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

Revision A (Document Number 2001-905-01) ................................................................. April 1992
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Revision F (Document Number 2001-905-01) ................................................................. November 2003
Revision G (Document Number 2001-905-01) ................................................................. May 2004
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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</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Mfg</th>
<th>Model</th>
<th>Description</th>
<th>Specifications*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke</td>
<td>5700A</td>
<td>Calibrator</td>
<td>±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</td>
</tr>
</tbody>
</table>
### Table 1-1 (cont.)
Recommended equipment for performance verification

<table>
<thead>
<tr>
<th>Mfg.</th>
<th>Model</th>
<th>Description</th>
<th>Specifications*</th>
</tr>
</thead>
</table>
| 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). |
| 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.
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 $2 \times 10^7$V•Hz between INPUT HI and INPUT LO, or instrument damage may occur.

**NOTE**

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

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.

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).

---

**Table 1-2**

Limits for DC volts verification

<table>
<thead>
<tr>
<th>2001 DCV range</th>
<th>Applied DC voltage</th>
<th>Reading limits (18° to 28°C, 1 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200mV</td>
<td>190.0000mV</td>
<td>189.9918mV to 190.0082mV</td>
</tr>
<tr>
<td>2V</td>
<td>1.900000V</td>
<td>1.899949V to 1.900052V</td>
</tr>
<tr>
<td>20V</td>
<td>19.00000V</td>
<td>18.99946V to 19.000054V</td>
</tr>
<tr>
<td>200V</td>
<td>190.0000V</td>
<td>189.9922V to 190.0078V</td>
</tr>
<tr>
<td>1000V</td>
<td>1000.000V</td>
<td>999.953V to 1000.047V</td>
</tr>
</tbody>
</table>

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

Model 2001

5725 Amplifier (Connect to calibrator)

5700A Calibrator (Output AC Voltage)

BNC to dual banana
50Ω terminator
50Ω Coax
Wideband output

Ground link installed.

Note: Use internal Guard (EX GRD LED is off).
### Table 1-3
Limits for normal mode AC voltage verification

<table>
<thead>
<tr>
<th>2001 ACV range</th>
<th>Applied voltage</th>
<th>Allowable readings (1 year, 18° to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20Hz</td>
</tr>
<tr>
<td>200mV</td>
<td>190mV</td>
<td>188.716mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>191.284mV to 190.315mV</td>
</tr>
<tr>
<td>2V</td>
<td>1.9V</td>
<td>1.88716V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.91284V to 1.90315V</td>
</tr>
<tr>
<td>200V</td>
<td>190V</td>
<td>188.709V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>191.291V to 190.322V</td>
</tr>
<tr>
<td>750V</td>
<td>750V</td>
<td>748.12V</td>
</tr>
</tbody>
</table>
|                 |                 | 751.88V to 751.28V | 751.51V to 751.88V | 751.51V to 751.88V | 751.51V to 751.88V | 751.51V to 751.88V | * | * | * | * | *

*CAUTION: Do not exceed $2 \times 10^7$ V 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.
Performance Verification

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 100.000mV AC 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 100mV AC at the remaining frequencies listed in the table.

9. Repeat steps 6 through 8 for the 2V, 20V, 200V, and 750V AC 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 1-4

<table>
<thead>
<tr>
<th>2001 ACV range</th>
<th>Applied voltage</th>
<th>Allowable readings (1 year, 18° to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200mV</td>
<td>190mV</td>
<td>189.837mV to 190.163mV</td>
</tr>
<tr>
<td>2V</td>
<td>1.9V</td>
<td>1.89837V to 1.90163V</td>
</tr>
<tr>
<td>20V</td>
<td>19V</td>
<td>18.9818V to 19.0182V</td>
</tr>
<tr>
<td>200V</td>
<td>190V</td>
<td>189.811V to 190.189V</td>
</tr>
<tr>
<td>750V</td>
<td>750V</td>
<td>—</td>
</tr>
</tbody>
</table>

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

---

**Table 1-5**

<table>
<thead>
<tr>
<th>ACV range</th>
<th>Applied voltage*</th>
<th>20Hz†</th>
<th>5kHz</th>
<th>25kHz</th>
<th>50kHz</th>
<th>100kHz</th>
<th>250kHz</th>
<th>500kHz</th>
<th>750kHz</th>
<th>1MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;200V</td>
<td>100mV</td>
<td>139.9mV to 142.9mV</td>
<td>139.9mV to 142.9mV</td>
<td>139.8mV to 143.0mV</td>
<td>139.6mV to 143.2mV</td>
<td>138.6mV to 144.2mV</td>
<td>136.5mV to 146.3mV</td>
<td>132.2mV to 150.6mV</td>
<td>127.3mV</td>
<td></td>
</tr>
<tr>
<td>2V</td>
<td>1V</td>
<td>1.407V to 1.421V</td>
<td>1.407V to 1.421V</td>
<td>1.406V to 1.422V</td>
<td>1.404V to 1.424V</td>
<td>1.394V to 1.434V</td>
<td>1.373V to 1.455V</td>
<td>1.330V to 1.498V</td>
<td>1.281V</td>
<td></td>
</tr>
<tr>
<td>200V</td>
<td>190V</td>
<td>267.8V to 269.6V</td>
<td>267.7V to 269.7V</td>
<td>267.6V to 270.0V</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>750V</td>
<td>750V</td>
<td>—</td>
<td>1054V to 1067V</td>
<td>1053V to 1068V</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

*Calibrator voltage is given as an RMS value. Model 2001 reading limits are peak AC values.
**CAUTION: Do not apply more than 2 × 10⁷VHz
†Use AC+DC input coupling for 20Hz tests only. (Use CONFIG-ACV to set coupling.)

NOTE: Limits shown do not include uncertainty calibrator.
Performance Verification

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.
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.

---

**Table 1-6**

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

**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.

---

Figure 1-4

Connections for DC current verification

---

5700A Calibrator (Output DC Current)

---

Model 2001

---

NOTES: Use internal Guard (EX GRD LED is off).
Table 1-7  
Limits for AC current verification

<table>
<thead>
<tr>
<th>2001 ACI range</th>
<th>Applied AC current</th>
<th>Reading limits (1 year, 18° to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>40Hz</td>
</tr>
<tr>
<td>200µA</td>
<td>190.000µA</td>
<td>188.260µA to 191.740µA</td>
</tr>
<tr>
<td>2mA</td>
<td>1.90000mA</td>
<td>1.88355mA to 1.91645mA</td>
</tr>
<tr>
<td>20mA</td>
<td>19.0000mA</td>
<td>18.8355mA to 19.1645mA</td>
</tr>
<tr>
<td>200mA</td>
<td>190.000mA</td>
<td>188.355mA to 191.645mA</td>
</tr>
<tr>
<td>2A</td>
<td>1.90000A</td>
<td>1.88250mA to 1.91750mA</td>
</tr>
</tbody>
</table>

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)**

<table>
<thead>
<tr>
<th>2001 ¾ range</th>
<th>Applied resistance</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20¾</td>
<td>19.000¾</td>
<td>18.99849¾ to 19.00151¾</td>
</tr>
<tr>
<td>200¾</td>
<td>190.000¾</td>
<td>189.9880¾ to 190.0120¾</td>
</tr>
<tr>
<td>2k¾</td>
<td>1.90000k¾</td>
<td>1.899897k¾ to 1.900103k¾</td>
</tr>
<tr>
<td>20k¾</td>
<td>19.0000k¾</td>
<td>18.99897k¾ to 19.00103k¾</td>
</tr>
<tr>
<td>200k¾</td>
<td>190.000k¾</td>
<td>189.9820k¾ to 190.0180k¾</td>
</tr>
<tr>
<td>2M¾</td>
<td>1.90000M¾</td>
<td>1.899687M¾ to 1.900313M¾</td>
</tr>
<tr>
<td>20M¾</td>
<td>19.0000M¾</td>
<td>18.98281M¾ to 19.01719M¾</td>
</tr>
<tr>
<td>200M¾</td>
<td>100.000M¾</td>
<td>97.9800M¾ to 102.0200M¾</td>
</tr>
</tbody>
</table>

**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.
Performance Verification

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 (2MΩ - 200MΩ ranges)

**Figure 1-8**  
1GΩ resistor test box construction

**Table 1-9**  
Limits for resistance verification (1GΩ range)

<table>
<thead>
<tr>
<th>Characterized resistor (R)</th>
<th>Reading limit (1 year, 18° to 28°C)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>GΩ</td>
<td>GΩ to GΩ</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Synthesizer frequency</th>
<th>Reading limits (1 year, 18° to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Hz</td>
<td>0.9997Hz to 1.0003Hz</td>
</tr>
<tr>
<td>10Hz</td>
<td>9.997Hz to 10.003Hz</td>
</tr>
<tr>
<td>100Hz</td>
<td>99.97Hz to 100.03Hz</td>
</tr>
<tr>
<td>1kHz</td>
<td>0.9997kHz to 1.0003kHz</td>
</tr>
<tr>
<td>10kHz</td>
<td>9.997kHz to 10.003kHz</td>
</tr>
<tr>
<td>100kHz</td>
<td>99.97kHz to 100.03kHz</td>
</tr>
<tr>
<td>1MHz</td>
<td>0.9997MHz to 1.0003MHz</td>
</tr>
<tr>
<td>10MHz</td>
<td>9.997MHz to 10.003MHz</td>
</tr>
<tr>
<td>15MHz</td>
<td>14.995MHz to 15.005MHz</td>
</tr>
</tbody>
</table>

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.

Table 1-11

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

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

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.
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>
<thead>
<tr>
<th>RTD probe type</th>
<th>Applied resistance</th>
<th>Displayed temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT385 (α=0.00385055)</td>
<td>64.30Ω</td>
<td>-90.08 to -89.92</td>
</tr>
<tr>
<td></td>
<td>100Ω</td>
<td>-0.08 to +0.08</td>
</tr>
<tr>
<td></td>
<td>109.73Ω</td>
<td>24.92 to 25.08</td>
</tr>
<tr>
<td></td>
<td>138.51Ω</td>
<td>99.92 to 100.08</td>
</tr>
<tr>
<td></td>
<td>313.71Ω</td>
<td>599.86 to 600.14</td>
</tr>
<tr>
<td>PT3916 (α=0.00392)</td>
<td>63.68Ω</td>
<td>-90.08 to -89.92</td>
</tr>
<tr>
<td></td>
<td>100Ω</td>
<td>-0.08 to +0.08</td>
</tr>
<tr>
<td></td>
<td>109.90Ω</td>
<td>24.92 to 25.08</td>
</tr>
<tr>
<td></td>
<td>139.16Ω</td>
<td>99.92 to 100.08</td>
</tr>
<tr>
<td></td>
<td>266.94Ω</td>
<td>449.86 to 450.14</td>
</tr>
</tbody>
</table>
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°C ± 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

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>:CALibration</td>
<td>Calibration root command.</td>
</tr>
<tr>
<td>:PROTected</td>
<td>All commands in this subsystem are protected by the CAL switch.</td>
</tr>
<tr>
<td>:LOCK</td>
<td>Lock out calibration (opposite of enabling cal with CAL switch).</td>
</tr>
<tr>
<td>:SWITch?</td>
<td>Request comprehensive CAL switch state.</td>
</tr>
<tr>
<td>:SAVE</td>
<td>Save cal constants to EEPROM.</td>
</tr>
<tr>
<td>:DATE “&lt;string&gt;”</td>
<td>Send cal date to 2001.</td>
</tr>
<tr>
<td>:NDUE “&lt;string&gt;”</td>
<td>Send next due cal date to 2001.</td>
</tr>
<tr>
<td>:LEVelf</td>
<td>Low-level calibration subsystem.</td>
</tr>
<tr>
<td>:SWITch?</td>
<td>Request low-level CAL switch state. (0 = locked; 1 = unlocked)</td>
</tr>
<tr>
<td>:STEP &lt;Step #&gt;</td>
<td>20V AC at 1kHz step.</td>
</tr>
<tr>
<td></td>
<td>20V AC at 30kHz step.</td>
</tr>
<tr>
<td></td>
<td>200V AC at 1kHz step.</td>
</tr>
<tr>
<td></td>
<td>200V AC at 30kHz</td>
</tr>
<tr>
<td></td>
<td>1.5V AC at 1kHz step.</td>
</tr>
<tr>
<td></td>
<td>0.2V AC at 1kHz step.</td>
</tr>
<tr>
<td></td>
<td>5mV AC at 100kHz step.</td>
</tr>
<tr>
<td></td>
<td>0.5mV AC at 1kHz step.</td>
</tr>
<tr>
<td></td>
<td>+2V DC step.</td>
</tr>
<tr>
<td></td>
<td>-2V DC step.</td>
</tr>
<tr>
<td></td>
<td>0V DC step.</td>
</tr>
<tr>
<td></td>
<td>20mA AC at 1kHz step.</td>
</tr>
<tr>
<td></td>
<td>+0.2A DC step.</td>
</tr>
<tr>
<td></td>
<td>+2A DC step.</td>
</tr>
<tr>
<td></td>
<td>2V AC at 1Hz step.</td>
</tr>
<tr>
<td>:CALCulate</td>
<td>Calculate low-level cal constants.</td>
</tr>
<tr>
<td>:DC</td>
<td>User calibration subsystem.</td>
</tr>
<tr>
<td>:ZERO</td>
<td>Low-thermal short calibration step.</td>
</tr>
<tr>
<td>:LOW &lt;value&gt;</td>
<td>+2V DC calibration step.</td>
</tr>
<tr>
<td>:HIGH &lt;value&gt;</td>
<td>+20V DC calibration step.</td>
</tr>
<tr>
<td>:LOHOM &lt;value&gt;</td>
<td>20kΩ calibration step.</td>
</tr>
<tr>
<td>:HOHOM &lt;value&gt;</td>
<td>1MΩ calibration step.</td>
</tr>
<tr>
<td>:OPEN</td>
<td>Open circuit calibration step.</td>
</tr>
<tr>
<td>:CALCulate</td>
<td>Calculate DC cal constants.</td>
</tr>
<tr>
<td>:UNPRotected</td>
<td>All commands in this subsystem are not protected by CAL switch.</td>
</tr>
<tr>
<td>:ACCompensation</td>
<td>Perform user AC calibration (disconnect all cables)</td>
</tr>
</tbody>
</table>

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.

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.
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.
Calibration

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>
<thead>
<tr>
<th>Error ID code</th>
<th>Error message</th>
</tr>
</thead>
<tbody>
<tr>
<td>-222</td>
<td>Parameter data out of range.</td>
</tr>
<tr>
<td>+438</td>
<td>Date of calibration not set.</td>
</tr>
<tr>
<td>+439</td>
<td>Next date of calibration not set.</td>
</tr>
<tr>
<td>+440</td>
<td>Calibration process not completed.</td>
</tr>
</tbody>
</table>

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$; ";*OPC" 'Send command to unit.
Cal: PRINT #1, "SPOLL 16" 'Check for completed cal.
INPUT #2, S 
IF (S AND 32) = 0 THEN GOTO Cal: 'Send query to unit.
GOTO Cmd 
Query: PRINT #1, "OUTPUT 16;"; A$ 
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

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

Table 2-3
Recommended equipment for comprehensive calibration

<table>
<thead>
<tr>
<th>Mfg.</th>
<th>Model</th>
<th>Description</th>
<th>Specifications*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke</td>
<td>5700A</td>
<td>Calibrator</td>
<td>±5ppm basic uncertainty. DC voltage: 2V: ±5ppm 20V: ±5ppm Resistance: 19k¾: ±11ppm 1M¾: ±18ppm</td>
</tr>
<tr>
<td>Keithley</td>
<td>8610</td>
<td>Low-thermal shorting plug</td>
<td></td>
</tr>
</tbody>
</table>

* 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

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:
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 = 20.000000
   (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 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: 20kΩ calibration

1. After completing 20kΩ calibration, the instrument will display the following:
   CONNECT 20kOHM RES
2. Set the calibrator output to 19.0000kΩ, and turn external sense on.
3. Press ENTER, and note that the Model 2001 displays the resistance calibration value:
   OHMS = 20000.000
   (At this point, you can use 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 9kΩ to 21kΩ.))
4. Press ENTER, and note that the instrument displays the following during 20kΩ calibration:
   Performing 20 kOHM Calibration

Step 6: 1MΩ calibration

1. After completing 20kΩ calibration, the instrument will display the following:
   CONNECT 1.0 MOHM RES
2. Set the calibrator output to 1.00000MΩ, and turn external sense off.
3. Press ENTER, and note that the Model 2001 displays the resistance calibration value:
   OHMS = 1000000.000
   (At this point, you can use 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 800kΩ to 2MΩ.))
4. Press ENTER, and note that the instrument displays the following during 1MΩ 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).
Calibration

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.

---

**Table 2-5**
IEEE-488 bus comprehensive calibration summary

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>IEEE-488 bus command</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Warm-up, unlock calibration</td>
<td>:CAL:PROT:DC:ZERO</td>
</tr>
<tr>
<td>2</td>
<td>DC zero calibration</td>
<td>:CAL:PROT:DC:LOW &lt;value&gt;</td>
</tr>
<tr>
<td>3</td>
<td>+2VDC calibration</td>
<td>:CAL:PROT:DC:HIGH &lt;value&gt;</td>
</tr>
<tr>
<td>4</td>
<td>+20VDC calibration</td>
<td>:CAL:PROT:DC:LOHM &lt;value&gt;</td>
</tr>
<tr>
<td>5</td>
<td>20kΩ calibration</td>
<td>:CAL:PROT:DC:HOHM &lt;value&gt;</td>
</tr>
<tr>
<td>6</td>
<td>1MΩ calibration</td>
<td>:CAL:PROT:DC:OPEN</td>
</tr>
<tr>
<td>7</td>
<td>Open-circuit calibration</td>
<td>:CAL:PROT:DC:CALC</td>
</tr>
<tr>
<td>8</td>
<td>Calculate constants</td>
<td>:SYP:ERR?</td>
</tr>
<tr>
<td>9</td>
<td>Check for errors</td>
<td>:CAL:UNPR:ACC</td>
</tr>
<tr>
<td>10</td>
<td>Perform user AC cal</td>
<td>:SYP:ERR?</td>
</tr>
<tr>
<td>11</td>
<td>Check for errors</td>
<td>:CAL:PROT:DATE “&lt;cal_date&gt;”</td>
</tr>
<tr>
<td>12</td>
<td>Save calibration dates</td>
<td>:CAL:PROT:NDUE “&lt;due_date&gt;”</td>
</tr>
<tr>
<td>13</td>
<td>Save calibration constants</td>
<td>:CAL:PROT:DC:SAVE</td>
</tr>
<tr>
<td>14</td>
<td>Lock out calibration</td>
<td>:CAL:PROT:LOCK</td>
</tr>
</tbody>
</table>
Calibration

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: 20kΩ calibration

1. Set the calibrator output to 19.0000kΩ, and turn external sense on.
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 18.9987kΩ, 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 20kΩ calibration before continuing.

Step 6: 1MΩ calibration

1. Set the calibrator output to 1.0000MΩ, 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 1.00023MΩ, 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 1MΩ 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.

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.

Table 2-6
Recommended equipment for low-level calibration

<table>
<thead>
<tr>
<th>Mfg.</th>
<th>Model</th>
<th>Description</th>
<th>Specifications*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke</td>
<td>5700A</td>
<td>Calibrator</td>
<td>±5ppm basic uncertainty. DC voltage: 0V: ±0.75µV, -2V, +2V: ±5ppm, 20V: ±5ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DC current: 200mA: ±65ppm, 2A: ±90ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AC voltage: 0.5mV @ 1kHz: ±10000ppm, 5mV @ 100kHz: ±2400ppm, 200mV @ 1kHz: ±150ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.5V @ 1kHz: ±80ppm, 20V @ 1kHz: ±80ppm, 20V @ 30kHz: ±140ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200V @ 1kHz: ±85ppm, 200V @ 30kHz: ±240ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AC current: 20mA @ 1kHz: ±160ppm</td>
</tr>
<tr>
<td>Keithley</td>
<td>3930A</td>
<td>Synthesizer</td>
<td>2V rms @ 1Hz</td>
</tr>
<tr>
<td>Keithley</td>
<td>8610</td>
<td>Low-thermal shorting plug</td>
<td></td>
</tr>
</tbody>
</table>

* 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.

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 2-7
Low-level calibration summary

<table>
<thead>
<tr>
<th>Calibration signal</th>
<th>Calibration command</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2V DC</td>
<td>:CAL:PROT:DC:LOW &lt;value&gt;</td>
<td>Comprehensive cal 2V.</td>
</tr>
<tr>
<td>+20V DC</td>
<td>:CAL:PROT:DC:HIGH &lt;value&gt;</td>
<td>Comprehensive cal 20V.</td>
</tr>
<tr>
<td>20kΩ</td>
<td>:CAL:PROT:DC:LOHM &lt;value&gt;</td>
<td>Comprehensive cal 20kΩ.</td>
</tr>
<tr>
<td>1MΩ</td>
<td>:CAL:PROT:DC:HOHM &lt;value&gt;</td>
<td>Comprehensive cal 1MΩ.</td>
</tr>
<tr>
<td>None</td>
<td>:CAL:PROT:DC:CALC</td>
<td>Calculate constants.</td>
</tr>
<tr>
<td>None</td>
<td>:SYST:ERR?</td>
<td>Check for DC errors.</td>
</tr>
<tr>
<td>None</td>
<td>:CAL:UNPR:ACC</td>
<td>AC user calibration.</td>
</tr>
<tr>
<td>None</td>
<td>:SYST:ERR?</td>
<td>Check for AC errors.</td>
</tr>
<tr>
<td>20V AC @ 1kHz</td>
<td>:CAL:PROT:LLEV:STEP 1</td>
<td>Low-level Step 1.</td>
</tr>
<tr>
<td>20V AC @ 30kHz</td>
<td>:CAL:PROT:LLEV:STEP 2</td>
<td>Low-level Step 2.</td>
</tr>
<tr>
<td>200V AC @ 1kHz</td>
<td>:CAL:PROT:LLEV:STEP 3</td>
<td>Low-level Step 3.</td>
</tr>
<tr>
<td>200V AC @ 30kHz</td>
<td>:CAL:PROT:LLEV:STEP 4</td>
<td>Low-level Step 4.</td>
</tr>
<tr>
<td>1.5V AC @ 1kHz</td>
<td>:CAL:PROT:LLEV:STEP 5</td>
<td>Low-level Step 5.</td>
</tr>
<tr>
<td>200mA AC @ 1kHz</td>
<td>:CAL:PROT:LLEV:STEP 6</td>
<td>Low-level Step 6.</td>
</tr>
<tr>
<td>5mA AC @ 100kHz</td>
<td>:CAL:PROT:LLEV:STEP 7</td>
<td>Low-level Step 7.</td>
</tr>
<tr>
<td>0.5mA AC @ 1kHz</td>
<td>:CAL:PROT:LLEV:STEP 8</td>
<td>Low-level Step 8.</td>
</tr>
<tr>
<td>0V DC</td>
<td>:CAL:PROT:LLEV:STEP 11</td>
<td>Low-level Step 11.</td>
</tr>
<tr>
<td>20mA AC @ 1kHz</td>
<td>:CAL:PROT:DATE “&lt;date&gt;”</td>
<td>Program cal date.</td>
</tr>
<tr>
<td>+200mA DC</td>
<td>:CAL:PROT:DATE “&lt;date&gt;”</td>
<td>Program cal due date.</td>
</tr>
<tr>
<td>+2A DC</td>
<td>:CAL:PROT:DATE “&lt;date&gt;”</td>
<td>Save constants.</td>
</tr>
<tr>
<td>2V rms @ 1Hz</td>
<td>:CAL:PROT:LLEV:CALC</td>
<td>Calculate constants.</td>
</tr>
<tr>
<td>None</td>
<td>:SYST:ERR?</td>
<td>Check for errors.</td>
</tr>
<tr>
<td>None</td>
<td>:CAL:PROT:DATE “&lt;date&gt;”</td>
<td>Program cal date.</td>
</tr>
<tr>
<td>None</td>
<td>:CAL:PROT:SAVE</td>
<td>Save constants.</td>
</tr>
<tr>
<td>None</td>
<td>:CAL:PROT:LOCK</td>
<td>Lock out calibration.</td>
</tr>
</tbody>
</table>
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 19.00000kΩ, and turn external sense on. (Allowable range is from 9kΩ to 20kΩ.)
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 20kΩ calibration:
   Performing 20 kOHM Calibration
22. After completing 20kΩ calibration, the instrument will display the following:
   CONNECT 1.0 MOHM RES
23. Set the calibrator output to 1.00000MΩ, and turn external sense off. (Allowable range is 800kΩ to 2MΩ.)
24. Press ENTER, and note that the Model 2001 displays the resistance calibration value:
   OHMS = 100000.00
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 1MΩ 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 the ENTER key. 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

![Model 2001](image)

**Figure 2-4**

*Current calibration connections*

---

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

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 19.0000kΩ, 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 18.9987kΩ, the command would appear as follows:

    :CAL:PROT:DC:LOHM 18.9987E3

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

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

12. Set the calibrator output to 1.0000MΩ, 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 1.00023MΩ, the command would appear as follows:

    :CAL:PROT:DC:HOHM 1.00023E6

    Wait until the Model 2001 finishes 1MΩ 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
3.1 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

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

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

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?**

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

```
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

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

**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

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>:LOW &lt;value&gt;</td>
<td>Low-thermal short calibration step.</td>
</tr>
<tr>
<td>:HIGH &lt;value&gt;</td>
<td>+20V DC calibration step.</td>
</tr>
<tr>
<td>:LOHM &lt;value&gt;</td>
<td>20kΩ calibration step.</td>
</tr>
<tr>
<td>:HOHM &lt;value&gt;</td>
<td>1MΩ calibration step.</td>
</tr>
<tr>
<td>:OPEN</td>
<td>Open circuit calibration step.</td>
</tr>
<tr>
<td>Calculate</td>
<td>DC cal constants.</td>
</tr>
</tbody>
</table>

: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  

: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**

**:LOHM**

(CALibration:PROTected:DC):LOHM

**Purpose**
To program the 20kΩ comprehensive calibration step.

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

**Parameters**
<Cal_resistance> = 9E3 to 20E3 [Ω]

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

**Programming example**
10  OUTPUT 716; “:CAL:PROT:DC:LOHM 19E3”! Program 19kΩ.

**:HOHM**

(CALibration:PROTected:DC):HOHM

**Purpose**
To program the 1MΩ comprehensive calibration step.

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

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

**Description**
:HOHM programs the 1MΩ comprehensive calibration step. The resistance parameter can be programmed for any value from 800kΩ (800E3) to 2MΩ (2E6). Use the 1MΩ 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 1MΩ 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; "CALC" ! Calculate new constants.
3.4  CALibration:UNPRotected Subsystem

3.3.11  ACCompensation

$\text{:CALibration:UNPRotected}:\text{ACCompensation}$

**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.

Table 3-4

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

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.

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.
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.
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

<table>
<thead>
<tr>
<th>MEASUREMENT FUNCTION</th>
<th>24 HOUR</th>
<th>90 DAY</th>
<th>1 YEAR</th>
<th>2 YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Volts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC Volts Peak Spikes</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>AC Volts rms</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>AC Volts Peak</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>AC Volts Average</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>AC Volts Crest Factor</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>Ohms</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>DC Current</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>DC In-Circuit Current</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>AC Current</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>Frequency</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>Temperature (Thermocouple)</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
<tr>
<td>Temperature (RTD)</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
<td>±0.1%</td>
</tr>
</tbody>
</table>

1 For TCAL ±1°C.
2 For TCAL ±5°C.
3 For ±2°C of last AC self cal.
**DC VOLTS**

**DCV INPUT CHARACTERISTICS AND ACCURACY**

<table>
<thead>
<tr>
<th>RANGE</th>
<th>FULL SCALE</th>
<th>RESOLUTION</th>
<th>DEFAULT RESOLUTION</th>
<th>INPUT RESISTANCE</th>
<th>ACCURACY*</th>
<th>TEMPERATURE COEFFICIENT</th>
<th>DCV READING RATES5,10</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mV</td>
<td>±210.00000</td>
<td>10 nV</td>
<td>100 nV &gt;10 kΩ</td>
<td>10 MΩ ±1%</td>
<td>±0.1%</td>
<td>2 ppm/°C</td>
<td>0.2 counts/s, 200 ms</td>
</tr>
<tr>
<td>2 V</td>
<td>±2100000</td>
<td>100 nV</td>
<td>1 kΩ &gt;100 kΩ</td>
<td>10 MΩ ±1%</td>
<td>±0.1%</td>
<td>2 ppm/°C</td>
<td>0.2 counts/s, 200 ms</td>
</tr>
<tr>
<td>20 V</td>
<td>±2100000</td>
<td>100 nV</td>
<td>1 kΩ &gt;100 kΩ</td>
<td>10 MΩ ±1%</td>
<td>±0.1%</td>
<td>2 ppm/°C</td>
<td>0.2 counts/s, 200 ms</td>
</tr>
<tr>
<td>200 V</td>
<td>±21000000</td>
<td>1000 nV</td>
<td>10 kΩ &gt;1000 kΩ</td>
<td>100 MΩ ±1%</td>
<td>±0.1%</td>
<td>2 ppm/°C</td>
<td>0.2 counts/s, 200 ms</td>
</tr>
</tbody>
</table>

**SPEED AND ACCURACY**

For TCAL following 55-minute warm-up. Specifications include factory traceability to US NIST.

**Noise Rejection (dB)**

<table>
<thead>
<tr>
<th>SPEED (Number of Power Line Cycles)</th>
<th>AC and DC CMRR4</th>
<th>AC NMRRC</th>
<th>RC LNC</th>
<th>RC MNRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PLC DFILT On</td>
<td>1 PLC DFILT Off</td>
<td>0.1 PLC DFILT Off</td>
<td>0.01 PLC DFILT Off</td>
<td></td>
</tr>
<tr>
<td>NPLC = 10</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>NPLC = 1</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>NPLC &lt; 1</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

**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 6 1/2 digits, 10 power line cycles, 10 reading digital filter.

**Input Bias Current:** ≤100 pA at 25°C

**Linearity:** ≤1 ppm of range typical, ≤2 ppm maximum

**Auto-ranging:** Auto ranges up to 10% range, down at 10% of range.

---

1. Specifications are for 1 power line cycle, Auto Zero on, 10 reading digital filter, except as noted.
2. For Tref ±1°C, following 55 minute warm-up. Tref = ambient temperature at calibration, which is 23°C from factory.
3. For Tref ±1°C, following 55 minute warm-up. Specifications include factory traceability to US NIST.
4. When properly zeroed using REL function.
5. For Tref ±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 1kHz 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.
### DCV Peak Spikes Measurement

#### Repetitive Spikes Accuracy

<table>
<thead>
<tr>
<th>Range</th>
<th>1kHz-10kHz</th>
<th>10kHz-30kHz</th>
<th>30kHz-50kHz</th>
<th>50kHz-100kHz</th>
<th>100kHz-300kHz</th>
<th>300kHz-500kHz</th>
<th>500kHz-750kHz</th>
<th>750kHz-1MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mV</td>
<td>0.08±0.7</td>
<td>0.08±0.7</td>
<td>0.1±0.7</td>
<td>0.15±0.7</td>
<td>0.25±0.7</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>2 V</td>
<td>0.08±0.3</td>
<td>0.08±0.3</td>
<td>0.1±0.3</td>
<td>0.15±0.3</td>
<td>0.25±0.3</td>
<td>1.0±0.3</td>
<td>2.5±0.3</td>
<td>5.5±0.3</td>
</tr>
<tr>
<td>20 V</td>
<td>0.09±0.7</td>
<td>0.1±0.7</td>
<td>0.12±0.7</td>
<td>0.17±0.7</td>
<td>0.25±0.7</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>200 V</td>
<td>0.09±0.3</td>
<td>0.1±0.3</td>
<td>0.12±0.3</td>
<td>0.17±0.3</td>
<td>0.25±0.3</td>
<td>1.0±0.3</td>
<td>2.5±0.3</td>
<td>5.5±0.3</td>
</tr>
<tr>
<td>1000 V</td>
<td>0.1±0.6</td>
<td>0.13±0.6</td>
<td>0.16±0.6</td>
<td>0.25±0.6</td>
<td>0.5±0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Max. % of Range: ±125% ±125% ±125% ±125% ±125% ±125% ±100% ±75%

#### Non-Repetitive Spikes

<table>
<thead>
<tr>
<th>Range</th>
<th>1kHz-10kHz</th>
<th>10kHz-30kHz</th>
<th>30kHz-50kHz</th>
<th>50kHz-100kHz</th>
<th>100kHz-300kHz</th>
<th>300kHz-500kHz</th>
<th>500kHz-750kHz</th>
<th>750kHz-1MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mV</td>
<td>0.08±0.7</td>
<td>0.09±0.7</td>
<td>0.1±0.7</td>
<td>0.15±0.7</td>
<td>0.25±0.7</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>2 V</td>
<td>0.08±0.3</td>
<td>0.09±0.3</td>
<td>0.1±0.3</td>
<td>0.15±0.3</td>
<td>0.25±0.3</td>
<td>1.0±0.3</td>
<td>2.5±0.3</td>
<td>5.5±0.3</td>
</tr>
<tr>
<td>20 V</td>
<td>0.09±0.7</td>
<td>0.1±0.7</td>
<td>0.12±0.7</td>
<td>0.17±0.7</td>
<td>0.25±0.7</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>200 V</td>
<td>0.09±0.3</td>
<td>0.1±0.3</td>
<td>0.12±0.3</td>
<td>0.17±0.3</td>
<td>0.25±0.3</td>
<td>1.0±0.3</td>
<td>2.5±0.3</td>
<td>5.5±0.3</td>
</tr>
<tr>
<td>1000 V</td>
<td>0.1±0.6</td>
<td>0.13±0.6</td>
<td>0.16±0.6</td>
<td>0.25±0.6</td>
<td>0.5±0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Max. % of Range: ±125% ±125% ±125% ±125% ±125% ±125% ±100% ±75%

### AC Volts

**AC Voltage Uncertainty:** = (% of reading) × (measured value) + (% of range) × (range used) / 100.

**PPM Accuracy:** (% of reading) × 10,000.

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

#### ACV Input Characteristics

<table>
<thead>
<tr>
<th>Range</th>
<th>PEAK INPUT</th>
<th>FULL SCALE</th>
<th>RESOLUTION</th>
<th>DEFAULT RESOLUTION</th>
<th>IMPEDANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mV</td>
<td>1 V</td>
<td>210.0000</td>
<td>100 nV</td>
<td>1 μV</td>
<td>1MΩ</td>
</tr>
<tr>
<td>2 V</td>
<td>8 V</td>
<td>210.0000</td>
<td>1 μV</td>
<td>10 μV</td>
<td>1MΩ</td>
</tr>
<tr>
<td>20 V</td>
<td>100 V</td>
<td>210.0000</td>
<td>100 μV</td>
<td>1 μV</td>
<td>1MΩ</td>
</tr>
<tr>
<td>200 V</td>
<td>800 V</td>
<td>210.0000</td>
<td>1000 μV</td>
<td>1 μV</td>
<td>1MΩ</td>
</tr>
<tr>
<td>750 V</td>
<td>775.000 Ω</td>
<td>1 mV</td>
<td>10 mV</td>
<td>1MΩ ±2% &lt;400Ω</td>
<td>0.004 ± 0.001</td>
</tr>
</tbody>
</table>

#### Temperature Coefficient

<table>
<thead>
<tr>
<th>Temperature Coefficient</th>
<th>±(% of reading + % of range)/°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside TCAL ±5°C</td>
<td>0.002 ± 0.003</td>
</tr>
</tbody>
</table>

**Default Measurement Resolution:** 3½ digits.

**AC Voltage Range:** 1–10Hz, 10–50Hz, 50–100Hz, 100–200kHz, 0.2–1MHz, 1–2MHz

### Non-Repetitive Spikes

**Specifications apply for spikes ≥1μs.**

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

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

**DCV Peak Spikes Accuracy**

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 × (VIN/100V)² additional uncertainty for inputs above 100V.
4. Specifications assume AC-DC coupling for frequencies below 200kHz. Below 20kHz add 0.1% of reading additional uncertainty.
AC VOLTS (cont’d)

**NORMAL MODE RMS**

<table>
<thead>
<tr>
<th>RANGE</th>
<th>20–50Hz</th>
<th>50–100Hz</th>
<th>0.1–2kHz</th>
<th>2–10kHz</th>
<th>10–30kHz</th>
<th>30–50kHz</th>
<th>50–100kHz</th>
<th>100–200kHz</th>
<th>0.2–1MHz</th>
<th>1–2MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mV</td>
<td>0.25±0.015</td>
<td>0.07±0.015</td>
<td>0.03±0.015</td>
<td>0.03±0.015</td>
<td>0.05±0.015</td>
<td>0.05±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>2±0.1</td>
<td>5±0.2</td>
</tr>
<tr>
<td>2 V</td>
<td>0.25±0.015</td>
<td>0.07±0.015</td>
<td>0.03±0.015</td>
<td>0.03±0.015</td>
<td>0.05±0.015</td>
<td>0.05±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>2±0.1</td>
<td>5±0.2</td>
</tr>
<tr>
<td>20 V</td>
<td>0.25±0.015</td>
<td>0.07±0.015</td>
<td>0.04±0.015</td>
<td>0.06±0.015</td>
<td>0.08±0.015</td>
<td>0.1±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>4±0.2</td>
<td>7±0.2</td>
</tr>
<tr>
<td>200 V^1</td>
<td>0.25±0.015</td>
<td>0.07±0.015</td>
<td>0.04±0.015</td>
<td>0.06±0.015</td>
<td>0.08±0.015</td>
<td>0.12±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>4±0.2</td>
<td>7±0.2</td>
</tr>
<tr>
<td>750 V^1</td>
<td>0.27±0.015</td>
<td>0.1±0.015</td>
<td>0.08±0.015</td>
<td>0.09±0.015</td>
<td>0.12±0.015</td>
<td>0.15±0.015</td>
<td>0.5±0.015</td>
<td>0.5±0.015</td>
<td>4±0.2</td>
<td>7±0.2</td>
</tr>
</tbody>
</table>

**NORMAL MODE RMS**

<table>
<thead>
<tr>
<th>RANGE</th>
<th>20–50Hz</th>
<th>50–100Hz</th>
<th>0.1–2kHz</th>
<th>2–10kHz</th>
<th>10–30kHz</th>
<th>30–50kHz</th>
<th>50–100kHz</th>
<th>100–200kHz</th>
<th>0.2–1MHz</th>
<th>1–2MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mV</td>
<td>0.25±0.015</td>
<td>0.08±0.015</td>
<td>0.05±0.015</td>
<td>0.05±0.015</td>
<td>0.05±0.015</td>
<td>0.06±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>2±0.1</td>
<td>5±0.2</td>
</tr>
<tr>
<td>2 V</td>
<td>0.25±0.015</td>
<td>0.08±0.015</td>
<td>0.05±0.015</td>
<td>0.05±0.015</td>
<td>0.05±0.015</td>
<td>0.06±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>2±0.1</td>
<td>5±0.2</td>
</tr>
<tr>
<td>20 V</td>
<td>0.25±0.015</td>
<td>0.08±0.015</td>
<td>0.06±0.015</td>
<td>0.08±0.015</td>
<td>0.12±0.015</td>
<td>0.13±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>4±0.2</td>
<td>7±0.2</td>
</tr>
<tr>
<td>200 V^1</td>
<td>0.25±0.015</td>
<td>0.08±0.015</td>
<td>0.06±0.015</td>
<td>0.08±0.015</td>
<td>0.12±0.015</td>
<td>0.13±0.015</td>
<td>0.17±0.015</td>
<td>0.5±0.025</td>
<td>4±0.2</td>
<td>7±0.2</td>
</tr>
<tr>
<td>750 V^1</td>
<td>0.27±0.015</td>
<td>0.11±0.015</td>
<td>0.1±0.015</td>
<td>0.13±0.015</td>
<td>0.18±0.015</td>
<td>0.22±0.015</td>
<td>0.5±0.015</td>
<td>0.5±0.015</td>
<td>4±0.2</td>
<td>7±0.2</td>
</tr>
</tbody>
</table>

**dB ACCURACY RMS**

<table>
<thead>
<tr>
<th>INPUT</th>
<th>-54 to 40 dB</th>
<th>40 to 34 dB</th>
<th>6 to 26 dB</th>
<th>26 to 46 dB</th>
<th>46 to 57.8 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>-54 to 40 dB</td>
<td>0.230</td>
<td>0.036</td>
<td>0.023</td>
<td>0.024</td>
<td>0.018</td>
</tr>
<tr>
<td>-40 to 34 dB</td>
<td>0.225</td>
<td>0.031</td>
<td>0.018</td>
<td>0.024</td>
<td>0.021</td>
</tr>
<tr>
<td>6 to 26 dB</td>
<td>0.236</td>
<td>0.041</td>
<td>0.028</td>
<td>0.028</td>
<td>0.049</td>
</tr>
<tr>
<td>26 to 46 dB</td>
<td>0.355</td>
<td>0.068</td>
<td>0.066</td>
<td>0.066</td>
<td>0.538</td>
</tr>
<tr>
<td>46 to 57.8 dB</td>
<td>0.538</td>
<td>0.538^b</td>
<td>0.350</td>
<td>0.350</td>
<td>0.538</td>
</tr>
</tbody>
</table>

**ACV READING RATES**

<table>
<thead>
<tr>
<th>NPLC</th>
<th>APERTURE (200 ms)</th>
<th>DEFAULT DIGITS</th>
<th>READINGS/SECONDS TO MEMORY</th>
<th>READINGS/SECONDS TO IEEE-488</th>
<th>READINGS/SECONDS WITH TIME STAMP TO IEEE-488</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>167 ms (200 ms)</td>
<td>26</td>
<td>64</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>33.4 ms (40 ms)</td>
<td>26</td>
<td>5</td>
<td>30</td>
<td>2 (2.6)</td>
</tr>
<tr>
<td>1</td>
<td>16.7 ms (20 ms)</td>
<td>25</td>
<td>5</td>
<td>57</td>
<td>38 (35)</td>
</tr>
<tr>
<td>0.1</td>
<td>1.67 ms (2 ms)</td>
<td>21</td>
<td>5</td>
<td>136</td>
<td>70 (70)</td>
</tr>
<tr>
<td>0.01</td>
<td>167 μs (167 μs)</td>
<td>16</td>
<td>4</td>
<td>140</td>
<td>71 (71)</td>
</tr>
</tbody>
</table>

**ACV PEAK VALUE MEASUREMENT**

<table>
<thead>
<tr>
<th>RANGE</th>
<th>20–100Hz</th>
<th>1kHz–10kHz</th>
<th>10kHz–30kHz</th>
<th>30kHz–50kHz</th>
<th>50kHz–100kHz</th>
<th>100kHz–500kHz</th>
<th>500kHz–750kHz</th>
<th>750kHz–1MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mV</td>
<td>0.08±0.07</td>
<td>0.09±0.07</td>
<td>0.1±0.07</td>
<td>0.15±0.07</td>
<td>0.25±0.07</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>2 V</td>
<td>0.08±0.03</td>
<td>0.09±0.03</td>
<td>0.1±0.03</td>
<td>0.15±0.03</td>
<td>0.25±0.03</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>20 V</td>
<td>0.1±0.07</td>
<td>0.11±0.07</td>
<td>0.14±0.07</td>
<td>0.19±0.07</td>
<td>0.25±0.07</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>200 V^4</td>
<td>0.1±0.03</td>
<td>0.11±0.03</td>
<td>0.14±0.03</td>
<td>0.19±0.03</td>
<td>0.25±0.03</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
<tr>
<td>750 V^4</td>
<td>0.12±0.06</td>
<td>0.16±0.06</td>
<td>0.2±0.06</td>
<td>0.25±0.06</td>
<td>0.5±0.06</td>
<td>1.0±0.7</td>
<td>2.5±0.7</td>
<td>5.5±0.7</td>
</tr>
</tbody>
</table>

**ACV CREST FACTOR MEASUREMENT**

<table>
<thead>
<tr>
<th>CREST FACTOR</th>
<th>Peak AC / rms AC.</th>
</tr>
</thead>
</table>

**ACV CREST FACTOR ADDITIONAL ERROR**

<table>
<thead>
<tr>
<th>ADDITIONAL ERROR</th>
<th>(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**ACV PEAK VALUE MEASUREMENT**

**REPEATITIVE PEAK ACCURACY**

<table>
<thead>
<tr>
<th>TEMPERATURE COEFFICIENT</th>
<th>± (% of reading + % of range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02±0.03</td>
<td>3–4</td>
</tr>
<tr>
<td>0.04±0.03</td>
<td>4–5</td>
</tr>
</tbody>
</table>

**ACV PEAK VALUE MEASUREMENT**

**REPEATITIVE PEAK ACCURACY**

**TEMPERATURE COEFFICIENT**

<table>
<thead>
<tr>
<th>TEMPERATURE COEFFICIENT</th>
<th>± (% of reading + % of range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02±0.03</td>
<td>3–4</td>
</tr>
<tr>
<td>0.04±0.03</td>
<td>4–5</td>
</tr>
</tbody>
</table>
AC VOLTS (cont’d)

SETTING CHARACTERISTICS:
Normal Mode (rms, avg.)
<300ms to 1% of step change
<150ms to 0.1% of step change
<50ms 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-Η PRODUCT: 2 × 10¹² Η 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 per °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 × (Vin/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, 5. Typical values.
7. For range 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)

<table>
<thead>
<tr>
<th>RANGE</th>
<th>FULL SCALE</th>
<th>RESOLUTION</th>
<th>DEFAULT RESOLUTION</th>
<th>CURRENT SOURCE</th>
<th>OPEN CIRCUIT1²</th>
<th>MAXIMUM LEAD RESISTANCE2</th>
<th>MAXIMUM OFFSET COMPENSATION3</th>
<th>TEMPERATURE COEFFICIENT ± (ppm of reading + ppm of range) °C</th>
<th>Outside TCAL ± °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Ω</td>
<td>21.000000</td>
<td>1 μΩ</td>
<td>10 μΩ</td>
<td>9.2 mA</td>
<td>5 V</td>
<td>1.7 Ω</td>
<td>±0.2 V</td>
<td>8 + 1.5</td>
<td>8 + 1.5</td>
</tr>
<tr>
<td>200 Ω</td>
<td>210.00000</td>
<td>10 μΩ</td>
<td>100 μΩ</td>
<td>0.98 mA</td>
<td>5 V</td>
<td>12 Ω</td>
<td>±0.2 V</td>
<td>4 + 1.5</td>
<td>4 + 1.5</td>
</tr>
<tr>
<td>2 kΩ</td>
<td>2100.000</td>
<td>100 μΩ</td>
<td>1 μΩ</td>
<td>0.98 mA</td>
<td>5 V</td>
<td>100 Ω</td>
<td>-0.2 V to +2 V</td>
<td>2.5 + 0.2</td>
<td>2.5 + 0.2</td>
</tr>
<tr>
<td>20 kΩ</td>
<td>21000.000</td>
<td>100 μΩ</td>
<td>10 mΩ</td>
<td>89 μA</td>
<td>5 V</td>
<td>1.5 kΩ</td>
<td>-0.2 V to +2 V</td>
<td>4 + 0.2</td>
<td>4 + 0.2</td>
</tr>
<tr>
<td>200 kΩ</td>
<td>210000.000</td>
<td>100 μΩ</td>
<td>100 mΩ</td>
<td>7 μA</td>
<td>5 V</td>
<td>1.5 kΩ</td>
<td>770 nA</td>
<td>11 + 0.2</td>
<td>11 + 0.2</td>
</tr>
<tr>
<td>2 MΩ</td>
<td>2100000.000</td>
<td>100 μΩ</td>
<td>770 nA</td>
<td>1 kΩ</td>
<td>5 V</td>
<td>1.5 kΩ</td>
<td>250 nA</td>
<td>250 + 0.2</td>
<td>250 + 0.2</td>
</tr>
<tr>
<td>20 MΩ</td>
<td>21000000.000</td>
<td>100 μΩ</td>
<td>3000 nA</td>
<td>1 kΩ</td>
<td>5 V</td>
<td>1.5 kΩ</td>
<td>1100 nA</td>
<td>4000 + 10</td>
<td>4000 + 10</td>
</tr>
<tr>
<td>1 GΩ</td>
<td>1.050000000</td>
<td>100 μΩ</td>
<td>30000 nA</td>
<td>1 kΩ</td>
<td>5 V</td>
<td>1.5 kΩ</td>
<td>40000 nA</td>
<td>40000 +10</td>
<td>40000 +10</td>
</tr>
</tbody>
</table>

MAXIMUM LEAD RESISTANCE ± (ppm of reading + ppm of range) °C
Outside TCAL ± °C

SPEED AND ACCURACY 90 Days

ACCURACY ± (ppm of reading + ppm of range + ppm of range rms noise)°C

<table>
<thead>
<tr>
<th>RANGE</th>
<th>1PLC</th>
<th>0.1PLC11</th>
<th>0.01PLC11</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Ω</td>
<td>52+ 740.6</td>
<td>52+ 30+10</td>
<td>110+200+ 35</td>
</tr>
<tr>
<td>200 Ω</td>
<td>36+ 740.6</td>
<td>36+ 30+10</td>
<td>110+200+ 35</td>
</tr>
<tr>
<td>2 kΩ</td>
<td>33+ 440.2</td>
<td>33+ 24+ 1</td>
<td>130+240+ 5</td>
</tr>
<tr>
<td>20 kΩ</td>
<td>32+ 440.2</td>
<td>32+ 24+ 2</td>
<td>130+240+ 5</td>
</tr>
<tr>
<td>200 kΩ</td>
<td>72+ 45.0</td>
<td>72+ 25+ 4</td>
<td>150+300+ 10</td>
</tr>
<tr>
<td>2 MΩ</td>
<td>110+ 4.5</td>
<td>110+ 25+ 15</td>
<td>150+300+150</td>
</tr>
<tr>
<td>20 MΩ</td>
<td>560+ 4.5</td>
<td>560+ 30+20</td>
<td>560+300+150</td>
</tr>
<tr>
<td>200 MΩ</td>
<td>10000+100+40</td>
<td>10000+120+80</td>
<td>10000+700+250</td>
</tr>
<tr>
<td>1 GΩ</td>
<td>20000+100+40</td>
<td>20000+120+80</td>
<td>20000+700+250</td>
</tr>
</tbody>
</table>

PLC = Power Line Cycles. DFILT = Digital Filter.

SETTLING CHARACTERISTICS: For first reading following step change, add the total 90-day measurement error for the present range. Pre-programmed settling delay times 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 – 2kΩ 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 RATES10,12

<table>
<thead>
<tr>
<th>NPLC</th>
<th>MEASUREMENT APERTURE</th>
<th>BITS</th>
<th>DEFAULT DIGITS</th>
<th>READINGS/SECOND TO MEMORY</th>
<th>READINGS/SECOND TO IEEE-488</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>167 ms (200 ms)</td>
<td>28</td>
<td>7½</td>
<td>6 (5.1)</td>
<td>5 (4)</td>
</tr>
<tr>
<td>2</td>
<td>33.4 ms (40 ms)</td>
<td>26</td>
<td>7½</td>
<td>30 (25)</td>
<td>28 (23)</td>
</tr>
<tr>
<td>1</td>
<td>16.7 ms (20 ms)</td>
<td>25</td>
<td>6½</td>
<td>58 (48)</td>
<td>53 (45)</td>
</tr>
</tbody>
</table>

| DCI INPUT CHARACTERISTICS AND ACCURACY |

<table>
<thead>
<tr>
<th>RANGE</th>
<th>FULL SCALE</th>
<th>RESOLUTION</th>
<th>MAXIMUM BURDEN VOLTAGE</th>
<th>MEASUREMENT APERTURE</th>
<th>BITS</th>
<th>DEFAULT DIGITS</th>
<th>READINGS/SECOND TO MEMORY</th>
<th>READINGS/SECOND TO IEEE-488</th>
</tr>
</thead>
</table>

DC AMPS

| DCI INPUT CHARACTERISTICS AND ACCURACY |

<table>
<thead>
<tr>
<th>RANGE</th>
<th>FULL SCALE</th>
<th>RESOLUTION</th>
<th>MAXIMUM BURDEN VOLTAGE</th>
<th>MEASUREMENT APERTURE</th>
<th>BITS</th>
<th>DEFAULT DIGITS</th>
<th>READINGS/SECOND TO MEMORY</th>
<th>READINGS/SECOND TO IEEE-488</th>
</tr>
</thead>
</table>

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 range resistance 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 20kΩ ranges).

6. For TCAL ±5°C, following 55 minute warm-up; TCAL is ambient temperature at calibration temperature (25°C at factory).

7. For TCAL ±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 TCAL ±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 10% 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 (cont’d)**

### SPEED AND ACCURACY

<table>
<thead>
<tr>
<th>RANGE</th>
<th>± (ppm of reading + ppm of range + ppm of range rms noise)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PLC</td>
<td>DFILT Off 300+25+0.3 300+200+80</td>
</tr>
<tr>
<td>0.1 PLC</td>
<td>DFILT Off 300+45+8 300+200+80</td>
</tr>
<tr>
<td>0.01 PLC</td>
<td>DFILT Off 300+200+80</td>
</tr>
<tr>
<td>200 µA</td>
<td>300+25+0.3 300+200+80</td>
</tr>
<tr>
<td>2 mA</td>
<td>300+200+0.3 300+200+80</td>
</tr>
<tr>
<td>20 mA</td>
<td>300+200+0.3 300+200+80</td>
</tr>
<tr>
<td>200 mA</td>
<td>300+200+0.3 300+200+80</td>
</tr>
<tr>
<td>2 A</td>
<td>600+20+0.3 600+200+80</td>
</tr>
</tbody>
</table>

PLC = Power Line Cycle. DFILT = Digital Filter.

### ACCURACY

- 90 Days
- TCAL = ±5°C
- Specifications include traceability to US NIST.

### SETTLING CHARACTERISTICS

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

### OVERLOAD PROTECTION

- Maximum Allowable Input: 2.1A, 250V.
- 2A fuse (250V), accessible from front (for front input) and rear (for rear input).

### 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.

### TYPICAL RANGES:

- Current: 100µA to 12A
- Trace Resistance: 1Ω to 10Ω typical
- Voltage: ±200mV max across trace
- Speed: 4 measurements/second at 1 power line cycle
- Accuracy: ±(5% + 2 counts).

### AC AMPS

- AC magnitude: RMS or Average.

### ACI INPUT CHARACTERISTICS

<table>
<thead>
<tr>
<th>RMS RANGE</th>
<th>PEAK INPUT</th>
<th>FULL SCALE RMS</th>
<th>RESOLUTION</th>
<th>DEFAULT RESOLUTION</th>
<th>MAXIMUM BURDEN VOLTAGE</th>
<th>TEMPERATURE COEFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 µA</td>
<td>1 mA</td>
<td>210.0000</td>
<td>100 pA</td>
<td>1 nA</td>
<td>0.25 V</td>
<td>±(0.01 + 0.001)</td>
</tr>
<tr>
<td>2 mA</td>
<td>10 mA</td>
<td>2.100000</td>
<td>1 nA</td>
<td>10 nA</td>
<td>0.31 V</td>
<td>±(0.01 + 0.001)</td>
</tr>
<tr>
<td>20 mA</td>
<td>100 mA</td>
<td>21.00000</td>
<td>10 nA</td>
<td>100 nA</td>
<td>0.4 V</td>
<td>±(0.01 + 0.001)</td>
</tr>
<tr>
<td>200 mA</td>
<td>1 A</td>
<td>210.0000</td>
<td>100 nA</td>
<td>1 µA</td>
<td>0.5 V</td>
<td>±(0.01 + 0.001)</td>
</tr>
<tr>
<td>2 A</td>
<td>2 A</td>
<td>2.100000</td>
<td>1 µA</td>
<td>10 µA</td>
<td>1.5 V</td>
<td>±(0.01 + 0.001)</td>
</tr>
</tbody>
</table>

### ACI ACCURACY

- 90 Days, 1 Year or 2 Years, TCAL ±5°C, for ≤5% to ≤100% of range, ±(% of reading + % of range)

### AC CURRENT UNCERTAINTY

\[ \text{AC CURRENT UNCERTAINTY} = \frac{\% \text{ of range}}{\% \text{ accuracy}} \times \frac{\text{measured value}}{\text{range used}} \times 100 \]

### AC Coupling

- For AC coupling, add the following % of reading:
  - 20–50Hz: 0.55
  - 50–100Hz: 0.09
  - 100–200Hz: 0.015

### AC+DC Coupling

- For DC current, apply the following additional uncertainty, multiplied by the ratio (DC/AC rms):
  - 20–50Hz: 0.05
  - 50–100Hz: 0.015
  - 100–200Hz: 0.1
### AC Amps (cont'd)

#### ACI Reading Rates$^4$

<table>
<thead>
<tr>
<th>NPLC</th>
<th>MEASUREMENT APERTURE</th>
<th>BITS</th>
<th>DEFAULT DIGITS</th>
<th>READINGS/SECOND TO MEMORY</th>
<th>READINGS/SECOND TO IEEE-488</th>
<th>READINGS/SECOND TO IEEE-488</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>167 μs (200 ms)</td>
<td>28</td>
<td>6½</td>
<td>6 (5.1)</td>
<td>2 (1.7)</td>
<td>6 (4.9)</td>
</tr>
<tr>
<td>2</td>
<td>33.4 μs (40 ms)</td>
<td>26</td>
<td>5½</td>
<td>30 (25)</td>
<td>9 (7.9)</td>
<td>28 (23)</td>
</tr>
<tr>
<td>1</td>
<td>16.7 μs (20 ms)</td>
<td>25</td>
<td>5½</td>
<td>57 (48)</td>
<td>39 (35)</td>
<td>53 (45)</td>
</tr>
<tr>
<td>0.1</td>
<td>1.67 ms (2 ms)</td>
<td>21</td>
<td>5½</td>
<td>157 (136)</td>
<td>70 (70)</td>
<td>123 (123)</td>
</tr>
<tr>
<td>0.01</td>
<td>167 μs (167 μs)</td>
<td>16</td>
<td>4½</td>
<td>156 (136)</td>
<td>70 (70)</td>
<td>140 (140)</td>
</tr>
</tbody>
</table>

#### Setting Characteristics:
- $<$800ms to 1% of step change
- $<$500ms to 0.1% of step change

#### Autoranging:
- Autoranges up to 105% of range, down to 10% of range.

#### High Crest Factor Additional Error ± (% of reading)

<table>
<thead>
<tr>
<th>CRESCENT FACTOR</th>
<th>ADDITIONAL ERROR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 2</td>
<td>0</td>
</tr>
<tr>
<td>2 – 3</td>
<td>0.1</td>
</tr>
<tr>
<td>3 – 4</td>
<td>0.2</td>
</tr>
<tr>
<td>4 – 5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

#### Average ACI Measurement

Rms specifications apply to 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 warmup.
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 $= (maximum voltage burden) \times (measurements/full scale)$.
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

<table>
<thead>
<tr>
<th>FREQUENCY RANGE</th>
<th>PERIOD RANGE</th>
<th>DEFAULT RESOLUTION</th>
<th>MINIMUM SIGNAL LEVEL</th>
<th>MAXIMUM INPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Hz to 15 MHz</td>
<td>67 ns to 1 s</td>
<td>5 digits</td>
<td>60 mV</td>
<td>105 mV</td>
</tr>
<tr>
<td>1 Hz to 1 MHz</td>
<td>1 μs to 1 s</td>
<td>5 digits</td>
<td>150 μV</td>
<td>420 mV</td>
</tr>
</tbody>
</table>

#### Frequency Notes

1. Subject to $2 \times 10^5$ Hz product (for inputs above 20V).

### Temperature (RTD)

#### Range

<table>
<thead>
<tr>
<th>TEMPERATURE RANGE</th>
<th>RESOLUTION</th>
<th>1 Hour $^2$</th>
<th>4-WIRE ACCURACY $^3$</th>
<th>90 Days, 1 Year</th>
<th>2 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-100^\circ$ to $+100^\circ$ C</td>
<td>0.003°C</td>
<td>±0.05°C</td>
<td>±0.05°C</td>
<td>±0.08°C</td>
<td>±0.12°C</td>
</tr>
<tr>
<td>$-200^\circ$ to $+630^\circ$ C</td>
<td>0.003°C</td>
<td>±0.05°C</td>
<td>±0.05°C</td>
<td>±0.12°C</td>
<td>±0.14°C</td>
</tr>
<tr>
<td>$-212^\circ$ to $+180^\circ$ F</td>
<td>0.003°F</td>
<td>±0.09°F</td>
<td>±0.09°F</td>
<td>±0.15°F</td>
<td>±0.22°F</td>
</tr>
<tr>
<td>$-360^\circ$ to $+1102^\circ$ F</td>
<td>0.001°F</td>
<td>±0.09°F</td>
<td>±0.15°F</td>
<td>±0.18°F</td>
<td>±0.33°F</td>
</tr>
</tbody>
</table>

#### RTD Type

- Platinum: DIN 43 760 or IPTS-68, alpha 0.00385, 0.00390, 0.003916, or 0.003912.
- 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

- $\pm(0.0013\% + 0.005°C/\circ C)$ or $\pm(0.001\% + 0.01°F)/\circ C$ outside $T_{CAL} \pm 5^\circ C$.

#### RTD Temperature Reading Rates

<table>
<thead>
<tr>
<th>NPLC</th>
<th>Auto Zero Off</th>
<th>Auto Zero On</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>5 (4.3)</td>
<td>5 (3.6)</td>
</tr>
<tr>
<td>1</td>
<td>7 (6.5)</td>
<td>6 (5.5)</td>
</tr>
<tr>
<td>0.1</td>
<td>12 (10.8)</td>
<td>9 (9)</td>
</tr>
<tr>
<td>0.01</td>
<td>12 (12)</td>
<td>10 (10)</td>
</tr>
</tbody>
</table>

### Temperature (Thermocouple)

#### Thermocouple Type

<table>
<thead>
<tr>
<th>TYPE</th>
<th>RANGE</th>
<th>DEFAULT RESOLUTION</th>
<th>ACCURACY $^4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>$-200^\circ$ to $+760^\circ$ C</td>
<td>0.1°C</td>
<td>$\pm 0.5°C$</td>
</tr>
<tr>
<td>K</td>
<td>$-200^\circ$ to $+1372^\circ$ C</td>
<td>0.1°C</td>
<td>$\pm 0.5°C$</td>
</tr>
<tr>
<td>T</td>
<td>$-200^\circ$ to $+400^\circ$ C</td>
<td>0.1°C</td>
<td>$\pm 0.5°C$</td>
</tr>
<tr>
<td>E</td>
<td>$-200^\circ$ to $+1000^\circ$ C</td>
<td>0.1°C</td>
<td>$\pm 0.6°C$</td>
</tr>
<tr>
<td>S</td>
<td>$0^\circ$ to $+1372^\circ$ C</td>
<td>0.1°C</td>
<td>$\pm 3°C$</td>
</tr>
<tr>
<td>B</td>
<td>$-250^\circ$ to $+1372^\circ$ C</td>
<td>0.1°C</td>
<td>$\pm 5°C$</td>
</tr>
</tbody>
</table>

#### TC Temperature Reading Rates

<table>
<thead>
<tr>
<th>NPLC</th>
<th>READINGS/SECOND TO MEMORY</th>
<th>READINGS/SECOND TO IEEE-488</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>6 (5.1)</td>
<td>4 (3.4)</td>
</tr>
<tr>
<td>2</td>
<td>30 (25)</td>
<td>28 (23)</td>
</tr>
<tr>
<td>1</td>
<td>57 (48)</td>
<td>53 (45)</td>
</tr>
<tr>
<td>0.1</td>
<td>129 (133)</td>
<td>126 (123)</td>
</tr>
<tr>
<td>0.01</td>
<td>177 (177)</td>
<td>156 (156)</td>
</tr>
</tbody>
</table>

### 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 $\pm 1^\circ C$, measured temperature $\pm 10^\circ C$, 10 reading digital filter.
3. Excluding probe errors. $T_{CAL} \pm 5^\circ C$.
4. Relative to external 0°C reference junction; exclusive of thermocouple errors. $J$-junction temperature may be external. Applies for 90 days, 1 year or 2 years, $T_{CAL} \pm 5^\circ C$. 

---

$^1$ Subject to 2
$^2$ Subject to 3
$^3$ Subject to 4
$^4$ Subject to 5
The following diagram illustrates the factors that determine a DMM's reading rate.

### COMMAND RECEIVE AND INTERPRET SPEED

<table>
<thead>
<tr>
<th>Time per character</th>
<th>FASTEST</th>
<th>TYPICAL</th>
<th>SLOWEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characters per second</td>
<td>0.16 ms</td>
<td>0.28 ms</td>
<td>0.66 ms</td>
</tr>
</tbody>
</table>

### TYPICAL COMMAND TIMES

<table>
<thead>
<tr>
<th>Command</th>
<th>Receive and Interpret Time</th>
<th>Rate (per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SENSE1:VOLTAGE:AC:RESOLUTION MAXIMUM</td>
<td>9.4 ms</td>
<td>106</td>
</tr>
<tr>
<td>VOLTC栎:RES:MAX</td>
<td>4.1 ms</td>
<td>243</td>
</tr>
<tr>
<td>SENSE1:FUNC 'VOLT:AC'</td>
<td>6.3 ms</td>
<td>158</td>
</tr>
<tr>
<td>RESISTANCE:RANGE:UPPER 1E9</td>
<td>9.0 ms</td>
<td>111</td>
</tr>
<tr>
<td>STATUS:QUEUE:CLEAR</td>
<td>5.1 ms</td>
<td>196</td>
</tr>
<tr>
<td>STAT:QUE:CLE</td>
<td>3.1 ms</td>
<td>322</td>
</tr>
<tr>
<td>*TRG</td>
<td>1.2 ms</td>
<td>833</td>
</tr>
</tbody>
</table>

### MEASUREMENT SPEED CHANGE TIMES

Typical delay before first reading after making a speed change.

### FUNCTION CHANGE SPEED

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>Range(s)</th>
<th>TIME</th>
<th>RATE</th>
<th>TIME</th>
<th>RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCV</td>
<td>200mV</td>
<td>2V</td>
<td>8.1 ms</td>
<td>120</td>
<td>36 ms</td>
<td>27</td>
</tr>
<tr>
<td>20V</td>
<td>8.1 ms</td>
<td>120</td>
<td>8.6 ms</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200V</td>
<td>24 ms</td>
<td>60</td>
<td>10.2 ms</td>
<td>190</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement Speed</td>
<td>11 ms</td>
<td>160</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### FUNCTION CHANGE SPEED (continued)

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>Range(s)</th>
<th>TIME</th>
<th>RATE</th>
<th>TIME</th>
<th>RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACV</td>
<td>200μA</td>
<td>2mA, 20mA</td>
<td>4.5 ms</td>
<td>220</td>
<td>4.1 ms</td>
<td>150</td>
</tr>
<tr>
<td>DCI</td>
<td>6.0 ms</td>
<td>160</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ohms (2-wire)</td>
<td>20kΩ, 2kΩ, 20kΩ, 200kΩ</td>
<td>12 ms</td>
<td>140</td>
<td>34.1 ms</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Ohms (4-wire)</td>
<td>200Ω, 2mA, 20mA</td>
<td>4.5 ms</td>
<td>45</td>
<td>22 ms</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>2MΩ</td>
<td>26 ms</td>
<td>10.5</td>
<td>690 ms</td>
<td>2.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20MΩ</td>
<td>265 ms</td>
<td>4</td>
<td>6.5 ms</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200MΩ, 1GΩ</td>
<td>366 ms</td>
<td>3</td>
<td>5.5 ms</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC Temperature</td>
<td>Frequency</td>
<td>61 ms</td>
<td>16</td>
<td>60 ms</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>RTD Temp. (2-wire)</td>
<td>79 ms</td>
<td>12</td>
<td>75 ms</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RTD Temp. (4-wire)</td>
<td>418 ms</td>
<td>2</td>
<td>416 ms</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC Temp.</td>
<td>6.0 ms</td>
<td>165</td>
<td>33 ms</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RTD Temp. (2-wire)</td>
<td>11.5 ms</td>
<td>150</td>
<td>37 ms</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC Temp.</td>
<td>8.0 ms</td>
<td>125</td>
<td>35 ms</td>
<td>28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### OPERATING SPEED (cont’d)

#### RANGE CHANGE SPEED

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>From</th>
<th>To</th>
<th>AUTO ZERO OFF TIME (per second)</th>
<th>AUTO ZERO ON TIME (per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCV</td>
<td>200mV, 2V</td>
<td>20V</td>
<td>4.5 ms</td>
<td>220</td>
</tr>
<tr>
<td>200V, 1000V</td>
<td>20V</td>
<td>8.0 ms</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>200mV, 2V, 20V</td>
<td>200mV, 2V, 20V</td>
<td>4.5 ms</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>200V, 1000V</td>
<td>200V</td>
<td>8.0 ms</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>ACV</td>
<td>Any</td>
<td>Any</td>
<td>563 ms</td>
<td>1.8</td>
</tr>
<tr>
<td>DCI</td>
<td>Any</td>
<td>Any</td>
<td>4.5 ms</td>
<td>220</td>
</tr>
<tr>
<td>ACI</td>
<td>Any</td>
<td>Any</td>
<td>525 ms</td>
<td>1.9</td>
</tr>
</tbody>
</table>

#### TRIGGER SPEED (External Trigger or Trigger-Link)

<table>
<thead>
<tr>
<th>TRIGGER CONFIGURATION</th>
<th>AUTO ZERO</th>
<th>TRIGGER LATENCY:</th>
<th>TRIGGER JITTER:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto Zero On</td>
<td>1.2 ms typical</td>
<td>±0.5 μs</td>
<td></td>
</tr>
<tr>
<td>Auto Zero Off</td>
<td>2.0 μs</td>
<td>±0.5 μs</td>
<td></td>
</tr>
</tbody>
</table>

#### ENGINEERING UNIT CONVERSION SPEED

**Configuration**

<table>
<thead>
<tr>
<th>CONFIGURATION</th>
<th>TIME</th>
<th>RATE (per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCV</td>
<td>2.4 ms</td>
<td>416</td>
</tr>
<tr>
<td>DCV, Filter on</td>
<td>2.4 ms</td>
<td>416</td>
</tr>
<tr>
<td>DCV, Relative on</td>
<td>2.5 ms</td>
<td>400</td>
</tr>
<tr>
<td>DCV, Ratio on</td>
<td>3.7 ms</td>
<td>270</td>
</tr>
<tr>
<td>ACV</td>
<td>5.3 ms</td>
<td>188</td>
</tr>
<tr>
<td>ACV, Relative on</td>
<td>5.3 ms</td>
<td>188</td>
</tr>
<tr>
<td>ACV, Filter on</td>
<td>6.8 ms</td>
<td>147</td>
</tr>
<tr>
<td>ACV, dB</td>
<td>9.4 ms</td>
<td>106</td>
</tr>
<tr>
<td>ACV, dBm</td>
<td>17.3 ms</td>
<td>57</td>
</tr>
</tbody>
</table>

#### 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.

#### SINGLE FUNCTION SCAN SPEED

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DCV (20V) Rate per Chan.</th>
<th>2-Wire Ohms (2kΩ) Rate per Chan.</th>
<th>4-Wire Ohms (2kΩ) Rate per Chan.</th>
<th>ACV Rate per Chan.</th>
<th>TC Temperature Rate per Chan.</th>
<th>RTD Temperature (2-Wire) Rate per Chan.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio or Delta (2 channels)</td>
<td>4 ms</td>
<td>250</td>
<td>4.4 ms</td>
<td>230</td>
<td>18.5 ms</td>
<td>54</td>
</tr>
<tr>
<td>Fast Scan (using solid state channels)</td>
<td>5.5 ms</td>
<td>181</td>
<td>7 ms</td>
<td>140</td>
<td>520 ms</td>
<td>-</td>
</tr>
<tr>
<td>Normal Scan</td>
<td>10.3 ms</td>
<td>97</td>
<td>12.1 ms</td>
<td>80</td>
<td>21 ms</td>
<td>47</td>
</tr>
</tbody>
</table>

#### MIXED FUNCTION SCAN SPEED

<table>
<thead>
<tr>
<th>SCAN CONFIGURATION</th>
<th>Average Time/ Channel</th>
<th>Average Rate (Channel/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 chan. DCV, 5 chan. 2W1</td>
<td>20 ms</td>
<td>50</td>
</tr>
<tr>
<td>3 DCV, 3 2W1, 4 TC</td>
<td>22 ms</td>
<td>45</td>
</tr>
<tr>
<td>5 2W1, 5 TC</td>
<td>60 ms</td>
<td>17</td>
</tr>
<tr>
<td>2 2W1, 5 2W1 RTD</td>
<td>60 ms</td>
<td>17</td>
</tr>
<tr>
<td>9 DCV, 1 ACV</td>
<td>73 ms</td>
<td>13</td>
</tr>
<tr>
<td>2 DCV, 1 ACV, 2 2W1, 1 4W1</td>
<td>122 ms</td>
<td>8</td>
</tr>
<tr>
<td>5 DCV, 5 Freq.</td>
<td>490 ms</td>
<td>2</td>
</tr>
<tr>
<td>3 DCV, 3 ACV, 2 2W1</td>
<td>220 ms</td>
<td>5</td>
</tr>
</tbody>
</table>

#### 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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Rated Input</th>
<th>Overload Recovery Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>HI to LO</td>
<td>±1100V pk</td>
<td>&lt; 900 ms</td>
</tr>
<tr>
<td>HI Sense to LO</td>
<td>± 350V pk</td>
<td>&lt; 900 ms</td>
</tr>
<tr>
<td>LO Sense to LO</td>
<td>± 350V pk</td>
<td>&lt; 900 ms</td>
</tr>
<tr>
<td>I Input to LO</td>
<td>2A, ± 250V</td>
<td>(fused)</td>
</tr>
<tr>
<td>HI to Earth</td>
<td>±1600V</td>
<td>&lt; 900 ms</td>
</tr>
<tr>
<td>LO to Earth</td>
<td>±500V</td>
<td></td>
</tr>
</tbody>
</table>

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, UNL, UNL.

**UNILINE COMMANDS:** FFC, REN, EOI, SRO, 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-28800E1 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 (3 ½ in. × 8 ½ in. × 14 ½ 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-28800E1. Designed to UL1244.
- **Reliability:** MIL-T-28800E1.
- **Maintainability:** MIL-T-28800E1.
- **MTTR:** <90 minutes (includes disassembly and assembly, excludes recalculation). 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 4566A 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

<table>
<thead>
<tr>
<th>Model</th>
<th>Size (Bytes)</th>
<th>4½-Digit</th>
<th>6½-Digit</th>
<th>Type</th>
<th>Number</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>8k</td>
<td>850</td>
<td>250</td>
<td>volatile</td>
<td>1</td>
<td>non-volatile</td>
</tr>
<tr>
<td>2001/MEM1</td>
<td>32k</td>
<td>7,000</td>
<td>1,400</td>
<td>non-volatile</td>
<td>5</td>
<td>non-volatile</td>
</tr>
<tr>
<td>2001/MEM2</td>
<td>128k</td>
<td>30,000</td>
<td>6,000</td>
<td>non-volatile</td>
<td>10</td>
<td>non-volatile</td>
</tr>
</tbody>
</table>

**Specifications subject to change without notice.**
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

<table>
<thead>
<tr>
<th>Mfg.</th>
<th>Model</th>
<th>Description</th>
<th>Specifications*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke</td>
<td>5700A</td>
<td>Calibrator</td>
<td>±5ppm basic uncertainty. DC voltage: 20V: ±5ppm 19kΩ: ±11ppm 1MΩ: ±18ppm</td>
</tr>
<tr>
<td>Keithley</td>
<td>8610</td>
<td>Low-thermal Shorting Plug</td>
<td></td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Mfg.</th>
<th>Model</th>
<th>Description</th>
<th>Specifications*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke</td>
<td>5700A</td>
<td>Calibrator</td>
<td>±5ppm basic uncertainty. DC voltage: 0V: ±0.75µV -2V, +2V: ±5ppm 20V: ±5ppm 200mA: ±65ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keithley</td>
<td>3930A</td>
<td>Synthesizer</td>
<td>2V rms @ 1Hz</td>
</tr>
<tr>
<td>Keithley</td>
<td>8610</td>
<td>Low-thermal Shorting Plug</td>
<td>2V rms @ 1Hz</td>
</tr>
</tbody>
</table>

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

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-2
Calibration connection for comprehensive calibration

Note: Use shielded cables to minimize noise. Enable or disable calibrator external sense as indicated in procedure. Use internal Guard (EX GRD LED is off).

Figure B-3
Calibration voltage connections

Note: Use internal Guard (EX GRD LED is off).
**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:"
CLS
,' PRINT "Model 2001 Multimeter Comprehensive Calibration Program"
GOSUB KeyCheck
GOSUB CheckSwitch
RESTORE CmdList
,
FOR I = 1 TO 8
READ Msg$, Cmd$
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
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$; ""
PRINT #1, "OUTPUT 16;:CAL:PROT:SAVE"  ' Save calibration constants.
PRINT #1, "OUTPUT 16;:CAL:PROT:LOCK"  ' Lock out calibration.
PRINT "Calibration completed."
END
,' KeyCheck:
PRINT "Press any key to continue (ESC to abort program)."
Wai: I$ = INKEY$: IF I$ = "" THEN GOTO Wai
IF I$ = CHR$(27) THEN
  CLOSE 1: CLOSE 2
  PRINT "Program halted."
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
  PRINT Err$
  PRINT "Calibration aborted."
  BEEP
  CLOSE 1: CLOSE 2
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[] = {
    };
    void keypress(), errcheck(), chkswit();
    char date[10];
    int i, calend();
    if (ieeseinit() == -1) {
        printf("Cannot initialize interface.\n");
        exit(1);
    }
    ieeewt("clear\n"); /* Send DCL. */
    ieeewt("remote 16\n"); /* Put 2001 in remote. */
    ieeewt("term if eo\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++) {
        printf("%s\n", msg[i]);
        if (i<6) keypress();
        ieeeprt("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).

```c
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");
        ieeerdrd(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");
    ieeerdrd(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).

```c
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 161*RST:*CLS"          ' Initialize 2001.
PRINT #1, "OUTPUT 161*ESE 1:*SRE 32"     ' Enable OPC and SRQ
PRINT #1, "OUTPUT 041*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
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).

```basic
CASE 7
   PRINT Msg$
CASE 8
   C$ = "CAL:" [newline]
   PRINT Msg$
END SELECT
GO SUB Dly
   '" Settling time.
PRINT #1, "OUTPUT 16:"; C$; CmIS; "*OPC" '" Send cal command to 2001.
GO SUB CalEnd
   '" Wait until cal step ends.
IF I = 7 OR I = 8 THEN GO SUB ErrCheck '" Check for cal error.
NEXT I

INPUT "Enter calibration date (mm/dd/yy)"); D$ [newline]
PRINT #1, "OUTPUT 16:CAL:PROT:DATE "; D$; ""
INPUT "Enter calibration due date (mm/dd/yy)"); D$ [newline]
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 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 MIDS$(ST$, 11, 2) = "SO" 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
```

B-12
Program B-3 (continued)
Comprehensive calibration program for use with Fluke 5700A calibrator (QuickBASIC Version).

ErrCheck:
    PRINT #1, "OUTPUT 16,:SYST:ERR?" ' Error check routine.
    PRINT #1, "ENTER 16" ' Query error queue.
    INPUT #2, E, Err$
    IF E <> 0 THEN
        PRINT
        PRINT Err$
        PRINT "Calibration aborted."
        BEEP
        CLOSE 1: CLOSE 2
    END IF
    RETURN

CheckSwitch:
    Print #1, "OUTPUT 16,:CAL:PROT:SWIT?" ' Check CAL switch status.
    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: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 1lf eol\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");
                ieeewt("output 04;%s\n", msg[i]);
                break;
        }
    }
}
Program B-4 (continued)

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

```c
    case 2: ieeprtf("output 04;%s\n",msg[i]);
        break;
    case 3:
    case 4: ieeprtf("output 04;%s\n",msg[i]);
        ieewt("output 04;oper\n");
            if (i==3)
                ieewt("output 04;extsense on\n");
            if (i==4)
                ieewt("output 04;extsense off\n");
        ieewt("output 04;out?\n");
        ieewt("enter 04\n");
        ieereq(buf);
        j=0;
        while (buf[j++] !=',',);
        buf[--j]='\0';
        break;
    case 5: ieewt("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)
            ieeprtf("output 16;%s%s;*opc\n",cmd[i],buf);
        else ieeprtf("output 16;%s;%s;*opc\n",cmd[i],buf);
        calend(i);
        if (i==6 || i==7) errcheck();
    }
    printf("Enter calibration date (mm/dd/yy): ");
    scanf("%s",date);
    ieeprtf("output 16;:cal:prot:date  ' %s\n",date);
    printf("Enter calibration due date (mm/dd/yy): ");
    scanf("%s",date);
    ieeprtf("output 16;:cal:prot:ndue ' %s\n",date);
    ieewt("output 16;:cal:prot:save\n");
    ieewt("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).

```c
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");
        ieeeerd(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");
    ieeeerd(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                           ' Check CAL switch status.
GOSUB CheckSwitch
,                                           ' Check CAL switch status.
RESTORE CmdList                           ' Loop for all cal points.
PRINT "Calibration in progress..."
,                                           ' Read message, cal strings.
SELECT CASE I
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).

```basic
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)."
Wait: I$ = INKEY$: IF I$ = "" THEN GOTO Wait
IF I$ = CHR$(27) THEN
    PRINT #1, "OUTPUT 04;STBY"    ' Abort if ESC is pressed.
    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$
 IF MID$(ST$, 11, 2) = "S0" THEN GOTO Stat ' Wait for operation complete.
PRINT #1, "OUTPUT 16;" ES?
PRINT #1, "ENTER 16" ' Clear OPC.
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 ' If error is detected, error
PRINT
PRINT Err$
PRINT "Calibration aborted." ' is displayed, and program
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 ' Low-level calibration is locked out.
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
Calibration Programs

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:HIGHT 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,30 KHZ","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 -2 v, 0 hz", "out 0 v, 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[] = {
    };
    void keypress(), errcheck(), chkswit();
    char buf[100], date[10];
    int i, j, calend();
    if (ieeexit() == -1) {
        printf("Cannot initialize interface.\n");
        exit(1);
    }
    ieeexw("clear\n");
    ieeexw("remote 16\n");
    ieeexw("remote 04\n");
    ieeexw("term if elo\n");
    ieeexw("output 16::*rst:*cls\n");
    ieeexw("output 16:eset:32\n");
    ieeexw("output 04:*rst:*cls\n");
    ieeexw("output 04:cur_post normal\n");
    ieeexw("output 04:cur_post normal\n");
    clrscr();
Program B-6 (continued)
Low-level calibration program for use with Fluke 5700A calibrator (Turbo C Version).

```c
printf("Model 2001 Low-Level Calibration Program.\n");
printf("This program controls the 5700A Calibrator.\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).

```c
  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: 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%*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).

```c
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");
    ieescanf("%d", &stat);
    ieeewt("spoll 16\n");
    ieescanf("%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:level:swit?\n");
    ieeewt("enter 16\n");
    ieescanf("%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);
    }
}
```
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**

<table>
<thead>
<tr>
<th>Error ID code</th>
<th>Error messages</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Error</td>
</tr>
<tr>
<td>-102</td>
<td>Syntax error</td>
</tr>
<tr>
<td>-113</td>
<td>Command header error</td>
</tr>
<tr>
<td>-200</td>
<td>Execution error</td>
</tr>
<tr>
<td>-221</td>
<td>Settings conflict</td>
</tr>
<tr>
<td>-222</td>
<td>Parameter data out of range</td>
</tr>
<tr>
<td>+353</td>
<td>200 mV gain out of spec</td>
</tr>
<tr>
<td>+354</td>
<td>200 mV offset out of spec</td>
</tr>
<tr>
<td>+355</td>
<td>2V gain out of spec</td>
</tr>
<tr>
<td>+356</td>
<td>2 V offset out of spec</td>
</tr>
<tr>
<td>+357</td>
<td>20 V gain out of spec</td>
</tr>
<tr>
<td>+358</td>
<td>20 V offset out of spec</td>
</tr>
<tr>
<td>+359</td>
<td>200 V gain out of spec</td>
</tr>
<tr>
<td>+360</td>
<td>200 V offset out of spec</td>
</tr>
<tr>
<td>+361</td>
<td>1000 V gain out of spec</td>
</tr>
<tr>
<td>+362</td>
<td>1000 V offset out of spec</td>
</tr>
<tr>
<td>+363</td>
<td>200 µA gain out of spec</td>
</tr>
<tr>
<td>+364</td>
<td>200 µA offset out of spec</td>
</tr>
<tr>
<td>+365</td>
<td>2 mA gain out of spec</td>
</tr>
<tr>
<td>+366</td>
<td>2 mA offset out of spec</td>
</tr>
<tr>
<td>+367</td>
<td>20 mA gain out of spec</td>
</tr>
<tr>
<td>+368</td>
<td>20 mA offset out of spec</td>
</tr>
<tr>
<td>+369</td>
<td>200 mA gain out of spec</td>
</tr>
<tr>
<td>+370</td>
<td>200 mA offset out of spec</td>
</tr>
<tr>
<td>+371</td>
<td>2 A gain out of spec</td>
</tr>
<tr>
<td>+372</td>
<td>2 A offset out of spec</td>
</tr>
<tr>
<td>+373</td>
<td>20 ohm 2W gain out of spec</td>
</tr>
<tr>
<td>+374</td>
<td>20 ohm 2W offset out of spec</td>
</tr>
<tr>
<td>+375</td>
<td>200 ohm 2W gain out of spec</td>
</tr>
<tr>
<td>+376</td>
<td>200 ohm 2W offset out of spec</td>
</tr>
<tr>
<td>+377</td>
<td>2 kohm 2W gain out of spec</td>
</tr>
<tr>
<td>+378</td>
<td>2 kohm 2W offset out of spec</td>
</tr>
<tr>
<td>+379</td>
<td>20 kohm 2W gain out of spec</td>
</tr>
<tr>
<td>+380</td>
<td>20 kohm 2W offset out of spec</td>
</tr>
<tr>
<td>+381</td>
<td>200 kohm 2W gain out of spec</td>
</tr>
<tr>
<td>+382</td>
<td>200 kohm 2W offset out of spec</td>
</tr>
<tr>
<td>+383</td>
<td>2 Mohm 2W gain out of spec</td>
</tr>
<tr>
<td>+384</td>
<td>2 Mohm 2W offset out of spec</td>
</tr>
<tr>
<td>+385</td>
<td>20 Mohm 2W gain out of spec</td>
</tr>
<tr>
<td>+386</td>
<td>20 Mohm 2W offset out of spec</td>
</tr>
<tr>
<td>+387</td>
<td>200 Mohm 2W gain out of spec</td>
</tr>
<tr>
<td>+388</td>
<td>200 Mohm 2W offset out of spec</td>
</tr>
<tr>
<td>+389</td>
<td>1 Gohm 2W gain out of spec</td>
</tr>
<tr>
<td>+390</td>
<td>1 Gohm 2W offset out of spec</td>
</tr>
<tr>
<td>+391</td>
<td>20 ohm 4W gain out of spec</td>
</tr>
<tr>
<td>+392</td>
<td>20 ohm 4W offset out of spec</td>
</tr>
<tr>
<td>+393</td>
<td>200 ohm 4W gain out of spec</td>
</tr>
<tr>
<td>+394</td>
<td>200 Ohm 4W offset out of spec</td>
</tr>
<tr>
<td>+395</td>
<td>2 kohm 4W gain out of spec</td>
</tr>
<tr>
<td>+396</td>
<td>2 kohm 4W offset out of spec</td>
</tr>
<tr>
<td>+397</td>
<td>20 kohm 4W gain out of spec</td>
</tr>
<tr>
<td>+398</td>
<td>20 kohm 4W offset out of spec</td>
</tr>
<tr>
<td>+399</td>
<td>200 kohm 4W gain out of spec</td>
</tr>
<tr>
<td>+400</td>
<td>200 kohm 4W offset out of spec</td>
</tr>
<tr>
<td>+401</td>
<td>2 Mohm 4W gain out of spec</td>
</tr>
<tr>
<td>+402</td>
<td>2 Mohm 4W offset out of spec</td>
</tr>
<tr>
<td>+403</td>
<td>7 V ref out of spec</td>
</tr>
<tr>
<td>+404</td>
<td>DCV rollover out of spec</td>
</tr>
<tr>
<td>+405</td>
<td>x1 rms gain out of spec</td>
</tr>
<tr>
<td>+406</td>
<td>x1 rms offset out of spec</td>
</tr>
<tr>
<td>+407</td>
<td>x10 rms gain out of spec</td>
</tr>
<tr>
<td>+408</td>
<td>x10 rms offset out of spec</td>
</tr>
<tr>
<td>+409</td>
<td>x1 fwr gain out of spec</td>
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<tr>
<td>+410</td>
<td>x1 fwr offset out of spec</td>
</tr>
<tr>
<td>+411</td>
<td>x10 fwr gain out of spec</td>
</tr>
<tr>
<td>+412</td>
<td>x10 fwr offset out of spec</td>
</tr>
<tr>
<td>+413</td>
<td>d100 atten out of spec</td>
</tr>
<tr>
<td>+414</td>
<td>d500 atten out of spec</td>
</tr>
<tr>
<td>+415</td>
<td>Pos x10 peak offset out of spec</td>
</tr>
<tr>
<td>+416</td>
<td>Neg x10 peak offset out of spec</td>
</tr>
<tr>
<td>+417</td>
<td>x1 peak offset out of spec</td>
</tr>
<tr>
<td>+418</td>
<td>Pos 20V peak offset out of spec</td>
</tr>
<tr>
<td>+419</td>
<td>Neg 20V peak offset out of spec</td>
</tr>
<tr>
<td>+420</td>
<td>d100 self cal DAC out of spec</td>
</tr>
<tr>
<td>+421</td>
<td>d500 self cal DAC out of spec</td>
</tr>
<tr>
<td>+422</td>
<td>x10 noise factor out of spec</td>
</tr>
<tr>
<td>+423</td>
<td>x1 cfc out of spec</td>
</tr>
<tr>
<td>+424</td>
<td>x10 cfc out of spec</td>
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<td>+425</td>
<td>Low V coupling fact out of spec</td>
</tr>
<tr>
<td>+426</td>
<td>High V coupling fact out of spec</td>
</tr>
<tr>
<td>+427</td>
<td>Input time constant out of spec</td>
</tr>
<tr>
<td>+428</td>
<td>Curr coupling fact out of spec</td>
</tr>
<tr>
<td>+429</td>
<td>Comparator DAC out of spec</td>
</tr>
<tr>
<td>+430</td>
<td>d100 div DAC out of spec</td>
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<tr>
<td>+431</td>
<td>200 V div DAC out of spec</td>
</tr>
<tr>
<td>+432</td>
<td>d500 div DAC out of spec</td>
</tr>
<tr>
<td>+433</td>
<td>d100 div DAC offset out of spec</td>
</tr>
<tr>
<td>+434</td>
<td>200 V div DAC offset out of spec</td>
</tr>
<tr>
<td>+435</td>
<td>d500 div DAC offset out of spec</td>
</tr>
<tr>
<td>+436</td>
<td>d100 div cal did not converge</td>
</tr>
<tr>
<td>+437</td>
<td>d500 div cal did not converge</td>
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<tr>
<td>+438</td>
<td>Date of calibration not set</td>
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<tr>
<td>+439</td>
<td>Next date of calibration not set</td>
</tr>
<tr>
<td>+440</td>
<td>Calibration process not completed</td>
</tr>
</tbody>
</table>
Table C-2  
Calibration constants returned by :CAL:PROT:DATA? Query

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>g1</td>
<td>RMS gain for 2V, 200V, and 750V AC ranges</td>
</tr>
<tr>
<td>of1</td>
<td>RMS offset for 2V, 200V, and 750V AC ranges</td>
</tr>
<tr>
<td>g10</td>
<td>RMS gain for 200mV and 20V AC ranges</td>
</tr>
<tr>
<td>of10</td>
<td>RMS offset for 200mV and 20V AC ranges</td>
</tr>
<tr>
<td>gfwr1</td>
<td>Average gain for 2V, 200V, and 750V AC ranges</td>
</tr>
<tr>
<td>offwr1</td>
<td>Average offset for 2V, 200V, and 750V AC ranges</td>
</tr>
<tr>
<td>gfwr10</td>
<td>Average gain for 200mV and 20V AC ranges</td>
</tr>
<tr>
<td>offwr10</td>
<td>Average offset for 200mV and 20V AC ranges</td>
</tr>
<tr>
<td>a100</td>
<td>100:1 divider attenuation factor</td>
</tr>
<tr>
<td>a500</td>
<td>500:1 divider attenuation factor</td>
</tr>
<tr>
<td>ofpkpos10</td>
<td>Positive peak offset for 200mV AC range</td>
</tr>
<tr>
<td>ofpkneg10</td>
<td>Negative peak offset for 200mV AC range</td>
</tr>
<tr>
<td>ofpk1</td>
<td>Positive and negative peak offset for 2V, 200V, and 750V AC ranges</td>
</tr>
<tr>
<td>ofpkpos20</td>
<td>Positive peak offset for 20V AC range</td>
</tr>
<tr>
<td>ofpkneg20</td>
<td>Negative peak offset for 20V AC range</td>
</tr>
<tr>
<td>div100self</td>
<td>Self-calibration code for frequency compensation DAC, 100:1 divider</td>
</tr>
<tr>
<td>div500self</td>
<td>Self-calibration code for frequency compensation DAC, 500:1 divider</td>
</tr>
<tr>
<td>noise10</td>
<td>Noise factor for 200mV and 20V AC ranges</td>
</tr>
<tr>
<td>cfc1</td>
<td>Crest factor correction factor for 2V, 200V, and 750V AC ranges</td>
</tr>
<tr>
<td>cfc10</td>
<td>Crest factor correction factor for 200mV and 20V AC ranges</td>
</tr>
<tr>
<td>acdcclow</td>
<td>AC-coupled correction factor for 200mV and 20V AC ranges</td>
</tr>
<tr>
<td>accdchigh</td>
<td>AC-coupled correction factor for 20V, 200V, and 750V AC ranges</td>
</tr>
<tr>
<td>inputtc</td>
<td>Input time constant</td>
</tr>
<tr>
<td>acdccur</td>
<td>AC-coupled correction factor for AC current</td>
</tr>
<tr>
<td>compval1</td>
<td>RMS comparator DAC code</td>
</tr>
<tr>
<td>div100</td>
<td>Frequency-compensation DAC code for 20V AC range</td>
</tr>
<tr>
<td>div200</td>
<td>Frequency-compensation DAC code for 20V AC range</td>
</tr>
<tr>
<td>div500</td>
<td>Frequency-compensation DAC code for 750V AC range</td>
</tr>
<tr>
<td>div100off</td>
<td>Frequency-compensation DAC offset for 20V AC range</td>
</tr>
<tr>
<td>div200off</td>
<td>Frequency compensation DAC offset for 200V AC range</td>
</tr>
<tr>
<td>div500off</td>
<td>Frequency compensation DAC offset for 750V AC range</td>
</tr>
<tr>
<td>dcv[200mV]gain</td>
<td>200mV DC gain</td>
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<tr>
<td>dcv[200mV]offset</td>
<td>200mV DC offset</td>
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<tr>
<td>dcv[2V]gain</td>
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<td>dcv[2V]offset</td>
<td>2V DC offset</td>
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<tr>
<td>dcv[20V]gain</td>
<td>20V DC gain</td>
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<td>dcv[20V]offset</td>
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<td>dcv[1000V]gain</td>
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<td>dcv[1000V]offset</td>
<td>1kV DC offset</td>
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<td>dca[200uA]gain</td>
<td>200µA DC gain</td>
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<tr>
<td>dca[200uA]offset</td>
<td>200µA DC offset</td>
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<tr>
<td>dca[2mA]gain</td>
<td>2mA DC gain</td>
</tr>
<tr>
<td>dca[2mA]offset</td>
<td>2mA DC offset</td>
</tr>
<tr>
<td>dca[20mA]gain</td>
<td>20mA DC gain</td>
</tr>
<tr>
<td>dca[20mA]offset</td>
<td>20mA DC offset</td>
</tr>
<tr>
<td>dca[200mA]gain</td>
<td>200mA DC gain</td>
</tr>
<tr>
<td>dca[200mA]offset</td>
<td>200mA DC offset</td>
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<tr>
<td>dca[2A]gain</td>
<td>2A DC gain</td>
</tr>
<tr>
<td>dca[2A]offset</td>
<td>2A DC offset</td>
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Table C-2 (continued)
 Calibration constants returned by :CAL:PROT:DATA? Query

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>ohm2[20]gain</td>
<td>2-wire 20¾ gain</td>
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<tr>
<td>ohm2[20]offset</td>
<td>2-wire 20¾ offset</td>
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<tr>
<td>ohm2[200]gain</td>
<td>2-wire 200¾ gain</td>
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<tr>
<td>ohm2[200]offset</td>
<td>2-wire 200¾ offset</td>
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<tr>
<td>ohm2[2k]gain</td>
<td>2-wire 2k¾ gain</td>
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<tr>
<td>ohm2[2k]offset</td>
<td>2-wire 2k¾ offset</td>
</tr>
<tr>
<td>ohm2[20k]gain</td>
<td>2-wire 20k¾ gain</td>
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<tr>
<td>ohm2[20k]offset</td>
<td>2-wire 20k¾ offset</td>
</tr>
<tr>
<td>ohm2[200k]gain</td>
<td>2-wire 200k¾ gain</td>
</tr>
<tr>
<td>ohm2[200k]offset</td>
<td>2-wire 200k¾ offset</td>
</tr>
<tr>
<td>ohm2[2M]gain</td>
<td>2-wire 2M¾ gain</td>
</tr>
<tr>
<td>ohm2[2M]offset</td>
<td>2-wire 2M¾ offset</td>
</tr>
<tr>
<td>ohm2[20M]gain</td>
<td>2-wire 20M¾ gain</td>
</tr>
<tr>
<td>ohm2[20M]offset</td>
<td>2-wire 20M¾ offset</td>
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<tr>
<td>ohm2[200M]gain</td>
<td>2-wire 200M¾ gain</td>
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<tr>
<td>ohm2[200M]offset</td>
<td>2-wire 200M¾ offset</td>
</tr>
<tr>
<td>ohm2[1G]gain</td>
<td>2-wire 1G¾ gain</td>
</tr>
<tr>
<td>ohm2[1G]offset</td>
<td>2-wire 1G¾ offset</td>
</tr>
<tr>
<td>ohm4[20]gain</td>
<td>4-wire 20¾ gain</td>
</tr>
<tr>
<td>ohm4[20]offset</td>
<td>4-wire 20¾ offset</td>
</tr>
<tr>
<td>ohm4[200]gain</td>
<td>4-wire 200¾ gain</td>
</tr>
<tr>
<td>ohm4[200]offset</td>
<td>4-wire 200¾ offset</td>
</tr>
<tr>
<td>ohm4[2k]gain</td>
<td>4-wire 2k¾ gain</td>
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<tr>
<td>ohm4[2k]offset</td>
<td>4-wire 2k¾ offset</td>
</tr>
<tr>
<td>ohm4[20k]gain</td>
<td>4-wire 20k¾ gain</td>
</tr>
<tr>
<td>ohm4[20k]offset</td>
<td>4-wire 20k¾ offset</td>
</tr>
<tr>
<td>ohm4[200k]gain</td>
<td>4-wire 200k¾ gain</td>
</tr>
<tr>
<td>ohm4[200k]offset</td>
<td>4-wire 200k¾ offset</td>
</tr>
<tr>
<td>ohm4[2M]gain</td>
<td>4-wire 2M¾ gain</td>
</tr>
<tr>
<td>ohm4[2M]offset</td>
<td>4-wire 2M¾ offset</td>
</tr>
<tr>
<td>ohm4[20M]gain</td>
<td>4-wire 20M¾ gain</td>
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<td>ohm4[20M]offset</td>
<td>4-wire 20M¾ offset</td>
</tr>
<tr>
<td>ohm4[200M]gain</td>
<td>4-wire 200M¾ gain</td>
</tr>
<tr>
<td>ohm4[200M]offset</td>
<td>4-wire 200M¾ offset</td>
</tr>
<tr>
<td>n7vref</td>
<td>7V reference value</td>
</tr>
<tr>
<td>rollover</td>
<td>±2V rollover</td>
</tr>
<tr>
<td>mux4d711</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4d711p5</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4d215</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4d011</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4d015</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4d0150</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4d015p5</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4dF150</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>mux4dF15</td>
<td>Multiplexer 4-1/2 digit counts (AC peak)</td>
</tr>
<tr>
<td>i20</td>
<td>20¾ range current source value</td>
</tr>
<tr>
<td>i200</td>
<td>200¾ range current source value</td>
</tr>
<tr>
<td>i2k</td>
<td>2k¾ range current source value</td>
</tr>
<tr>
<td>i20k</td>
<td>20k¾ range current source value</td>
</tr>
<tr>
<td>i200k</td>
<td>200k¾ range current source value</td>
</tr>
<tr>
<td>i2m</td>
<td>2M¾ range current source value</td>
</tr>
<tr>
<td>i20m</td>
<td>20M¾ range current source value</td>
</tr>
<tr>
<td>i200m</td>
<td>200M¾ range current source value</td>
</tr>
<tr>
<td>i1g</td>
<td>1G¾ range current source value</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Manufacturer and Model</th>
<th>Function(s)</th>
<th>Comparison to 5700A uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke 5440B Direct Voltage Calibrator</td>
<td>DCV</td>
<td>Equivalent</td>
</tr>
<tr>
<td>Fluke 5450B Resistance Calibration</td>
<td>Ohms</td>
<td>Equivalent</td>
</tr>
<tr>
<td>Fluke 5200A Precision Alternating Voltage Calibrator</td>
<td>ACV</td>
<td>Less precise</td>
</tr>
<tr>
<td>Datron 4808 Multifunction Calibrator (Options 10, 20, 30, 40, 50)</td>
<td>DCV, ACV, DCl, ACI, Ohms</td>
<td>Similar</td>
</tr>
</tbody>
</table>
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.