIMER
Lp: IF (TIMER - T) < 5 THEN GOTO Lp        ' Wait 5 seconds.
RETURN
'
CmdList:
DATA "Connect low-thermal short to inputs, wait 3 minutes.","DC:ZERO"
DATA "OUT 2 V","DC:LOW 2"
DATA "OUT 20 V","DC:HIGH 20.0"
DATA "OUT 19 KOHM","DC:LOHM"
DATA "OUT 1 MOHM","DC:HOHM"
DATA "Disconnect calibrator from INPUT and SENSE jacks.","DC:OPEN"
DATA "Calculating new DC constants.","DC:CALC"
DATA "Performing AC calibration, please wait...","UNPR:ACC"
```

Program B-4

Comprehensive calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```
/* Model 2001 comprehensive calibration program for use
   with the Fluke 5700A calibrator. */

#include "ieeeio.h"
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>

main()
{
        static char *msg[] = {
                "Connect low-thermal short, wait 3 minutes",
                "out 2 v","out 20 v","out 19 kohm","out 1 mohm",
                "Disconnect calibrator from INPUT jacks",
                "Calculating new DC constants",
                "Performing AC calibration"
        };
        static char *cmd[] = {
                ":cal:prot:dc:zero",":cal:prot:dc:low 2.0",
                ":cal:prot:dc:high 20.0",":cal:prot:dc:lohm ",
                ":cal:prot:dc:hohm ",":cal:prot:dc:open",
                ":cal:prot:dc:calc",":cal:unpr:acc"
        };
        void keypress(),errcheck(),chkswit();
        char buf [100],date[10];
        int i,j,calend();
        if (ieeeinit()==-1){
                printf("Cannot initialize interface.\n");
                exit(1);
        }
        ieeewt("remote 16\n");          /* Put 2001 in remote. */
        ieeewt("remote 04\n");          /* Put 5700A in remote. */
        ieeewt("clear\n");              /* Send DCL. */
        ieeewt("term lf eoi\n");        /* Set terminator. */
        ieeewt("output 16;*rst;*cls\n");/* Initialize 2001. */
        ieeewt("output 16;*ese 1;*sre 32\n"); /* Enable OPC, SRQ. */
        ieeewt("output 04;*rst;*cls\n");      /* Reset 5700A. */
        clrscr();                       /* Clear CRT. */

        printf("Model 2001 Comprehensive Calibration Program.\n");
        printf("This program controls the 5700A Calibrator.\n");
        chkswit();                      /* Check cal switch. */
        for(i=0;i<=7;i++) {             /* Loop for cal points. */
                switch(i) {
                case 0: printf("%s\n",msg[i]);
                        keypress();
                        break;
                case 1: printf("Connect calibrator to 2001.\n");
                        keypress();
                        ieeewt("output 04;oper\n");
                        ieeewt("output 04;extsense off\n");
                        ieeeprtf("output 04;%s\n",msg[i]);
                        break;
```

Program B-4 (continued)

Comprehensive calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```
                case 2: ieeeprtf("output 04;%s\n",msg[i]);
                        break;
                case 3:
                case 4: ieeeprtf("output 04;%s\n",msg[i]);
                        ieeewt("output 04;oper\n");
                        if (i==3)
                                ieeewt("output 04;extsense on\n");
                        if (i==4)
                                ieeewt("output 04;extsense off\n");
                        ieeewt("output 04;out?\n");
                        ieeewt("enter 04\n");
                        ieeerd(buf);
                        j=0;
                        while (buf[j++] !=',');
                        buf[--j]='\0';
                        break;
                case 5: ieeewt("output 04;stby\n");
                        printf("%s\n",msg[i]);
                        keypress();
                        break;
                case 6:
                case 7: printf("%s\n",msg[i]);
                        break;
                }
                delay(5000);
                if (i==3 || i==4)
                     ieeeprtf("output 16;%s%s;*opc\n",cmd[i],buf);
                else ieeeprtf("output 16;%s;*opc\n",cmd[i]);
                calend(i);
                if (i==6 || i==7) errcheck();
        }
        printf("Enter calibration date (mm/dd/yy): ");
        scanf("%s",date);
        ieeeprtf("output 16;:cal:prot:date '%s'\n",date);
        printf("Enter calibration due date (mm/dd/yy): ");
        scanf("%s",date);
        ieeeprtf("output 16;:cal:prot:ndue '%s'\n",date);
        ieeewt("output 16;:cal:prot:save\n");
        ieeewt("output 16;:cal:prot:lock\n");
        printf("Calibration completed.\n");
}
void keypress()                           /* Wait for keypress. */
{
        printf("Press any key to continue.\n");
        while(kbhit()==0);
        getch();
}
```

Program B-4 (continued)

Comprehensive calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```
int calend(n)                                   /* Check for cal end. */
int n;
{
        char status[40];
        int stat;
        printf("Waiting for cal step %d completion.\n",n+1);
        do {
                ieeewt("status\n");
                ieeerd(status);
        }
        while (status[11]=='0');
        ieeewt("output 16;*esr?\n");
        ieeewt("enter 16\n");
        ieeescnf("%d",&stat);
        ieeewt("spoll 16\n");
        ieeescnf("%d",&stat);
}
void errcheck()                                 /* Check for error. */
{
        char errbuf[100];
        ieeewt("output 16;:syst:err?\n");
        ieeewt("enter 16\n");
        ieeerd(errbuf);
        if (atoi(errbuf) !=0){
                printf("%s\n",errbuf);
                printf("Calibration aborted.\n");
                exit (1);
        }
}
void chkswit()                                  /* Check cal switch. */
{
        int swit=0;
        while (swit==0){
                ieeewt("output 16;:cal:prot:swit?\n");
                ieeewt("enter 16\n");
                ieeescnf("%d",&swit);
                if (swit==0){
                        printf("Press CAL switch to "
                                "unlock calibration.\n");
                        ieeewt("local 16\n");
                        keypress();
                }
        }
}
```

Program B-5

Low-level calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

```
' Model 2001 low-level calibration program
' for use only with the Fluke 5700A calibrator.
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1     ' Open IEEE-488 output path.
OPEN "\DEV\IEEEIN" FOR INPUT AS #2       ' Open IEEE-488 input path.
IOCTL #1, "BREAK"                        ' Reset interface.
PRINT #1, "RESET"                        ' Warm start interface
PRINT #1, "CLEAR"                        ' Send DCL.
PRINT #1, "REMOTE 16"                    ' Put 2001 in remote.
PRINT #1, "REMOTE 04"                    ' Put 5700A in remote.
PRINT #1, "TERM LF EOI"                  ' Set terminator to LF + EOI.
PRINT #1, "OUTPUT 16;*RST;*CLS"          ' Initialize 2001.
PRINT #1, "OUTPUT 16;*ESE 1;*SRE 32"     ' Enable OPC and SRQ.
PRINT #1, "OUTPUT 04;*RST;*CLS"          ' Reset 5700A calibrator.
PRINT #1, "OUTPUT 04;CUR_POST NORMAL"    ' Normal current output.
C$ = ":CAL:PROT:"                        ' 2001 partial command header.
'
CLS                                      ' Clear CRT.
PRINT "Model 2001 Multimeter Low-level Calibration Program"
PRINT "This program also controls the Fluke 5700A Calibrator."
PRINT : PRINT "WARNING: Hazardous voltage will be present on Model 2001"
PRINT "and calibrator terminals!": PRINT
GOSUB KeyCheck
GOSUB CheckSwitch                        ' Check CAL switch status.
'
RESTORE CmdList
PRINT "Calibration in progress..."
'
FOR I = 1 TO 24                          ' Loop for all cal points.
READ Msg$, Cmd$                          ' Read message, cal strings.
SELECT CASE I                            ' Select cal sequence.
        CASE 1
                PRINT Msg$
                GOSUB KeyCheck
        CASE 2
                PRINT "Connect calibrator to INPUT and SENSE jacks"
                GOSUB KeyCheck
                PRINT #1, "OUTPUT 04;OPER"
                PRINT #1, "OUTPUT 04;EXTSENSE OFF"
                PRINT #1, "OUTPUT 04;"; Msg$
        CASE 3
                PRINT #1, "OUTPUT 04;"; Msg$
        CASE 4, 5
                PRINT #1, "OUTPUT 04;"; Msg$
                PRINT #1, "OUTPUT 04;OPER"
                S$ = "ON": IF I = 5 THEN S$ = "OFF"
                PRINT #1, "OUTPUT 04;EXTSENSE "; S$
                PRINT #1, "OUTPUT 04;OUT?"
                PRINT #1, "ENTER 04"
                INPUT #2, R, R$, S
                Cmd$ = Cmd$ + " " + STR$(R)
        CASE 6
                PRINT #1, "OUTPUT 04;STBY"
                PRINT Msg$
                GOSUB KeyCheck
```

Program B-5 (continued)

Low-level calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

```
        CASE 7
                PRINT Msg$
        CASE 8
                PRINT "Performing AC calibration, please wait..."
                C$ = ":CAL:"
        CASE 9
                C$ = ":CAL:PROT:"
                PRINT "Connect calibrator to INPUT HI and LO jacks."
                GOSUB KeyCheck
                PRINT #1, "OUTPUT 04;"; Msg$
                PRINT #1, "OUTPUT 04;OPER"
        CASE 10 TO 19, 21, 22
                PRINT #1, "OUTPUT 04;"; Msg$
                PRINT #1, "OUTPUT 04;OPER"
        CASE 20
                PRINT #1, "OUTPUT 04;STBY"
                PRINT "Connect calibrator to AMPS and INPUT LO"
                GOSUB KeyCheck
                PRINT #1, "OUTPUT 04;"; Msg$
                PRINT #1, "OUTPUT 04;OPER"
        CASE 23
                PRINT #1, "OUTPUT 04;STBY"
                PRINT Msg$
                GOSUB KeyCheck
        CASE 24
                PRINT Msg$
                GOSUB KeyCheck
END SELECT
GOSUB Dly
PRINT #1, "OUTPUT 16;"; C$; Cmd$; ";*OPC"' Send cal command to 2001.
GOSUB CalEnd                              ' Wait until cal step ends.
IF I = 7 OR I = 8 OR I = 24 THEN GOSUB ErrCheck' Check for cal error.
NEXT I
'
INPUT "Enter calibration date (mm/dd/yy)"; D$
PRINT #1, "OUTPUT 16;:CAL:PROT:DATE '"; D$; "'"
INPUT "Enter calibration due date (mm/dd/yy)"; D$
PRINT #1, "OUTPUT 16;:CAL:PROT:NDUE '"; D$; "'"
PRINT #1, "OUTPUT 16;:CAL:PROT:SAVE"    ' Save calibration constants.
PRINT #1, "OUTPUT 16;:CAL:PROT:LOCK"    ' Lock out calibration.
PRINT "Low-level calibration procedure completed."
END
'
KeyCheck:                                 ' Check for key press routine.
PRINT "Press any key to continue (ESC to abort program)."
Wai: I$ = INKEY$: IF I$ = "" THEN GOTO Wai
IF I$ = CHR$(27) THEN                     ' Abort if ESC is pressed.
        PRINT #1, "OUTPUT 04;STBY"        ' Put calibrator in standby.
        CLOSE 1: CLOSE 2
        PRINT "Program halted."
        END
END IF
RETURN
```

Program B-5 (continued)

Low-level calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

```
CalEnd:                                      ' Check for cal step completion.
PRINT "Waiting for calibration step"; I; "completion..."
Stat: PRINT #1, "STATUS"                     ' Request bus status.
INPUT #2, ST$                                ' Read bus status.
IF MID$(ST$, 11, 2) = "S0" THEN GOTO Stat' Wait for operation complete.
PRINT #1, "OUTPUT 16;*ESR?"                  ' Clear OPC.
PRINT #1, "ENTER 16"
INPUT #2, S
PRINT #1, "SPOLL 16"                         ' Serial poll 2001.
INPUT #2, S
RETURN
'
ErrCheck:                                    ' Error check routine.
PRINT #1, "OUTPUT 16;:SYST:ERR?"             ' Query error queue.
PRINT #1, "ENTER 16"
INPUT #2, E, Err$
IF E <> 0 THEN
        PRINT                                ' If error is detected, error
        PRINT Err$                           ' is displayed, and program
        PRINT "Calibration aborted."         ' is halted.
        BEEP
        CLOSE 1: CLOSE 2
        END
END IF
RETURN
'
CheckSwitch:                                 ' Check CAL switch status.
PRINT #1, "OUTPUT 16;:CAL:PROT:LLEV:SWIT?"
PRINT #1, "ENTER 16"
INPUT #2, SW
IF SW = 0 THEN
        PRINT "Low-level calibration is locked out."
        PRINT "To unlock, hold in CAL while turning on 2001 power."
        PRINT "Restart program to perform calibration."
        CLOSE 1: CLOSE 2
        END
END IF
RETURN
'
Dly:                                         ' Delay routine.
T = TIMER
Lp: IF (TIMER - T) < 7 THEN GOTO Lp          ' Wait 7 seconds.
RETURN
```

Program B-5 (continued)

Low-level calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

```
CmdList:
DATA "Connect low-thermal short to inputs, wait 3 minutes.","DC:ZERO"
DATA "OUT 2 V","DC:LOW 2"
DATA "OUT 20 V","DC:HIGH 20.0"
DATA "OUT 19 KOHM","DC:LOHM"
DATA "OUT 1 MOHM","DC:HOHM"
DATA "Disconnect calibrator from INPUT and SENSE jacks.","DC:OPEN"
DATA "Calculating new constants.","DC:CALC"
DATA "Performing AC calibration, please wait...","UNPR:ACC"
DATA "OUT 20 V,1 KHZ","LLEV:STEP 1"
DATA "OUT 20 V,30 KHZ","LLEV:STEP 2"
DATA "OUT 200 V,1 KHZ","LLEV:STEP 3"
DATA "OUT 200 V,30KHZ","LLEV:STEP 4"
DATA "OUT 1.5 V,1 KHZ","LLEV:STEP 5"
DATA "OUT 0.2 V,1 KHZ","LLEV:STEP 6"
DATA "OUT 5 MV,100 KHZ","LLEV:STEP 7"
DATA "OUT 0.5 MV,1 KHZ","LLEV:STEP 8"
DATA "OUT 2 V,0 HZ","LLEV:STEP 9"
DATA "OUT -2V,0 HZ","LLEV:STEP 10"
DATA "OUT 0 V,0 HZ","LLEV:STEP 11"
DATA "OUT 20 MA,1 KHZ","LLEV:STEP 12"
DATA "OUT 0.2 A,0 HZ","LLEV:STEP 13"
DATA "OUT 2 A,0 HZ","LLEV:STEP 14"
DATA "Apply 2V rms @ 1Hz from synthesizer to INPUT jacks","LLEV:STEP 15"
DATA "Disconnect all test leads from input jacks","LLEV:CALC"
```

Program B-6

Low-level calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```
/* Model 2001 low-level calibration program for use only
   with the Fluke 5700A calibrator. */

#include "ieeeio.h"
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>

main()
{
        static char *msg[] = {
                "Connect low-thermal short, wait 3 minutes",
                "out 2 v","out 20 v","out 19 kohm","out 1 mohm",
                "Disconnect calibrator from INPUT jacks",
                "Calculating new DC constants",
                "Performing AC calibration",
                "out 20 v,1 khz","out 20 v,30 khz",
                "out 200 v,1 khz","out 200 v,30 khz",
                "out 1.5 v,1 khz","out 0.2 v,1 khz",
                "out 5 mv,100 khz","out 0.5 mv,1 khz",
                "out 2 v,0 hz","out -2v,0 hz","out 0v,0 hz",
                "out 20 ma,1 khz","out 0.2 a,0 hz","out 2 a,0 hz",
                "Apply 2V rms @ 1Hz to INPUT jacks",
                "Disconnect leads from INPUT jacks"
        };
        static char *cmd[] = {
                ":cal:prot:dc:zero",":cal:prot:dc:low 2.0",
                ":cal:prot:dc:high 20.0",":cal:prot:dc:lohm ",
                ":cal:prot:dc:hohm ",":cal:prot:dc:open",
                ":cal:prot:dc:calc",":cal:unpr:acc",
                ":cal:prot:llev:step 1",":cal:prot:llev:step 2",
                ":cal:prot:llev:step 3",":cal:prot:llev:step 4",
                ":cal:prot:llev:step 5",":cal:prot:llev:step 6",
                ":cal:prot:llev:step 7",":cal:prot:llev:step 8",
                ":cal:prot:llev:step 9",":cal:prot:llev:step 10",
                ":cal:prot:llev:step 11",":cal:prot:llev:step 12",
                ":cal:prot:llev:step 13",":cal:prot:llev:step 14",
                ":cal:prot:llev:step 15",":cal:prot:llev:calc"
        };
        void keypress(),errcheck(),chkswit();
        char buf [100],date[10];
        int i,j,calend();
        if (ieeeinit()==-1){
                printf("Cannot initialize interface.\n");
                exit(1);
        }
        ieeewt("clear\n");                 /* Send DCL. */
        ieeewt("remote 16\n");             /* Put 2001 in remote. */
        ieeewt("remote 04\n");             /* Put 5700A in remote. */
        ieeewt("term lf eoi\n");           /* Set terminator. */
        ieeewt("output 16;*rst;*cls\n");/* Initialize 2001. */
        ieeewt("output 16;*ese 1;*sre 32\n"); /* Enable OPC, SRQ. */
        ieeewt("output 04;*rst;*cls\n");      /* Reset 5700A. */
        ieeewt("output 04;cur_post normal\n"); /* Current output. */
        clrscr();                          /* Clear CRT. */
```

Program B-6 (continued)

Low-level calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```
printf("Model 2001 Low-Level Calibration Program.\n");
printf("This program controls the 5700A Calibrator.\n\n");
printf("WARNING: hazardous voltage will be present on "
        "Model 2001\nand calibrator terminals!\n\n");
chkswit();
printf("Calibration in progress...\n");
for(i=0;i<=23;i++) {            /* Loop for cal points. */
        switch(i) {
        case 0: printf("%s\n",msg[i]);
                keypress();
                break;
        case 1: printf("Connect calibrator to 2001.\n");
                keypress();
                ieeewt("output 04;oper\n");
                ieeewt("output 04;extsense off\n");
                ieeeprtf("output 04;%s\n",msg[i]);
                break;
        case 2: ieeeprtf("output 04;%s\n",msg[i]);
                break;
        case 3:
        case 4: ieeeprtf("output 04;%s\n",msg[i]);
                ieeewt("output 04;oper\n");
                if (i==3)
                        ieeewt("output 04;extsense on\n");
                if (i==4)
                        ieeewt("output 04;extsense off\n");
                ieeewt("output 04;out?\n");
                ieeewt("enter 04\n");
                ieeerd(buf);
                j=0;
                while (buf[j++] !=',');
                buf[--j]='\0';
                break;
        case 5: ieeewt("output 04;stby\n");
                printf("%s\n",msg[i]);
                keypress();
                break;
        case 6:
        case 7: printf("%s\n",msg[i]);
                break;
        case 8: printf("Connect calibrator to INPUT.\n");
                keypress();
                ieeeprtf("output 04;%s\n",msg[i]);
                ieeewt("output 04;oper\n");
                break;
        case 9:
        case 10:
        case 11:
```

Program B-6 (continued)

Low-level calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```
                case 12:
                case 13:
                case 14:
                case 15:
                case 16:
                case 17:
                case 18:ieeeprtf("output 04;%s\n",msg[i]);
                        ieeewt("output 04;oper\n");
                        break;
                case 19:ieeewt("output 04;stby\n");
                        printf("Connect calibrator to AMPS.\n");
                        keypress();
                        ieeeprtf("output 04;%s\n",msg[i]);
                        ieeewt("output 04;oper\n");
                        break;
                case 20:
                case 21:ieeeprtf("output 04;%s\n",msg[i]);
                        ieeewt("output 04;oper\n");
                        break;
                case 22:ieeewt("output 04;stby\n");
                        printf("%s\n",msg[i]);
                        keypress();
                        break;
                case 23:printf("%s\n",msg[i]);
                        keypress();
                        break;
                }
                delay(7000);
                if (i==3 || i==4)
                    ieeeprtf("output 16;%s%s;*opc\n",cmd[i],buf);
                else ieeeprtf("output 16;%s;*opc\n",cmd[i]);
                calend(i);
                if (i==6 || i==7 || i==23) errcheck();
        }
        printf("Enter calibration date (mm/dd/yy): ");
        scanf("%s",date);
        ieeeprtf("output 16;:cal:prot:date '%s'\n",date);
        printf("Enter calibration due date (mm/dd/yy): ");
        scanf("%s",date);
        ieeeprtf("output 16;:cal:prot:ndue '%s'\n",date);
        ieeewt("output 16;:cal:prot:save\n");
        ieeewt("output 16;:cal:prot:lock\n");
        printf("Calibration completed.\n");
}
void keypress()                             /* Wait for keypress. */
{
        printf("Press any key to continue.\n");
        while(kbhit()==0);
        getch();
}
```

Program B-6 (continued)

Low-level calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```
int calend(n)                                   /* Check for cal end. */
int n;
{
        char status[40];
        int stat;
        printf("Waiting for cal step %d completion.\n",n+1);
        do {
                ieeewt("status\n");
                ieeerd(status);
        }
        while (status[11]=='0');
        ieeewt("output 16;*esr?\n");
        ieeewt("enter 16\n");
        ieeescnf("%d",&stat);
        ieeewt("spoll 16\n");
        ieeescnf("%d",&stat);
}
void errcheck()                                 /* Check for error. */
{
        char errbuf[100];
        ieeewt("output 16;:syst:err?\n");
        ieeewt("enter 16\n");
        ieeerd(errbuf);
        if (atoi(errbuf) !=0){
                printf("%s\n",errbuf);
                printf("Calibration aborted.\n");
                exit (1);
        }
}
void chkswit()                                  /* Check cal switch. */
{
        int swit;
        ieeewt("output 16;:cal:prot:llev:swit?\n");
        ieeewt("enter 16\n");
        ieeescnf("%d",&swit);
        if (swit==0) {
                printf("Calibration is locked.\n"
                        "To unlock, hold in CAL while turning on "
                        "power, then restart program.\n");
                exit (1);
        }
}
```

C
Calibration Messages

Introduction

This appendix lists all calibration errors that may occur during calibration as well as the :CAL:PROT:DATA? response.

Error summary

Table C-1 summarizes Model 2001 calibration errors. The error string returned over the bus by the :SYST:ERR? query include the error ID code and message separated by a comma and the message surrounded by quotes. For example:

+438, “Date of calibration not set”

Calibration data query response

Table C-2 lists the response to the :CAL:PROT:DATA? query. The response is an ASCII string of 99 numbers separated by commas, and is not affected by the FORMAT command. Constants listed in Table C-2 are shown in the order they are sent.

Table C-1
Calibration errors

Error ID code	Error messages
0	No Error
-102	Syntax error
-113	Command header error
-200	Execution error
-221	Settings conflict
-222	Parameter data out of range
+353	200 mV gain out of spec
+354	200 mV offset out of spec
+355	2V gain out of spec
+356	2 V offset out of spec
+357	20 V gain out of spec
+358	20 V offset out of spec
+359	200 V gain out of spec
+360	200 V offset out of spec
+361	1000 V gain out of spec
+362	1000 V offset out of spec
+363	200 µA gain out of spec
+364	200 µA offset out of spec
+365	2 mA gain out of spec
+366	2 mA offset out of spec
+367	20 mA gain out of spec
+368	20 mA offset out of spec
+369	200 mA gain out of spec
+370	200 mA offset out of spec
+371	2 A gain out of spec
+372	2 A offset out of spec
+373	20 ohm 2w gain out of spec
+374	20 ohm 2w offset out of spec
+375	200 ohm 2w gain out of spec
+376	200 ohm 2w offset out of spec
+377	2 kohm 2w gain out of spec
+378	2 kohm 2w offset out of spec
+379	20 kohm 2w gain out of spec
+380	20 kohm 2w offset out of spec
+381	200 kohm 2w gain out of spec
+382	200 kohm 2w offset out of spec
+383	2 Mohm 2w gain out of spec
+384	2 Mohm 2w offset out of spec
+385	20 Mohm 2w gain out of spec
+386	20 Mohm 2w offset out of spec
+387	200 Mohm 2w gain out of spec
+388	200 Mohm 2w offset out of spec
+389	1 Gohm 2w gain out of spec
+390	1 Gohm 2w offset out of spec
+391	20 ohm 4w gain out of spec
+392	20 ohm 4w offset out of spec
+393	200 ohm 4w gain out of spec

Table C-1 (continued)
Calibration errors

Error ID code	Error messages
+394	200 ohm 4w offset out of spec
+395	2 kohm 4w gain out of spec
+396	2 kohm 4w offset out of spec
+397	20 kohm 4w gain out of spec
+398	20 kohm 4w offset out of spec
+399	200 kohm 4w gain out of spec
+400	200 kohm 4w offset out of spec
+401	2 Mohm 4w gain out of spec
+402	2 Mohm 4w offset out of spec
+403	7 V ref out of spec
+404	DCV rollover out of spec
+405	x1 rms gain out of spec
+406	x1 rms offset out of spec
+407	x10 rms gain out of spec
+408	x10 rms offset out of spec
+409	x1 fwr gain out of spec
+410	x1 fwr offset out of spec
+411	x10 fwr gain out of spec
+412	x10 fwr offset out of spec
+413	d100 atten out of spec
+414	d500 atten out of spec
+415	Pos x10 peak offset out of spec
+416	Neg x10 peak offset out of spec
+417	x1 peak offset out of spec
+418	Pos 20V peak offset out of spec
+419	Neg 20V peak offset out of spec
+420	d100 self cal DAC out of spec
+421	d500 self cal DAC out of spec
+422	x10 noise factor out of spec
+423	x1 cfc out of spec
+424	x10 cfc out of spec
+425	Low V coupling fact out of spec
+426	High V coupling fact out of spec
+427	Input time constant out of spec
+428	Curr coupling fact out of spec
+429	Comparator DAC out of spec
+430	d100 div DAC out of spec
+431	200 V div DAC out of spec
+432	d500 div DAC out of spec
+433	d100 div DAC offset out of spec
+434	200 V div DAC offset out of spec
+435	d500 div DAC offset out of spec
+436	d100 div cal did not converge
+437	d500 div cal did not converge
+438	Date of calibration not set
+439	Next date of calibration not set
+440	Calibration process not completed

Table C-2
Calibration constants returned by :CAL:PROT:DATA? Query

Constant	Description
g1	RMS gain for 2V, 200V, and 750V AC ranges
of1	RMS offset for 2V, 200V, and 750V AC ranges
g10	RMS gain for 200mV and 20V AC ranges
of10	RMS offset for 200mV and 20V AC ranges
gfwr1	Average gain for 2V, 200V, and 750V AC ranges
offwr1	Average offset for 2V, 200V, and 750V AC ranges
gfwr10	Average gain for 200mV and 20V AC ranges
offwr10	Average offset for 200mV and 20V AC ranges
a100	100:1 divider attenuation factor
a500	500:1 divider attenuation factor
ofpkpos10	Positive peak offset for 200mV AC range
ofpkneg10	Negative peak offset for 200mV AC range
ofpk1	Positive and negative peak offset for 2V, 200V, and 750V AC ranges
ofpkpos20	Positive peak offset for 20V AC range
ofpkneg20	Negative peak offset for 20V AC range
div100self	Self-calibration code for frequency compensation DAC, 100:1 divider
div500self	Self-calibration code for frequency compensation DAC, 500:1 divider
noise10	Noise factor for 200mV and 20V AC ranges
cfc1	Crest factor correction factor for 2V, 200V, and 750V AC ranges
cfc10	Crest factor correction factor for 200mV and 20V AC ranges
acdclow	AC-coupled correction factor for 200mV and 2V AC ranges
acdchigh	AC-coupled correction factor for 20V, 200V, and 750V AC ranges
inputtc	Input time constant
acdccur	AC-coupled correction factor for AC current
compval1	RMS comparator DAC code
div100	Frequency-compensation DAC code for 20V AC range
div200	Frequency-compensation DAC code for 200V AC range
div500	Frequency-compensation DAC code for 750V AC range
div100off	Frequency-compensation DAC offset for 20V AC range
div200off	Frequency compensation DAC offset for 200V AC range
div500off	Frequency compensation DAC offset for 750V AC range
dcv[200mV]gain	200mV DC gain
dcv[200mV]offset	200mV DC offset
dcv[2V]gain	2V DC gain
dcv[2V]offset	2V DC offset
dcv[20V]gain	20V DC gain
dcv[20V]offset	20V DC offset
dcv[200V]gain	200V DC gain
dcv[200V]offset	200V DC offset
dcv[1000V]gain	100V DC gain
dcv[1000V]offset	1000V DC offset
dca[200uA]gain	200µA DC gain
dca[200uA]offset	200µA DC offet
dca[2mA]gain	2mA DC gain
dca[2mA]offset	2mA DC offset
dca[20mA]gain	20mA DC gain
dca[20mA]offset	20mA DC offset
dca[200mA]gain	200mA DC gain
dca[200mA]offset	200mA DC offset
dca[2A]gain	2A DC gain
dca[2A]offset	2A DC offset

Table C-2 (continued)
Calibration constants returned by :CAL:PROT:DATA? Query

Constant	Description
ohm2[20]gain	2-wire 20¾ gain
ohm2[20]offset	2-wire 20¾ offset
ohm2[200]gain	2-wire 200¾ gain
ohm2[200]offset	2-wire 200¾ offset
ohm2[2k]gain	2-wire 2k¾ gain
ohm2[2k]offset	2-wire 2k¾ offset
ohm2[20k]gain	2-wire 20k¾ gain
ohm2[20k]offset	2-wire 20k¾ offset
ohm2[200k]gain	2-wire 200k¾ gain
ohm2[200k]offset	2-wire 200k¾ offset
ohm2[2M]gain	2-wire 2M¾ gain
ohm2[2M]offset	2-wire 2M¾ offset
ohm2[20M]gain	2-wire 20M¾ gain
ohm2[20M]offset	2-wire 20M¾ offset
ohm2[200M]gain	2-wire 200M¾ gain
ohm2[200M]offset	2-wire 200M¾ offset
ohm2[1G]gain	2-wire 1G¾ gain
ohm2[1G]offset	2-wire 1G¾ offset
ohm4[20]gain	4-wire 20¾ gain
ohm4[20]offset	4-wire 20¾ offset
ohm4[200]gain	4-wire 200¾ gain
ohm4[200]offset	4-wire 200¾ offset
ohm4[2k]gain	4-wire 2k¾ gain
ohm4[2k]offset	4-wire 2k¾ offset
ohm4[20k]gain	4-wire 20k¾ gain
ohm4[20k]offset	4-wire 20k¾ offset
ohm4[200k]gain	4-wire 200k¾ gain
ohm4[200k]offset	4-wire 200k¾ offset
n7vref	7V reference value
rollover	±2V rollover
mux4d711	Multiplexer 4-1/2 digit counts (AC peak)
mux4d711p5	Multiplexer 4-1/2 digit counts (AC peak)
mux4d215	Multiplexer 4-1/2 digit counts (AC peak)
mux4d011	Multiplexer 4-1/2 digit counts (AC peak)
mux4d015	Multiplexer 4-1/2 digit counts (AC peak)
mux4d0150	Multiplexer 4-1/2 digit counts (AC peak)
mux4d011p5	Multiplexer 4-1/2 digit counts (AC peak)
mux4dF150	Multiplexer 4-1/2 digit counts (AC peak)
mux4dF15	Multiplexer 4-1/2 digit counts (AC peak)
i20	20¾ range current source value
i200	200¾ range current source value
i2k	2k¾ range current source value
i20k	20k¾ range current source value
i200k	200k¾ range current source value
i2m	2M¾ range current source value
i20m	20M¾ range current source value
i200m	200M¾ range current source value
i1g	1G¾ range current source value

NOTE: All values are expressed in NR3 format (floating point with exponent). Constants are listed in order transmitted and are separated by commas.

D

Alternate Calibration Sources

Introduction

As stated in Sections 1 and 2, the Fluke 5700A Calibrator is the calibration source recommended for both performance verification and calibration. Table D-1 summarizes alternate calibration equipment that may be substituted for the recommended Model 5700A. Note, however, that the alternate equipment may not be as precise for certain calibration values. Refer to the manufacturers' specifications for more detailed information.

Table D-1
Alternate calibration sources

Manufacturer and Model	**Function(s)**	**Comparison to 5700A uncertainty**
Fluke 5440B Direct Voltage Calibrator	DCV	Equivalent
Fluke 5450B Resistance Calibration	Ohms	Equivalent
Fluke 5200A Precision Alternating Voltage Calibrator	ACV	Less precise
Datron 4808 Multifunction Calibrator (Options 10, 20, 30, 40, 50)	DCV, ACV, DCI, ACI, Ohms	Similar

KEITHLEY

Service Form

Model No. ____________ **Serial No.** ____________ **Date** ____________

Name and Telephone No. ____________

Company ____________

List all control settings, describe problem and check boxes that apply to problem. ____________

____

____

- o Intermittent
- o Analog output follows display
- o Particular range or function bad; specify ____________
- o IEEE failure
- o Obvious problem on power-up
- o Batteries and fuses are OK
- o Front panel operational
- o All ranges or functions are bad
- o Checked all cables

Display or output (check one)

- o Drifts
- o Unable to zero
- o Unstable
- o Will not read applied input
- o Overload

- o Calibration only
- o Certificate of calibration required
- o Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

____

____

What power line voltage is used? ____________ Ambient temperature? ____________°F

Relative humidity? ____________ Other? ____________

Any additional information. (If special modifications have been made by the user, please describe.)

____

____

Be sure to include your name and phone number on this service form.

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