WARRANTY

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

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

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

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley’s express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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Model 2701 Ethernet-Based DMM / Data Acquisition System
Service Manual

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Manual Print History

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

Revision A (Document Number 2701-902-01) ................................................................. June 2002
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 manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product 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 manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

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

Keithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation 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 Manual.

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 1000 volts, 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, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

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 ca-**
bles or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

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

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

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

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

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

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

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

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

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

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

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

Instrumentation and accessories shall not be connected to humans.

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

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

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

Use the procedures in this section to verify that Model 2701 Ethernet Multimeter/Data Acquisition System accuracy is within the limits stated in the instrument’s one-year accuracy specifications. You can perform these verification procedures:

- Upon receiving the instrument, make sure it was not damaged during shipment and the unit meets factory specifications.
- If the instrument’s accuracy is questionable.
- Following calibration.

WARNING The information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.

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. If the unit is not under warranty and it fails to meet specified limits, refer to the calibration procedures in Section 2.

There are two general verification procedures in this section:

- **Model 2701 verification** — Covers procedures to verify measurement accuracy of the Model 2701 using the front panel terminals.
- **Model 7700 verification** — Discusses procedures to verify accuracy of measurement made through the Model 7700 20-Channel Multiplexer. Note that the same general procedures can be used to verify measurement accuracy of other Model 2701 plug-in modules that have similar functions. For specific information about the individual modules, refer to the appropriate appendices in the Model 2701 User’s Manual.
Verification test requirements

Be sure that you perform the verification tests:

- Under the proper environmental conditions.
- After the specified warm-up period.
- Using the correct line voltage.
- Using the proper calibration equipment.
- Using the specified reading limits.

Environmental conditions

Conduct your performance verification procedures in a test environment that has:

- An ambient temperature of 18°C to 28°C (65°F to 82°F).
- A relative humidity of less than 80% unless otherwise noted.

Warm-up period

Allow the Model 2701 to warm up for at least two hours before conducting the verification procedures.

If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument’s internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Also, allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

The Model 2701 requires a line voltage of 100V/120V/220V/240V ±10% and a line frequency of 45Hz to 66Hz or 360Hz to 440Hz. Note that the line frequency is automatically sensed at power-up, but the line voltage must be manually set to either 100V/120V or 220V/240V as described in Section 3.
Recommended test equipment

Table 1-1 summarizes recommended verification equipment. You can use alternate equipment as long as that equipment has specifications at least as good as those listed in Table 1-1. Keep in mind, however, that calibrator uncertainty will add to the uncertainty of each measurement.

<table>
<thead>
<tr>
<th>Fluke 5700A Calibrator:</th>
<th>AC voltage (1kHz, 50kHz)</th>
<th>DC current</th>
<th>AC current (1kHz)</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100mV ±14ppm</td>
<td>100mV ±200ppm</td>
<td>20mA ±60ppm</td>
<td>1A ±690ppm</td>
<td>100Ω ±17ppm</td>
</tr>
<tr>
<td>1.0V ±7ppm</td>
<td>1.0V ±82ppm</td>
<td>100mA ±70ppm</td>
<td>2.2A ±682ppm</td>
<td>1kΩ ±12ppm</td>
</tr>
<tr>
<td>10V ±5ppm</td>
<td>10V ±82ppm</td>
<td>1A ±110ppm</td>
<td>100kΩ ±13ppm</td>
<td>10kΩ ±11ppm</td>
</tr>
<tr>
<td>100V ±7ppm</td>
<td>100V ±90ppm</td>
<td>2.2A ±94ppm</td>
<td>1MΩ ±18ppm</td>
<td>100kΩ ±13ppm</td>
</tr>
<tr>
<td>1000V ±9ppm</td>
<td>700V ±85ppm</td>
<td></td>
<td></td>
<td>1MΩ ±18ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10MΩ ±37ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100MΩ ±120ppm</td>
</tr>
</tbody>
</table>

Fluke 5725A Amplifier:
- AC Voltage, 50kHz, 700V, ±375ppm
- DC Current, 3A, ±500ppm
- AC Current, 1kHz, 3A, ±457ppm

Stanford Research Systems DS345 Function Generator:
- 1V RMS 1kHz, ±5ppm

General Radio 1433-T Precision Decade Resistance Box:
- 10Ω to 400Ω, ±0.02%

Miscellaneous Equipment:
- Double banana plug to double banana plug shielded cables (2)
- BNC to double banana plug shielded cable

NOTE: The Fluke 5725A amplifier is necessary only if you wish to verify the 750V AC range at 50kHz and 3A AC and DC current ranges at 3A. Verification at 220V, 50kHz, and 2.2A on the current ranges using only the 5700A calibrator is adequate for most applications.
Verification limits

The verification limits stated in this section have been calculated using only the Model 2701 one-year accuracy specifications, and they do not include test equipment uncertainty. If a particular measurement falls slightly outside the allowable range, recalculate new limits based on both Model 2701 specifications and pertinent calibration equipment specifications.

Example reading limit calculation

The following is an example of how reading limits have been calculated. Assume you are testing the 10V DC range using a 10V input value. Using the Model 2701 one-year accuracy specification for 10V DC of ± (30ppm of reading + 5ppm of range), the calculated limits are:

- Reading limits = 10V ± [(10V × 30ppm) + (10V × 5ppm)]
- Reading limits = 10V ± (0.0003 + 0.00005)
- Reading limits = 10V ± 0.00035V
- Reading limits = 9.99965V to 10.00035V

Calculating resistance reading limits

Resistance reading limits must be recalculated based on the actual calibration resistance values supplied by the equipment manufacturer. Calculations are performed in the same manner as shown in the preceding example, except, of course, that you should use the actual calibration resistance values instead of the nominal values when performing your calculations.

For example, assume that you are testing the 10kΩ range using an actual 10.03kΩ calibration resistance value. Using Model 2701 one-year 10kΩ range accuracy of ± (100ppm of reading + 6ppm of range), the calculated reading limits are:

- Reading limits = 10.03kΩ ± [(10.03kΩ × 100ppm) + (10kΩ × 6ppm)]
- Reading limits = 10.02894kΩ to 10.03106kΩ

Restoring factory defaults

Before performing the verification procedures, restore the instrument to its factory defaults as follows:

1. Press SHIFT and then SETUP. The instrument will display the following prompt:
   RESTORE: FACT.
2. Using either range key, select FACT, then restore the factory default conditions by pressing ENTER.
Performing the verification test procedures

**Verification test summary**

Verification tests can be performed either through the Model 2701 front panel terminals or through plug-in modules. This section contains the following procedures:

- **Model 2701 verification** — Use this procedure to test Model 2701 accuracy through the front panel terminals.
- **Model 7700 verification** — Use this procedure to test accuracy through any of the available plug-in modules with the same functions as the Model 7700 20-Channel Multiplexer Card.

**Model 2701 tests**

Model 2701 verification test procedures include:

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

**Model 7700 tests**

Model 7700 verification test procedures include:

- DC volts
- AC volts
- DC current
- AC current
- Resistance
- Temperature
- Frequency
- Ratio and average
Test considerations

When performing the verification procedures:

• Be sure to restore factory defaults as outlined above.
• Make sure that the equipment is properly warmed up and connected to the correct input terminals. Also, make sure that the INPUTS switch is in the correct position.
• Do not use autoranging for any verification tests, because autorange hysteresis may cause the Model 2701 to be on an incorrect range. For each test signal, you must manually set the correct range for the Model 2701 using the range keys.
• Make sure the calibrator is in operate before you verify each measurement.
• Always let the source signal settle before taking a reading.

WARNING Observe the following safety precautions when performing these tests:

• 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 or death caused by electric shock.

• For the front panel terminals only, 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.

• For the plug-in modules, the maximum common-mode voltage (voltage between any plug-in module terminal and chassis ground) is 300V DC or 300V RMS. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.

• When using the front panel terminals simultaneously with plug-in modules, all cable insulation voltage ratings must equal or exceed the maximum voltage applied to either the front panel terminals or the plug-in module terminals.
**Model 2701 verification**

Perform these tests to verify accuracy using the Model 2701 front panel terminals.

**Verifying DC voltage**

Check DC voltage accuracy by applying accurate voltages from the DC voltage calibrator to the Model 2701 INPUT jacks and verifying that the displayed readings fall within specified limits.

*CAUTION*  Do not exceed 1000V peak between front terminals INPUT HI and INPUT LO because instrument damage may occur.

Follow these steps to verify DC voltage accuracy:

1. Connect the Model 2701 HI and LO INPUT jacks to the DC voltage calibrator as shown in Figure 1-1. Make sure the INPUTS switch is set to the FRONT position.

*NOTE*  Use shielded, low-thermal connections when testing the 100mV and 1V ranges to avoid errors caused by noise or thermal effects. Connect the shield to the calibrator’s output LO terminal.

---

**Figure 1-1**

*Connections for Model 2701 DC volts verification*
2. Select the DC volts function by pressing the DCV key and set the Model 2701 to the 100mV range.
3. Set the calibrator output to 0.00000mV DC and allow the reading to settle.
4. Enable the Model 2701 REL mode. Leave REL enabled for the remainder of the DC volts verification tests.
5. Source positive and negative and full-scale voltages for each of the ranges listed in Table 1-2. For each voltage setting, be sure that the reading is within stated limits.

**Table 1-2**

*DCV reading limits*

<table>
<thead>
<tr>
<th>Range</th>
<th>Applied DC voltage*</th>
<th>Reading limits (1 year, 18° to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mV</td>
<td>100.0000mV</td>
<td>99.9935 to 100.0065mV</td>
</tr>
<tr>
<td>1V</td>
<td>1.000000V</td>
<td>0.999963 to 1.000037V</td>
</tr>
<tr>
<td>10V</td>
<td>10.00000V</td>
<td>9.99965 to 10.00035V</td>
</tr>
<tr>
<td>100V</td>
<td>100.0000V</td>
<td>99.9946 to 100.0054V</td>
</tr>
<tr>
<td>1000V</td>
<td>1000.000V</td>
<td>999.941 to 1000.059V</td>
</tr>
</tbody>
</table>

*Source positive and negative values for each range.*
Verifying AC voltage

Check AC voltage accuracy by applying accurate AC voltages at specific frequencies from the AC voltage calibrator to the Model 2701 inputs and verifying that the displayed readings fall within specified ranges.

**CAUTION** Do not exceed 1000V peak between front terminals INPUT HI and INPUT LO, or $8 \times 10^7$ V•Hz input, because instrument damage may occur.

Follow these steps to verify AC voltage accuracy:

1. Connect the Model 2701 HI and LO INPUT jacks to the AC voltage calibrator as shown in Figure 1-2. Be sure the INPUTS switch is in the FRONT position.

*Figure 1-2
Connections for Model 2701 AC volts verification*
2. Select the AC volts function by pressing the ACV key.

3. Set the Model 2701 for the 100mV range; make sure that REL is disabled.

4. Source 1kHz and 50kHz AC voltages for each of the ranges summarized in Table 1-3 and make sure that the respective Model 2701 readings fall within stated limits.

**Table 1-3**

*ACV reading limits*

<table>
<thead>
<tr>
<th>ACV range</th>
<th>Applied AC voltage</th>
<th>1kHz reading limits (1 year, 18°C to 28°C)</th>
<th>50kHz reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mV</td>
<td>100.0000mV</td>
<td>99.910 to 100.090mV</td>
<td>99.830 to 100.170mV</td>
</tr>
<tr>
<td>1V</td>
<td>1.000000V</td>
<td>0.99910 to 1.00090V</td>
<td>0.99830 to 1.00170V</td>
</tr>
<tr>
<td>10V</td>
<td>10.00000V</td>
<td>9.9910 to 10.0090V</td>
<td>9.9830 to 10.0170V</td>
</tr>
<tr>
<td>100V</td>
<td>100.0000V</td>
<td>99.910 to 100.090V</td>
<td>99.830 to 100.170V</td>
</tr>
<tr>
<td>750V</td>
<td>700.0000V*</td>
<td>699.36 to 700.64V</td>
<td>698.79 to 701.21V</td>
</tr>
</tbody>
</table>

* If the 5725A amplifier is not available, change the 700V @ 50kHz step to 220V @ 50kHz. Reading limits for 220V @ 50kHz = 219.36 to 220.64V.
Verifying DC current

Check DC current accuracy by applying accurate DC currents from the DC current calibrator to the AMPS input of the Model 2701 and verifying that the displayed readings fall within specified limits.

Follow these steps to verify DC current accuracy:

1. Connect the Model 2701 AMPS and INPUT LO jacks to the calibrator as shown in Figure 1-3. Be sure the INPUTS switch is in the FRONT position.

Figure 1-3

Connections for Model 2701 DC current verification

2. Select the DC current measurement function by pressing the DCI key.
3. Set the Model 2701 for the 20mA range.
4. Source positive and negative full-scale currents for each of the ranges listed in Table 1-4 and verify that the readings for each range are within stated limits.

Table 1-4

<table>
<thead>
<tr>
<th>DCI range</th>
<th>Applied DC current*</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mA</td>
<td>20.0000mA</td>
<td>19.98840 to 20.011160mA</td>
</tr>
<tr>
<td>100mA</td>
<td>100.0000mA</td>
<td>99.8700 to 100.1300mA</td>
</tr>
<tr>
<td>1A</td>
<td>1.000000A</td>
<td>0.999120 to 1.000880A</td>
</tr>
<tr>
<td>3A</td>
<td>3.000000A**</td>
<td>2.99628 to 3.00372A</td>
</tr>
</tbody>
</table>

* Source positive and negative currents with values shown.
** If the Fluke 5725 amplifier is not available, apply 2.2A from calibrator. Reading limits for 2.2A input are: 2.197240 to 2.202760A.
Verifying AC current

Check AC current accuracy by applying accurate AC voltage current at specific frequencies from the AC current calibrator to the Model 2701 input, verifying that the displayed readings fall within specified limits. Follow these steps to verify AC current.

1. Connect the Model 2701 AMPS and INPUT LO jacks to the calibrator as shown in Figure 1-4. Be sure the INPUTS switch is in the FRONT position.

2. Select the AC current function by pressing the ACI key.
3. Set the Model 2701 for the 1A range.
4. Source 1A and 3A, 1kHz full-scale AC currents as summarized in Table 1-5, and verify that the readings are within stated limits.

Table 1-5
ACI limits

<table>
<thead>
<tr>
<th>ACV range</th>
<th>Applied AC voltage</th>
<th>Reading limits @ 1kHz (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>1.000000A</td>
<td>0.99860 to 1.00140A</td>
</tr>
<tr>
<td>3A</td>
<td>3.000000A*</td>
<td>2.9817 to 3.0183A</td>
</tr>
</tbody>
</table>

* If the Fluke 5725A amplifier is not available, apply 2.2A from the calibrator. Reading limits for 2.2A are 2.1949 to 2.2051A.
Verifying resistance

Check resistance by connecting accurate resistance values to the Model 2701 and verifying that its resistance readings are within the specified limits.

**CAUTION** Do not apply more than 1000V peak between front terminals INPUT HI and LO or more than 350V peak between SENSE HI and LO, or instrument damage could occur.

Follow these steps to verify resistance accuracy:

1. Using shielded, Teflon-insulated or equivalent cables in a 4-wire configuration, connect the Model 2701 INPUT and SENSE jacks to the calibrator as shown in Figure 1-5. Be sure the INPUTS switch is in the FRONT position.

2. Set the calibrator for 4-wire resistance with external sense on.
3. Select the Model 2701 4-wire resistance function by pressing the Ω4 key, then choose the SLOW integration rate with the RATE key.
4. Set the Model 2701 for the 100Ω range and make sure the FILTER is on. Enable OCOMP (offset-compensated ohms) for 100Ω range verification. (Press SHIFT then OCOMP.)
5. Recalculate reading limits based on actual calibrator resistance values.
6. Source the nominal full-scale resistance values for the 100Ω-10MΩ ranges summarized in Table 1-6 and verify that the readings are within calculated limits.
7. Connect the Model 2701 INPUT and SENSE jacks to the calibrator as shown in Figure 1-6.
8. Disable external sense on the calibrator.
9. Set the Model 2701 for the 100MΩ range.
10. Source a nominal 100MΩ resistance value and verify that the reading is within calculated limits for the 100MΩ range.

![Figure 1-6](image)

Connections for Model 2701 resistance verification (100MΩ range)

![Table 1-6](image)

<table>
<thead>
<tr>
<th>Ω Range</th>
<th>Nominal resistance</th>
<th>Nominal reading limits (1 year, 18°C to 28°C)</th>
<th>Recalculated limits**</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Ω*</td>
<td>100Ω</td>
<td>99.9880 to 100.0120Ω</td>
<td>100Ω to 100.0120Ω</td>
</tr>
<tr>
<td>1kΩ</td>
<td>1kΩ</td>
<td>0.999894 to 1.000106kΩ</td>
<td>1kΩ to 1.000106kΩ</td>
</tr>
<tr>
<td>10kΩ</td>
<td>10kΩ</td>
<td>9.99894 to 10.00106kΩ</td>
<td>10kΩ to 10.00106kΩ</td>
</tr>
<tr>
<td>100kΩ</td>
<td>100kΩ</td>
<td>99.9890 to 100.0110kΩ</td>
<td>100kΩ to 100.0110kΩ</td>
</tr>
<tr>
<td>1MΩ</td>
<td>1MΩ</td>
<td>0.999890 to 1.000110MΩ</td>
<td>1MΩ to 1.000110MΩ</td>
</tr>
<tr>
<td>10MΩ</td>
<td>10MΩ</td>
<td>9.99590 to 10.00410MΩ</td>
<td>10MΩ to 10.00410MΩ</td>
</tr>
<tr>
<td>100MΩ</td>
<td>100MΩ</td>
<td>99.7970 to 100.2030MΩ</td>
<td>100MΩ to 100.2030MΩ</td>
</tr>
</tbody>
</table>

* Enable O COMP (offset-compensated ohms) when testing 100Ω range.
** Calculate limits based on actual calibration resistance values and Model 2701 one-year resistance accuracy specifications. See Verification limits.
Verifying temperature

Thermocouple, thermistor, and RTD temperature readings are derived from DC volts and resistance measurements respectively. For that reason, it is not necessary to independently verify the accuracy of temperature measurements. As long as the DC volts and resistance functions meet or exceed specifications, temperature function accuracy is automatically verified. However, temperature verification procedures are provided below for those who wish to separately verify temperature accuracy.

Thermocouple temperature

1. Connect the DC voltage calibrator output terminals to the Model 2701 INPUT jacks using low-thermal shielded connections. (Use 2-wire connections similar to those shown in Figure 1-1.) Be sure the INPUTS switch is in the FRONT position.
2. Configure the Model 2701 for °C units, type J temperature sensor, and 0°C simulated reference junction as follows:
   a. Press SHIFT then SENSOR and note the unit displays the temperature units: UNITS: C. (If necessary, use the cursor and range keys to select °C units.)
   b. Press ENTER. The unit displays the sensor type: SENS: TCOUPLE.
   c. Make sure that TCOUPLE is displayed, then press ENTER. The unit then displays the thermocouple type: TYPE: K.
   d. Select a type J temperature sensor, then press ENTER. The unit then displays the reference junction type: JUNC: SIM.
   e. Make certain that the simulated reference junction type is selected, then press ENTER. The unit then displays the current simulated reference junction temperature: SIM: 023.
   f. Using the cursor and range keys, set the reference junction temperature to 0°C, then press ENTER twice to complete the temperature configuration process.
3. Select the temperature function by pressing the TEMP key.
4. Source each of the voltages summarized in Table 1-7 and verify that the temperature readings are within limits. Be sure to select the appropriate thermocouple type for each group of readings. (See step 2 above.)

Table 1-7

<table>
<thead>
<tr>
<th>Thermocouple type</th>
<th>Applied DC voltage*</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>-7.659mV 0mV 42.280mV</td>
<td>-190.2° to -189.8°C -0.2° to +0.2°C 749.8° to 750.2°C</td>
</tr>
<tr>
<td>K</td>
<td>-5.730mV 0mV 54.138mV</td>
<td>-190.2° to -189.8°C -0.2° to +0.2°C 1349.8° to 1350.2°C</td>
</tr>
</tbody>
</table>

* Voltages shown are based on ITS-90 standard using 0°C reference junction temperature. See text for procedure to set reference junction temperature.
RTD temperature

1. Connect the precision decade resistance box (listed in Table 1-1) to the Model 2701 INPUT and SENSE jacks using four-wire connections. (See Figure 1-5 for similar connecting scheme.) Be sure the INPUTS switch is in the FRONT position.

2. Configure the Model 2701 temperature function for °C units and RTD temperature sensor (α=0.00385) as follows:
   a. Press SHIFT then SENSOR and note the unit displays the temperature units: UNITS: C.
   b. Press ENTER and note the unit displays the sensor type: SENS: TCOUPLE.
   c. Using the cursor and range keys, set the display as follows: SENS: 4W-RTD.
   d. Press ENTER and note the unit displays: TYPE: PT100.
   e. Using the cursor and range keys, set the unit for the following display: TYPE: PT385.
   f. Press ENTER to complete the temperature configuration process.

3. Select the temperature function by pressing the TEMP key.

4. Set the decade resistance box to each of the values shown in Table 1-8 and verify that the temperature readings are within the required limits.

Table 1-8
Four-wire RTD temperature verification reading limits

<table>
<thead>
<tr>
<th>Applied resistance*</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.80Ω</td>
<td>-190.06 to -189.94°C</td>
</tr>
<tr>
<td>100.00Ω</td>
<td>-0.06 to +0.06°C</td>
</tr>
<tr>
<td>313.59Ω</td>
<td>599.94 to 600.06°C</td>
</tr>
</tbody>
</table>

*Based on α = 0.00385. See text.
Verifying frequency

Follow the steps below to verify the Model 2701 frequency function:

1. Connect the function generator to the Model 2701 INPUT jacks. (See Figure 1-7.) Be sure the INPUTS switch is in the FRONT position.
2. Set the function generator to output a 1kHz, 1V RMS sine wave.
3. Select the Model 2701 frequency function by pressing the FREQ key.
4. Verify that the Model 2701 frequency reading is between 999.9Hz and 1.0001kHz.

Figure 1-7
Connections for Model 2701 frequency verification

Model 7700 verification

Use these procedures to verify measurement accuracy through the Model 7700 20-Channel Multiplexer Card.

NOTE Although the following tests are based on the Model 7700 20-Channel Multiplexer, the same general procedures can be used for other plug-in modules that have similar capabilities. Refer to the Model 2701 User’s Manual for specific information on terminals and connections for other plug-in modules.

Verifying DC voltage

Check DC voltage accuracy by applying accurate voltages from the DC voltage calibrator to the Model 7700 input terminals and verifying that the displayed readings fall within specified limits.

CAUTION Do not exceed 300V DC between plug-in module INPUT H and L terminals or between any adjacent channels.
Follow these steps to verify DC voltage accuracy:

1. Connect the Model 7700 CH1 H and L INPUT terminals to the DC voltage calibrator as shown in Figure 1-8.

**NOTE** Use shielded, low-thermal connections when testing the 100mV and 1V ranges to avoid errors caused by noise or thermal effects. Connect the shield to the calibrator’s output LO terminal.

2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS switch is set to the REAR position.

3. Select the DC volts function by pressing the DCV key and set the Model 2701 to the 100mV range. Close Channel 1 by pressing the CLOSE key and then keying in 101.

4. Set the calibrator output to 0.00000mV DC and allow the reading to settle.

5. Enable the Model 2701 REL mode. Leave REL enabled for the remainder of the DC volts verification tests.

6. Source positive and negative and full-scale voltages for each of the ranges listed in Table 1-9. For each voltage setting, be sure that the reading is within stated limits.

7. Press the OPEN key to open Channel 1.

**Table 1-9**
Plug-in module DCV reading limits

<table>
<thead>
<tr>
<th>Range</th>
<th>Applied DC voltage*</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mV</td>
<td>100.00000mV</td>
<td>99.9935 to 100.0065mV</td>
</tr>
<tr>
<td>1V</td>
<td>1.0000000V</td>
<td>0.999963 to 1.000037V</td>
</tr>
<tr>
<td>10V</td>
<td>10.000000V</td>
<td>9.99965 to 10.00035V</td>
</tr>
<tr>
<td>100V</td>
<td>100.00000V</td>
<td>99.9946 to 100.0054V</td>
</tr>
<tr>
<td>1000V</td>
<td>300.00000V</td>
<td>299.976 to 300.024V</td>
</tr>
</tbody>
</table>

*Source positive and negative values for each range.
Verifying AC voltage

Check AC voltage accuracy by applying accurate AC voltages at specific frequencies from the AC voltage calibrator to the Model 7700 inputs and verifying that the displayed readings fall within specified ranges.

CAUTION Do not exceed 300V RMS between plug-in module INPUT H and L terminals or between adjacent channels, or $8 \times 10^7$ V•Hz input, because instrument damage may occur.

Follow these steps to verify AC voltage accuracy:

1. Connect the Model 7700 CH1 H and L INPUT terminals to the AC voltage calibrator as shown in Figure 1-9.

Figure 1-9
Connections for Model 7700 AC volts verification
2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow
the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS
switch is set to the REAR position.
3. Select the AC volts function by pressing the ACV key. Close Channel 1 by pressing the
CLOSE key and then keying in 101.
4. Set the Model 2701 for the 100mV range, make sure that REL is disabled.
5. Source 1kHz and 50kHz AC voltages for each of the ranges summarized in Table 1-10
and make sure that the respective Model 2701 readings fall within stated limits.
6. Press the OPEN key to open Channel 1.

Table 1-10
Plug-in module ACV reading limits

<table>
<thead>
<tr>
<th>ACV range</th>
<th>Applied AC voltage</th>
<th>1kHz reading limits (1 year, 18°C to 28°C)</th>
<th>50kHz reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mV</td>
<td>100.0000mV</td>
<td>99.910 to 100.090mV</td>
<td>99.830 to 100.170mV</td>
</tr>
<tr>
<td>1V</td>
<td>1.000000V</td>
<td>0.99910 to 1.00090V</td>
<td>0.99830 to 1.00170V</td>
</tr>
<tr>
<td>10V</td>
<td>10.000000V</td>
<td>9.9910 to 10.0090V</td>
<td>9.98300 to 10.0170V</td>
</tr>
<tr>
<td>100V</td>
<td>100.0000V</td>
<td>99.910 to 100.090V</td>
<td>99.830 to 100.170V</td>
</tr>
<tr>
<td>750V</td>
<td>300.0000V*</td>
<td>299.60 to 300.40V</td>
<td>299.27 to 300.73V</td>
</tr>
</tbody>
</table>

* If the 5725A amplifier is not available, change the 300V @ 50kHz step to 220V @ 50kHz. Reading limits for 220V @ 50kHz = 219.36 to 220.64V.
Verifying DC current

Check DC current accuracy by applying accurate DC currents from the DC current calibrator to the input terminals of the Model 7700 and verifying that the displayed readings fall within specified limits.

Follow these steps to verify DC current accuracy:

1. Connect the Model 7700 CH21 H and L terminals to the calibrator as shown in Figure 1-10.

Figure 1-10
Connections for Model 7700 DC current verification

Note: Be sure calibrator is set for normal current output.
2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS switch is set to the REAR position.

3. Select the DC current measurement function by pressing the DCI key.

4. Set the Model 2701 for the 20mA range. Close Channel 21 by pressing the CLOSE key and keying in 121.

5. Source positive and negative full-scale currents for each of the ranges listed in Table 1-11, and verify that the readings for each range are within stated limits.

6. Press the OPEN key to open Channel 21.

<table>
<thead>
<tr>
<th>Table 1-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug-in module DCI limits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DCI range</th>
<th>Applied DC current*</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mA</td>
<td>20.0000mA</td>
<td>19.99840 to 20.01160mA</td>
</tr>
<tr>
<td>100mA</td>
<td>100.0000mA</td>
<td>99.98700 to 100.1300mA</td>
</tr>
<tr>
<td>1A</td>
<td>1.000000A</td>
<td>0.999120 to 1.000880A</td>
</tr>
<tr>
<td>3A</td>
<td>3.000000A**</td>
<td>2.99628 to 3.00372A</td>
</tr>
</tbody>
</table>

* Source positive and negative currents with values shown.

** If the Fluke 5725 amplifier is not available, apply 2.2A from calibrator. Reading limits for 2.2A input are: 2.197240 to 2.202760A.
Verifying AC current

Check AC current accuracy by applying accurate AC voltage current at specific frequencies from the AC current calibrator to the Model 7700 input terminals and verifying that the displayed readings fall within specified limits. Follow these steps to verify AC current:

1. Connect the Model 7700 CH21 H and L terminals to the calibrator as shown in Figure 1-11.

Figure 1-11
Connections for Model 7700 AC current verification

2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS switch is set to the REAR position.

3. Select the AC current function by pressing the ACI key.

4. Set the Model 2701 for the 1A range. Close Channel 21 by pressing the CLOSE key and keying in 121.

5. Source 1A and 3A, 1kHz full-scale AC currents as summarized in Table 1-12 and verify that the readings are within stated limits.

6. Press the OPEN key to open Channel 21.

Table 1-12
Plug-in module ACI limits

<table>
<thead>
<tr>
<th>ACV range</th>
<th>Applied AC voltage</th>
<th>Reading limits @ 1kHz (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>1.000000A</td>
<td>0.99860 to 1.00140A</td>
</tr>
<tr>
<td>3A</td>
<td>3.000000A*</td>
<td>2.9817 to 3.0183A</td>
</tr>
</tbody>
</table>

* If the Fluke 5725A amplifier is not available, apply 2.2A from the calibrator. Reading limits for 2.2A are 2.1949 to 2.2051A.
Verifying resistance

Check resistance by connecting accurate resistance values to the Model 7700 and verifying that its resistance readings are within the specified limits.

CAUTION Do not apply more than 300V between plug-in module INPUT or SENSE H and L terminal, or between any adjacent channels, or instrument damage could occur.

Follow these steps to verify resistance accuracy:

1. Using shielded Teflon or equivalent cables in a 4-wire configuration, connect the Model 7700 CH1 H and L INPUT terminals and CH11 H and L SENSE terminals to the calibrator as shown in Figure 1-12.

Figure 1-12
Connections for Model 7700 resistance verification (100Ω to 10MΩ ranges)

Note: Use shielded, low-thermal cables to minimize noise. Enable or disable calibrator external sense as indicated in procedure.
2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow
the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS
switch is set to the REAR position.
3. Set the calibrator for 4-wire resistance with external sense on.
4. Select the Model 2701 4-wire resistance function by pressing the Ω4 key. Close
Channel 1 by pressing the CLOSE key and keying in 101.
5. Set the Model 2701 for the 100Ω range and make sure the FILTER is on. Enable
OCOMP (offset-compensated ohms) for the 100Ω range test. (Press SHIFT then
OCOMP.)
6. Recalculate reading limits based on actual calibrator resistance values.
7. Source the nominal full-scale resistance values for the 100Ω-10MΩ ranges summarized
in Table 1-13 and verify that the readings are within calculated limits.

Table 1-13
Limits for plug-in module resistance verification

<table>
<thead>
<tr>
<th>Ω Range</th>
<th>Nominal resistance</th>
<th>Nominal reading limits (1 year, 18°C to 28°C)</th>
<th>Recalculated limits**</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Ω*</td>
<td>100Ω</td>
<td>99.9880 to 100.0120Ω</td>
<td>______ to ______ Ω</td>
</tr>
<tr>
<td>1kΩ</td>
<td>1kΩ</td>
<td>0.999894 to 1.000106kΩ</td>
<td>______ to ______ kΩ</td>
</tr>
<tr>
<td>10kΩ</td>
<td>10kΩ</td>
<td>9.99894 to 10.00106kΩ</td>
<td>______ to ______ kΩ</td>
</tr>
<tr>
<td>100kΩ</td>
<td>100kΩ</td>
<td>99.9890 to 100.0110kΩ</td>
<td>______ to ______ kΩ</td>
</tr>
<tr>
<td>1MΩ</td>
<td>1MΩ</td>
<td>0.999890 to 1.000110MΩ</td>
<td>______ to ______ MΩ</td>
</tr>
<tr>
<td>10MΩ</td>
<td>10MΩ</td>
<td>9.99370 to 10.00630MΩ</td>
<td>______ to ______ MΩ</td>
</tr>
<tr>
<td>100MΩ</td>
<td>100MΩ</td>
<td>99.5770 to 100.4230MΩ</td>
<td>______ to ______ MΩ</td>
</tr>
</tbody>
</table>

* Enable OCOMP for 100Ω range.
** Calculate limits based on actual calibration resistance values and Model 2701 one-year resistance accuracy specifications. See Verification limits.
8. Connect the Model 7700 CH1 and CH11 terminals to the calibrator as shown in Figure 1-13.
9. Disable external sense on the calibrator.
10. Set the Model 2701 for the 100MΩ range.
11. Source a nominal 100MΩ resistance value and verify that the reading is within calculated limits for the 100MΩ range.
12. Press the OPEN key to open Channel 1.

Figure 1-13
Connections for Model 7700 resistance verification (100MΩ range)

Note: Use shielded cables to minimize noise. Disable calibrator external sense mode.
Verifying temperature

Thermocouple, thermistor, and RTD temperature readings are derived from DC volts and resistance measurements respectively. For that reason, it is not necessary to independently verify the accuracy of temperature measurements. As long as the DC volts and resistance functions meet or exceed specifications, temperature function accuracy is automatically verified. However, temperature verification procedures are provided below for those who wish to separately verify temperature accuracy.

Thermocouple temperature

1. Connect the DC voltage calibrator output terminals and ice point reference to the Model 7700 CH1 H and L INPUT terminals using low-thermal shielded connections, as shown in Figure 1-14.
2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS switch is set to the REAR position.
3. Select the temperature function by pressing the TEMP key. Close Channel 1 by pressing the CLOSE key and keying in 101.
4. Configure the Model 2701 for °C units, type K temperature sensor, and internal reference junction as follows:
   a. Press SHIFT then SENSOR and note the unit displays the temperature units: UNITS: C. (If necessary, use the cursor and range keys to select °C units.)
   b. Press ENTER. The unit then displays the sensor type: SENS: TCouple.
   c. Make sure that TCouple is displayed, then press ENTER. The unit displays the thermocouple type: TYPE: J.
   d. Select a type K temperature sensor, then press ENTER. The unit then displays the reference junction type: JUNC: SIM.
   e. Select INT reference junction, then press ENTER.
5. Source each of the voltages summarized in Table 1-14 and verify that the temperature readings are within limits. Be sure to select the appropriate thermocouple type for each group of readings. (See step 3 above.) Open Channel 1 after the test is complete.

**Table 1-14**
Model 7700 thermocouple temperature verification reading limits

<table>
<thead>
<tr>
<th>Thermocouple type</th>
<th>Applied DC voltage*</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>-7.659mV, 0mV, 42.280mV</td>
<td>-191.0° to -189.0°C, -1.0° to +1.0°C, 749.0° to 751.0°C</td>
</tr>
<tr>
<td>K</td>
<td>-5.730mV, 0mV, 54.138mV</td>
<td>-191.0° to -189.0°C, -1.0° to +1.0°C, 1349.0° to 1351.0°C</td>
</tr>
</tbody>
</table>

*Voltages shown are based on ITS-90 standard.
RTD temperature

1. Connect the precision decade resistance box (listed in Table 1-1) to the Model 7700 CH1 and CH11 H and L terminals using four-wire connections. (See Figure 1-12 for similar connecting scheme.)

2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS switch is set to the REAR position.

3. Select the temperature function by pressing the TEMP key. Close Channel 1 by pressing the CLOSE key and keying in 101.

4. Configure the Model 2701 temperature function for °C units and RTD temperature sensor ($\alpha=0.00385$) as follows:
   a. Press SHIFT then SENSOR and note the unit displays the temperature units: UNITS: C.
   b. Press ENTER and note the unit displays the sensor type: SENS: TCOUPLE.
   c. Using the cursor and range keys, set the display as follows: SENS: 4W-RTD.
   d. Press ENTER and note the unit displays: TYPE: PT100.
   e. Using the cursor and range keys, set the unit for the following display: TYPE: PT385.
   f. Press ENTER to complete the temperature configuration process.

5. Set the decade resistance box to each of the values shown in Table 1-15 and verify that the temperature readings are within the required limits. Open Channel 1 when finished.

<table>
<thead>
<tr>
<th>Applied resistance*</th>
<th>Reading limits (1 year, 18°C to 28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.80Ω</td>
<td>-190.06° to -189.94°C</td>
</tr>
<tr>
<td>100.00Ω</td>
<td>-0.06° to +0.06°C</td>
</tr>
<tr>
<td>313.59Ω</td>
<td>599.94° to 600.06°C</td>
</tr>
</tbody>
</table>

*Based on $\alpha = 0.00385$. See text.
Verifying frequency

Follow the steps below to verify the Model 2701 frequency function:

1. Connect the function generator to the Model 7700 CH1 H and L INPUT terminals. (See Figure 1-15.)
2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow the unit to warm up for one hour before proceeding. Be sure the front panel INPUTS switch is set to the REAR position.
3. Set the function generator to output a 1kHz, 1V RMS sine wave.
4. Select the Model 2701 frequency function by pressing the FREQ key. Close Channel 1 by pressing the CLOSE key and keying in 101.
5. Verify that the Model 2701 frequency reading is between 0.9999kHz and 1.0001kHz.

Figure 1-15
Connections for Model 7700 frequency verification
Verifying ratio and average

Follow the procedure below to verify ratio and average.

**CAUTION** Exceeding 300V between plug-in module INPUT or SENSE H and L terminals may cause instrument damage.

1. Connect the Model 7700 CH1 and CH11 H and L terminals to the DC calibrator, as shown in Figure 1-16.
2. Install the Model 7700 in Slot 1 of the Model 2701, then turn on the power and allow the unit to warm up for two hours before proceeding. Be sure the front panel INPUTS switch is set to the REAR position.
3. Select the Model 2701 DCV function and the 1V range. Close Channel 1 by pressing the CLOSE key and keying in 101.
4. Select the Model 2701 RATIO function (press SHIFT then RATIO).
5. Set the calibrator output to 1.00000V DC and allow the reading to settle.
6. Verify that the ratio reading is between 0.9999926 and 1.000074.
7. Press OPEN to open Channel 1.

*Figure 1-16*
Connections for Model 7700 ratio and average verification

Note: Use shielded cables to minimize noise.
2 Calibration
Introduction

Use the procedures in this section to calibrate the Model 2701. Calibration procedures include:

- Comprehensive calibration: Usually the only calibration required in the field.
- Manufacturing calibration: Usually only performed at the factory (unless the unit has been repaired).
- Model 7700 calibration: Covers calibration procedures specific to Model 7700 cards.

WARNING The information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.

All the procedures require accurate calibration equipment to supply precise DC and AC voltages, DC and AC currents, and resistance values. Comprehensive calibration can be performed any time by an operator either from the front panel or by using the SCPI commands sent either over the Ethernet port or the RS-232 port. DC-only and AC-only calibration may be performed individually, if desired.

Environmental conditions

Conduct the calibration procedures in a location that has:

- An ambient temperature of 18° to 28°C (65° to 82°F).
- A relative humidity of less than 80% unless otherwise noted.

Warm-up period

Allow the Model 2701 Ethernet Multimeter/Data Acquisition system to warm up for at least two hours before performing calibration.

If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow extra time for the instrument’s internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

Also, allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

The Model 2701 requires a line voltage of 100V/120V/220V/240V ±10% and a line frequency of 45Hz to 66Hz or 360Hz to 440Hz. Note that the line frequency is automatically sensed at power-up, but the line voltage must be manually set to either 100V/120V or 220V/240V as described in Section 3.
Calibration considerations

When performing the calibration procedures:

- Make sure that the equipment is properly warmed up and connected to the appropriate input jacks. Also make sure that the correct front or rear terminals are selected with the INPUTS switch.
- Make sure the calibrator is in OPERATE before you complete each calibration step.
- Always let the source signal settle before calibrating each point.
- If an error occurs during calibration, the Model 2701 will generate an appropriate error message. See Appendix B for more information.

**WARNING**  Observe the following safety precautions when performing these tests:

- 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 or death caused by electric shock.

- For the front panel terminals only, 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.

- For the plug-in modules, the maximum common-mode voltage (voltage between any plug-in module terminal and chassis ground) is 300V DC or 300V RMS. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.

- When using the front panel terminals simultaneously with plug-in modules, all cable insulation voltage ratings must equal or exceed the maximum voltage applied to either the front panel terminals or the plug-in module terminals.
Calibration code

Before performing comprehensive calibration, you must first unlock calibration by entering the appropriate calibration code.

**Front panel calibration code**

For front panel calibration, follow these steps:

1. Access the calibration menu by pressing SHIFT then TEST, then use the up or down range key to display TEST: CALIB. Press ENTER and note that the instrument displays the following:
   
   CAL: DATES

2. Use the up or down range key to scroll through the available calibration items until the unit displays RUN, then press ENTER.

3. The Model 2701 then prompts you to enter a code:
   
   CODE? 000000

   (The factory default code is 002701.) Use the left and right arrow keys to move among the digits; use the up range key to increment numbers and press the down range key to specify alphabetic letters. Confirm the code by pressing ENTER.

4. The Model 2701 allows you to define a new calibration code. Use the up and down range keys to toggle between yes and no. Choose N if you do not want to change the code. Choose Y if you want to change the code. The unit then prompts you to enter a new code. Enter the code and press ENTER.

**Remote calibration code**

If you are performing calibration over the Ethernet port or the RS-232 port, send this command to unlock calibration:

`:CAL:PROT:CODE '<8-character string>'.`

The default code command is:

`:CAL:PROT:CODE 'KI002701'.`

To change the code via remote, simply send the :CAL:PROT:CODE command twice; first with the present code and then with the new code.
Comprehensive calibration

The comprehensive calibration procedure calibrates the DCV, DCL, ACV, ACL, and ohms functions. You can also choose to calibrate only the DCV/DCL and resistance or ACV/ACL functions.

These procedures are usually the only calibration required in the field. Manufacturing calibration is normally done only at the factory, but it should also be done in the field if the unit has been repaired. See “Manufacturing calibration” at the end of this section for more information.

Calibration cycle

Perform comprehensive calibration at least once a year or every 90 days to ensure the unit meets the corresponding specifications.

Recommended equipment

Table 2-1 lists the recommended equipment you need for comprehensive, DC-only, and AC-only calibration procedures. You can use alternate equipment, such as a DC transfer standard and characterized resistors, as long as that equipment has specifications at least as good as those listed in Table 2-1.

Table 2-1
Recommended equipment for comprehensive calibration

<table>
<thead>
<tr>
<th>Fluke 5700A Calibrator:</th>
<th>AC voltage (1kHz, 50kHz)*</th>
<th>DC current</th>
<th>AC current (1kHz)</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10V ±5ppm</td>
<td>10mV ±710ppm</td>
<td>10mA ±60ppm</td>
<td>100mA ±190ppm</td>
<td>1kΩ ±12ppm</td>
</tr>
<tr>
<td>100V ±7ppm</td>
<td>100mV ±200ppm</td>
<td>100mA ±70ppm</td>
<td>100mA ±190ppm</td>
<td>10kΩ ±11ppm</td>
</tr>
<tr>
<td></td>
<td>1V ±82ppm</td>
<td>1A ±110ppm</td>
<td>1A ±690ppm</td>
<td>100kΩ ±13ppm</td>
</tr>
<tr>
<td></td>
<td>10V ±82ppm</td>
<td></td>
<td>2A ±670ppm</td>
<td>1MΩ ±13ppm</td>
</tr>
<tr>
<td></td>
<td>100V ±90ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>700V ±85ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous equipment:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Keithley 8610 low-thermal shorting plug</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Double banana plug to double banana plug shielded cable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BNC to double banana plug shielded cable</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-1: Recommended equipment for comprehensive calibration

*1kHz specifications. 10mV and 700V points require 1kHz only. All calibrator specifications are 90-day, 23°C ±5°C specifications and indicate total absolute uncertainty at specified output.
**Aborting calibration**

You can abort the front panel calibration process at any time by pressing EXIT. The instrument will then ask you to confirm your decision to abort with the following message:

ABORT CAL?

Press EXIT to abort calibration at this point or press any other key to return to the calibration process.

*NOTE*  The Model 2701 will not respond to any remote programming commands while the ABORT CAL? message is displayed.

**Front panel calibration**

Perform the steps in the following paragraphs in the order shown for comprehensive, DC only, and AC only calibration procedures.

The procedures for front panel calibration include:

- Preparing the Model 2701 for calibration
- Front panel short and open calibration
- DC voltage calibration
- Resistance calibration
- DC current calibration
- AC voltage calibration
- AC current calibration
- Setting calibration dates and saving calibration

**Preparing the Model 2701 for calibration**

1. Turn on the Model 2701 and allow it to warm up for at least two hours before performing a calibration procedure.

2. Start the calibration process as follows:
   a. Access the calibration menu by pressing SHIFT then TEST, then display TEST: CALIB using the up or down range key. Press ENTER.
   b. Use the up or down range key to scroll through the available calibration menu items until the unit displays RUN, then press ENTER.
   c. At the prompt, enter the calibration code. (The default code is 002701.) Use the left and right arrow keys to move among the digits; use the up range key to increment numbers and press the down range key to specify alphabetic letters. Confirm the code by pressing ENTER.
   d. Choose N at the prompt to proceed without changing the code, then press ENTER.

3. Choose which of the calibration tests summarized in Table 2-2 you want to run at the CAL: RUN prompt. Use the up and down range keys to scroll through the options; select your choice by pressing ENTER.
Front panel short and open calibration

At the Model 2701 prompt for a front panel short, perform the following:

1. Connect the Model 8610 low-thermal short to the instrument front panel INPUT and SENSE terminals as shown in Figure 2-1. Make sure the INPUTS button is not pressed in so that the front inputs are selected. Wait at least three minutes before proceeding to allow for thermal equilibrium.

2. Press ENTER to start short-circuit calibration. While the unit is calibrating, it will display:
   CALIBRATING

3. When the unit is finished with short-circuit calibration, it will display the following prompt:
   OPEN CIRCUIT

4. Remove the calibration short and press ENTER. During this phase, the CALIBRATING message will be displayed.

NOTE: Be sure to minimize movement near front Input terminals. Excessive movements can cause capacitive coupling errors, which could affect calibration accuracy.

---

**Table 2-2**

Comprehensive calibration procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Menu choice</th>
<th>Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full calibration</td>
<td>ALL</td>
<td>All comprehensive calibration steps (DC and AC)</td>
</tr>
<tr>
<td>DCV, DCI, and ohms</td>
<td>DC</td>
<td>DC voltage, DC current, and resistance calibration</td>
</tr>
<tr>
<td>ACV and ACI</td>
<td>AC</td>
<td>AC voltage and AC current calibration</td>
</tr>
</tbody>
</table>

**Front panel short and open calibration**

At the Model 2701 prompt for a front panel short, perform the following:

1. Connect the Model 8610 low-thermal short to the instrument front panel INPUT and SENSE terminals as shown in Figure 2-1. Make sure the INPUTS button is not pressed in so that the front inputs are selected. Wait at least three minutes before proceeding to allow for thermal equilibrium.

2. Press ENTER to start short-circuit calibration. While the unit is calibrating, it will display:
   CALIBRATING

3. When the unit is finished with short-circuit calibration, it will display the following prompt:
   OPEN CIRCUIT

4. Remove the calibration short and press ENTER. During this phase, the CALIBRATING message will be displayed.

NOTE: Be sure to minimize movement near front Input terminals. Excessive movements can cause capacitive coupling errors, which could affect calibration accuracy.

---

**Figure 2-1**

Low thermal short connections

- Model 2701
- Model 8610 Low-thermal short
- S+ HI
- S- LO
DC voltage calibration

After the front panel short and open procedure, the unit will prompt you for the first DC voltage: +10V. Do the following:

1. Connect the calibrator to the Model 2701 as shown in Figure 2-2. Wait three minutes to allow for thermal equilibrium before proceeding.

![Figure 2-2](Connections for DC volts and ohms calibration)

**NOTE** Although 4-wire connections are shown, the sense leads are connected and disconnected at various points in this 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 calibrator to output DC volts and turn external sense off.
3. Perform the steps listed in Table 2-3 to complete DC volts calibration. For each calibration step:
   - Set the calibrator to the indicated value and make sure it is in OPERATE.
   - Press the ENTER key to calibrate that step.
   - Wait until the Model 2701 finishes each step. (The unit will display the CALIBRATING message while calibrating.)
NOTE  If your calibrator cannot output the values recommended in Table 2-3, use the left and right arrow keys and the up and down range keys to set the Model 2701 display value to match the calibrator output voltage.

Table 2-3
DC volts calibration summary

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator voltage</th>
<th>Allowable range</th>
</tr>
</thead>
<tbody>
<tr>
<td>+10V</td>
<td>+10.000000V</td>
<td>+9V to +11V</td>
</tr>
<tr>
<td>-10V</td>
<td>-10.000000V</td>
<td>-9V to -11V</td>
</tr>
<tr>
<td>100V</td>
<td>+100.000000V</td>
<td>+90V to +110V</td>
</tr>
</tbody>
</table>

Resistance calibration

Completing the 100V DC calibration step ends the DC voltage calibration procedure. The Model 2701 will then prompt you to connect 1kΩ. Follow these steps for resistance calibration:

1. Set the calibrator output for resistance and turn on external sense.

NOTE  Use external sense (4-wire Ω) when calibrating all resistance ranges. Be sure that the calibrator external sense mode is turned on.

2. Perform the calibration steps summarized in Table 2-4. For each step:
   • Set the calibrator to the indicated value and place the unit in operate. (If the calibrator cannot output the exact resistance value, use the Model 2701 left and right arrow keys and the range keys to adjust the Model 2701 display to agree with the actual calibrator resistance.)
   • Press the ENTER key to calibrate each point.
   • Wait for the Model 2701 to complete each step before continuing.

Table 2-4
Ohms calibration summary

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator resistance*</th>
<th>Allowable range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1kΩ</td>
<td>1kΩ</td>
<td>0.9kΩ to 1.1kΩ</td>
</tr>
<tr>
<td>10kΩ</td>
<td>10kΩ</td>
<td>9kΩ to 11kΩ</td>
</tr>
<tr>
<td>100kΩ</td>
<td>100kΩ</td>
<td>90kΩ to 110kΩ</td>
</tr>
<tr>
<td>1MΩ</td>
<td>1MΩ</td>
<td>0.9MΩ to 1.1MΩ</td>
</tr>
</tbody>
</table>

*Nominal resistance. Adjust Model 2701 calibration parameter to agree with actual value.
**DC current calibration**

After the 1MΩ resistance point has been calibrated, the unit will prompt you to apply 10mA. Follow these steps for DC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2701 as shown in Figure 2-3.

**Figure 2-3**
*Connections for DC and AC amps calibration*

2. Calibrate each current step summarized in Table 2-5. For each step:
   - Set the calibrator to the indicated DC current and make sure the unit is in OPERATE.
   - Make sure the Model 2701 display indicates the correct calibration current.
   - Press ENTER to complete each step.
   - Allow the Model 2701 to finish each step.

**NOTE**  *If you are performing DC-only calibration, proceed to “Setting calibration dates and saving calibration.”*

**Table 2-5**
*DC current calibration summary*

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator current</th>
<th>Allowable range</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mA</td>
<td>10.0000mA</td>
<td>9mA to 11mA</td>
</tr>
<tr>
<td>100mA</td>
<td>100.0000mA</td>
<td>90mA to 110mA</td>
</tr>
<tr>
<td>1A</td>
<td>1.000000A</td>
<td>0.9A to 1.1A</td>
</tr>
</tbody>
</table>
AC voltage calibration

Follow these steps for AC voltage calibration:

1. Connect the calibrator to the Model 2701 INPUT HI and LO terminals as shown in Figure 2-4.

Figure 2-4
Connections for AC volts calibration

2. Perform the calibration steps summarized in Table 2-6. For each step:
   - Set the calibrator to the indicated value and make sure the calibrator is in OPERATE.
   - Press ENTER to complete each step.
   - Wait until the Model 2701 completes each step.

Table 2-6
AC voltage calibration summary

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator voltage, frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mV AC at 1kHz</td>
<td>10.00000mV, 1kHz</td>
</tr>
<tr>
<td>100mV AC at 1kHz</td>
<td>100.0000mV, 1kHz</td>
</tr>
<tr>
<td>100mV AC at 50kHz</td>
<td>100.0000mV, 50kHz</td>
</tr>
<tr>
<td>1V AC at 1kHz</td>
<td>1.000000V, 1kHz</td>
</tr>
<tr>
<td>1V AC at 50kHz</td>
<td>1.000000V, 50kHz</td>
</tr>
<tr>
<td>10V AC at 1kHz</td>
<td>10.00000V, 1kHz</td>
</tr>
<tr>
<td>10V AC at 50kHz</td>
<td>10.00000V, 50kHz</td>
</tr>
<tr>
<td>100V AC at 1kHz</td>
<td>100.0000V, 1kHz</td>
</tr>
<tr>
<td>100V AC at 50kHz</td>
<td>100.0000V, 50kHz</td>
</tr>
<tr>
<td>700V AC at 1kHz</td>
<td>700.0000V, 1kHz</td>
</tr>
</tbody>
</table>
AC current calibration

After the 700VAC at 1kHz point has been calibrated, the unit will prompt you for 100mA at 1kHz. Follow these steps for AC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2701 as shown in Figure 2-3.
2. Perform the calibration steps summarized in Table 2-7. For each step:
   - Set the calibrator to the indicated current and frequency, make sure the unit is in OPERATE.
   - Press ENTER to complete each calibration step.
   - Allow the unit to complete each step before continuing.

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator current, frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mA at 1kHz</td>
<td>100.0000mA, 1kHz</td>
</tr>
<tr>
<td>1A at 1kHz</td>
<td>1.000000A, 1kHz</td>
</tr>
<tr>
<td>2A at 1kHz</td>
<td>2.000000A, 1kHz</td>
</tr>
</tbody>
</table>

Setting calibration dates and saving calibration

At the end of the calibration procedure, the instrument will display the CALIBRATION COMPLETE message. Press ENTER to continue and the Model 2701 will prompt you to enter the calibration date and the calibration due date. Set these dates as follows:

1. At the CAL DATE: prompt, use the left and right arrow keys and the range keys to set the calibration date, then press ENTER.
2. The unit will then prompt you to enter the next calibration due date with this prompt: CAL NDUE:. Use the left and right arrow keys and the range keys to set the calibration due date, then press ENTER.
3. The unit will prompt you to save new calibration constants with this message: SAVE CAL? YES. To save the new constants, press ENTER. If you do not want to save the new constants, press the down range key to toggle to NO, then press ENTER.

NOTE Calibration constants calculated during the present calibration procedure will not be saved unless you choose the YES option. Previous calibration constants will be retained if you select NO.
Remote calibration

Follow the steps in this section to perform comprehensive procedures via remote. See Appendix B for a detailed list and description of remote calibration commands.

When sending calibration commands, be sure that the Model 2701 completes each step before sending the next command. You can do so either by observing the front panel CALIBRATING message or by detecting the completion of each step via remote. (See “Detecting calibration step completion” in Appendix B.)

The procedures for calibrating the Model 2701 via remote include:

- Preparing the Model 2701 for calibration
- Short and open calibration
- DC voltage calibration
- Resistance calibration
- DC current calibration
- AC voltage calibration
- AC current calibration
- Programming calibration dates
- Saving calibration constants
- Locking out calibration

NOTE   As with front panel calibration, you can choose to perform comprehensive, DC-only, or AC-only calibration. Be sure to include a space character between each command and parameter.

Preparing the Model 2701 for calibration

1. Connect the Model 2701 to the Ethernet or connect the unit to a computer through the RS-232 port using a straight-through 9-pin to 9-pin cable (use a 9-25-pin adapter if necessary).
2. Turn on the Model 2701 and allow it to warm up for at least two hours before performing calibration.
3. Unlock the calibration function by sending this command:
   :CAL:PROT:CODE 'KI002701'
   (The above command shows the default code, KI002701. Substitute the correct code if changed.)
4. Send the following command to initiate calibration:
   :CAL:PROT:INIT
Short and open calibration

1. Connect the Model 8610 low-thermal short to the instrument INPUT and SENSE terminals as shown in Figure 2-1. Make sure the INPUTS button is not pressed in so that the front inputs are active. 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.

2. Send the following command:
   :CAL:PROT:DC:STEP1

3. After the Model 2701 completes this step, remove the low-thermal short and then send this command:
   :CAL:PROT:DC:STEP2

**NOTE** Be sure to minimize movement near front Input terminals. Excessive movements can cause capacitive coupling errors, which could affect calibration accuracy.

DC voltage calibration

After the front panel short and open steps, perform the following:

1. Connect the calibrator to the Model 2701 as shown in Figure 2-2. Allow three minutes for thermal equilibrium.

**NOTE** Although 4-wire connections are shown, the sense leads are connected and disconnected at various points in this 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. Perform the calibration steps summarized in Table 2-8. For each step:
   • Set the calibrator to the indicated voltage and make sure the unit is in operate. (Use the recommended voltage if possible.)
   • Send the indicated programming command. (Change the voltage parameter if you are using a different calibration voltage.)
   • Wait until the Model 2701 completes each step before continuing.
NOTE  Ensure the calibrator has settled to the final value. You can do so by verifying that
the “Settled” indicator is off or by using the *OPC? (operation complete) query.

Table 2-8
DC voltage calibration programming steps

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator voltage</th>
<th>Calibration command*</th>
<th>Parameter range</th>
</tr>
</thead>
<tbody>
<tr>
<td>+10V</td>
<td>+10.00000V</td>
<td>:CAL:PROT:DC:STEP3 10</td>
<td>9 to 11</td>
</tr>
<tr>
<td>-10V</td>
<td>-10.00000V</td>
<td>:CAL:PROT:DC:STEP4 -10</td>
<td>-9 to -11</td>
</tr>
<tr>
<td>100V</td>
<td>100.00000V</td>
<td>:CAL:PROT:DC:STEP5 100</td>
<td>90 to 110</td>
</tr>
</tbody>
</table>

*Use recommended value where possible. Change parameter accordingly if using a different calibrator voltage.

Resistance calibration

Follow these steps for resistance calibration:

1. Set the calibrator to the resistance mode and turn on external sensing.

NOTE  Use external sense (4-wire $\Omega$) when calibrating all resistance ranges. Be sure that
the calibrator external sense mode is turned on.

2. Perform the calibration steps summarized in Table 2-9. For each step:
   - Set the calibrator to the indicated resistance and make sure the unit is in operate.
     (Use the recommended resistance or the closest available value.)
   - Send the indicated programming command. (Change the command parameter if you are using a different calibration resistance than that shown.)
   - Wait until the Model 2701 completes each step before continuing.

Table 2-9
Resistance calibration programming steps

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator resistance</th>
<th>Calibration command*</th>
<th>Parameter range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1k(\Omega)</td>
<td>1k(\Omega)</td>
<td>:CAL:PROT:DC:STEP6 1E3</td>
<td>900 to 1.1E3</td>
</tr>
<tr>
<td>10k(\Omega)</td>
<td>10k(\Omega)</td>
<td>:CAL:PROT:DC:STEP7 10E3</td>
<td>9E3 to 11E3</td>
</tr>
<tr>
<td>100k(\Omega)</td>
<td>100k(\Omega)</td>
<td>:CAL:PROT:DC:STEP8 100E3</td>
<td>90E3 to 110E3</td>
</tr>
<tr>
<td>1M(\Omega)</td>
<td>1M(\Omega)</td>
<td>:CAL:PROT:DC:STEP9 1E6</td>
<td>900E3 to 1.1E6</td>
</tr>
</tbody>
</table>

*Use exact calibrator resistance value for parameter.
DC current calibration

After the 1MΩ resistance point has been calibrated, follow these steps for DC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2701 as shown in Figure 2-3.
2. Perform the calibration steps listed in Table 2-10. For each step:
   • Set the calibrator to the indicated current and make sure the unit is in operate. (Use the recommended current if possible.)
   • Send the indicated programming command. (Change the current parameter if you are using a different calibration current.)
   • Wait until the Model 2701 completes each step before continuing.

**NOTE** If you are performing DC-only calibration, proceed to “Programming calibration dates” on page 2-18

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator current</th>
<th>Calibration command*</th>
<th>Parameter range</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mA</td>
<td>10.00000mA</td>
<td>:CAL:PROT:DC:STEP10 10E-3</td>
<td>9E-3 to 11E-3</td>
</tr>
<tr>
<td>100mA</td>
<td>100.00000mA</td>
<td>:CAL:PROT:DC:STEP11 100E-3</td>
<td>90E-3 to 110E-3</td>
</tr>
<tr>
<td>1A</td>
<td>1.000000A</td>
<td>:CAL:PROT:DC:STEP12 1</td>
<td>0.9 to 1.1</td>
</tr>
</tbody>
</table>

*Change parameter if using different current.
**AC voltage calibration**

Follow these steps for AC voltage calibration:

1. Connect the calibrator to the Model 2701 INPUT HI and LO terminals as shown in Figure 2-4.

2. Perform the calibration steps summarized in Table 2-11. For each step:
   - Set the calibrator to the indicated voltage and frequency, make sure the unit is in operate. (You must use the stated voltage and frequency.)
   - Send the indicated programming command.
   - Wait until the Model 2701 completes each step before continuing.

**Table 2-11**

**AC voltage calibration programming steps**

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator voltage, frequency</th>
<th>Calibration command</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mV AC at 1kHz</td>
<td>10.00000mV, 1kHz</td>
<td>:CAL: PROT: AC: STEP1</td>
</tr>
<tr>
<td>100mV AC at 1kHz</td>
<td>100.0000mV, 1kHz</td>
<td>:CAL: PROT: AC: STEP2</td>
</tr>
<tr>
<td>100mV AC at 50kHz</td>
<td>100.0000mV, 50kHz</td>
<td>:CAL: PROT: AC: STEP3</td>
</tr>
<tr>
<td>1VAC at 1kHz</td>
<td>1.000000V, 1kHz</td>
<td>:CAL: PROT: AC: STEP4</td>
</tr>
<tr>
<td>1VAC at 50kHz</td>
<td>1.000000V, 50kHz</td>
<td>:CAL: PROT: AC: STEP5</td>
</tr>
<tr>
<td>10VAC at 1kHz</td>
<td>10.00000V, 1kHz</td>
<td>:CAL: PROT: AC: STEP6</td>
</tr>
<tr>
<td>10VAC at 50kHz</td>
<td>10.00000V, 50kHz</td>
<td>:CAL: PROT: AC: STEP7</td>
</tr>
<tr>
<td>100VAC at 1kHz</td>
<td>100.0000V, 1kHz</td>
<td>:CAL: PROT: AC: STEP8</td>
</tr>
<tr>
<td>100VAC at 50kHz</td>
<td>100.0000V, 50kHz</td>
<td>:CAL: PROT: AC: STEP9</td>
</tr>
<tr>
<td>700VAC at 1kHz</td>
<td>700.0000V, 1kHz</td>
<td>:CAL: PROT: AC: STEP10</td>
</tr>
</tbody>
</table>
**AC current calibration**

Follow these steps for AC current calibration:

1. Connect the calibrator to the AMPS and INPUT LO terminals of the Model 2701 as shown in Figure 2-3.
2. Perform the calibration steps summarized in Table 2-12. For each step:
   - Set the calibrator to the indicated current and frequency, make sure the unit is in operate. (You must use the stated current and frequency.)
   - Send the indicated programming command.
   - Wait until the Model 2701 completes each step before continuing.

<table>
<thead>
<tr>
<th>Calibration step</th>
<th>Calibrator current, frequency</th>
<th>Calibration command</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mA at 1kHz</td>
<td>100.0000mA, 1kHz</td>
<td>:CAL:PROT:AC:STEP11</td>
</tr>
<tr>
<td>1A at 1kHz</td>
<td>1.000000A, 1kHz</td>
<td>:CAL:PROT:AC:STEP12</td>
</tr>
<tr>
<td>2A at 1kHz</td>
<td>2.000000A, 1kHz</td>
<td>:CAL:PROT:AC:STEP13</td>
</tr>
</tbody>
</table>

**Programming calibration dates**

Program the present calibration date and calibration due date by sending the following commands:

:CAL:PROT:DATE <year>, <month>, <day>
:CAL:PROT:NDUE <year>, <month>, <day>

For example, the following commands assume calibration dates of 12/15/1999 and 12/15/2000 respectively:

:CAL:PROT:DATE 1999, 12, 15
:CAL:PROT:NDUE 2000, 12, 15

**Saving calibration constants**

After completing the calibration procedure, send the following command to save the new calibration constants:

:CAL:PROT:SAVE

**NOTE** Calibration constants will not be saved unless the :CAL:PROT:SAVE command is sent.

**Locking out calibration**

After saving calibration, send the following command to lock out calibration:

:CAL:PROT:LOCK
Manufacturing calibration

The manufacturing calibration procedure is normally performed only at the factory, but the necessary steps are included here in case the unit is repaired and the unit requires these calibration procedures.

NOTE If the unit has been repaired, the entire comprehensive calibration procedure should also be performed in addition to the manufacturing calibration procedure.

Recommended test equipment

Table 2-13 summarizes the test equipment required for the manufacturing calibration steps. In addition, you will need the calibrator (see Table 2-1) and signal generator to complete the comprehensive calibration steps.

Table 2-13
Recommended equipment for manufacturing calibration

<table>
<thead>
<tr>
<th>Stanford Research Systems DS345 Function Generator:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1V RMS, 3Hz, ±5ppm</td>
</tr>
<tr>
<td>1V RMS, 1kHz, ±5ppm</td>
</tr>
<tr>
<td>Keithley Model 2001 or 2002 Digital Multimeter:</td>
</tr>
<tr>
<td>1V, 3Hz AC, ±0.13%</td>
</tr>
<tr>
<td>Keithley 7797 Calibration System</td>
</tr>
</tbody>
</table>

Calibration card preparation

Before performing manufacturing calibration, short the HI, LO, SHI, and SLO terminals of TE100 on the Model 7797 Calibration System card together using the supplied jumpers. (See the Model 7797 documentation.) These connections will form a low-thermal short necessary for the manufacturing calibration procedure. The Model 7797 should then be installed in scanner Slot #1.

Unlocking manufacturing calibration

To unlock manufacturing calibration, press and hold in the OPEN key while turning on the power.
Measuring function generator signal amplitude

The 3Hz function generator signal amplitude must be accurately measured using the digital multimeter listed in Table 2-13. Proceed as follows:

1. Connect the function generator output to the digital multimeter INPUT jacks. (See Figure 2-5 for typical connections.)
2. Turn on the function generator and multimeter, allow a two-hour warm-up period before measuring.
3. Set the function generator to output a 1V RMS sine wave at 3Hz. Measure and record the signal amplitude.

Front panel manufacturing calibration

1. Install the shorted Model 7797 calibration board (see “Calibration card preparation” earlier in this section) in scanner card Slot 1 and select the rear inputs with the INPUTS switch. Allow three minutes for thermal equilibrium.
2. Press and hold the OPEN key while turning on the power.
3. Press SHIFT then TEST, then display CALIB: TEST with the up or down range key. Press ENTER, select RUN, then enter the appropriate calibration code (default: 002701).
4. Select ALL at the CAL:RUN prompt.
5. Press ENTER to perform the first manufacturing calibration step.
6. Perform the entire front panel comprehensive calibration procedure discussed earlier in this section. (See “Comprehensive calibration” earlier in this section.)
7. Connect the function generator to the Model 2701 front panel INPUT jacks as shown in Figure 2-5. Select the front input jacks with the INPUTS switch.

Figure 2-5
Function generator connections for manufacturing calibration

Note: Output voltage must be accurately measured. (See text.)
8. After the last AC current calibration step, the instrument will prompt you to enter 3Hz at 1V RMS and 1kHz with the following prompts:
   - **Low-frequency cal** — Set the function generator to output a 1V RMS, 3Hz sine wave. Use the left and right arrow keys and the range keys to adjust the display to agree with the generator amplitude you measured previously, then press ENTER.
   - **Frequency cal** — Set the function generator to output a 1V RMS, 1kHz sine wave. Enter 1.000000kHz at the prompt, then press ENTER.
9. Set the calibration dates, then save calibration to complete the process.

**Remote manufacturing calibration**

1. Install the shorted Model 7797 calibration board (see “Calibration card preparation” earlier in this section) in scanner card Slot 1 and select the rear inputs with the INPUTS switch. Allow three minutes for thermal equilibrium.
2. Press and hold the OPEN key while turning on the power.
3. Enable calibration by sending the :CODE command. For example, the default command is:
   ::CAL:PROT:CODE 'KI002701'
4. Initiate calibration by sending the following command:
   ::CAL:PROT:INIT
5. Calibrate step 0 with the following command:
   ::CAL:PROT:DC:STEP0
6. Perform the entire remote comprehensive calibration procedure discussed earlier in this section. (See “Comprehensive calibration” on page 2-5.)
7. Connect the function generator to the Model 2701 INPUT jacks as shown in Figure 2-5. Select the front input jacks with the INPUTS switch.
8. Set the generator to output a 1V RMS, 3Hz sine wave, then send the following command:
   ::CAL:PROT:AC:STEP14 <Cal_voltage>
   Here <Cal_voltage> is the actual 3Hz generator signal amplitude you measured previously.
9. Set the generator to output a 1V RMS, 1kHz sine wave, then send the following command:
   ::CAL:PROT:AC:STEP15 1E3
10. Send the following commands to set calibration dates, save calibration, and lock out calibration:
   ::CAL:PROT:DATE <year>, <month>, <day>
   ::CAL:PROT:NDUE <year>, <month>, <day>
   ::CAL:PROT:SAVE
   ::CAL:PROT:LOCK
Model 7700 calibration

The following procedures calibrate the temperature sensors on the Model 7700 plug-in modules.

NOTE For additional information about the Keithley modules, refer to the appropriate appendix in the Model 2701 User's Manual.

Recommended test equipment

In order to calibrate the Model 7700, you will need equipment summarized in Table 2-14.

Table 2-14
Recommended equipment for Model 7700 calibration

<table>
<thead>
<tr>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Thermometer:</td>
</tr>
<tr>
<td>18° to 28°C, ±0.1°C</td>
</tr>
<tr>
<td>Keithley Model 7797 Calibration System</td>
</tr>
</tbody>
</table>

Calibration card connections

The Model 7700 being calibrated should be connected to the Model 7797 Calibration System card and the card should then be installed in scanner Slot #1. (See the Model 7797 documentation.) Note that the module being calibrated will be external to the Model 2701 to avoid card heating during calibration.

Model 7700 calibration

NOTE Before calibrating the Model 7700, make sure that power has been removed from the card for at least two hours to allow card circuitry to cool down. After turning on the power during the calibration procedure, complete the procedure as quickly as possible to minimize card heating that could affect calibration accuracy. Allow the Model 2701 to warm up for at least two hours.

Front panel Model 7700 calibration

1. Connect the Model 7700 to the Model 7797 Calibration System card (see “Calibration card connections” above).
2. With the power off, install the Model 7700/7797 combination in Slot 1 and select the rear inputs with the INPUTS switch. Allow three minutes for thermal equilibrium.
3. Accurately measure and record the cold temperature of the Model 7700 card surface at the center of the card with an RTD sensor.
4. Press and hold the Model 2701 OPEN key while turning on the power.
5. Press SHIFT then TEST, then display TEST:CALIB with the up or down range key. Press ENTER, select RUN, then enter the appropriate calibration code (default: 002701).

6. Using the up or down range key, select CARD at the CAL:RUN prompt, then press ENTER.

7. Set the display value to the cold calibration temperature (°C) you measured in Step 3, then press ENTER to complete Model 7700 calibration.

Remote Model 7700 calibration

1. Connect the Model 7700 to the Model 7797 Calibration System card (see “Calibration card connections” on page 2-22).

2. With the power off, install the Model 7700/7797 combination in Slot 1 and select the rear inputs with the INPUTS switch. Allow three minutes for thermal equilibrium.

3. Accurately measure and record the cold temperature of the Model 7700 card surface at the center of the card.

4. Press and hold the Model 2701 OPEN key while turning on the power.

5. Enable calibration by sending the :CODE command. For example, the default command is:
   :CAL:PROT:CODE 'KI002701'

6. Initiate calibration by sending the following command:
   :CAL:PROT:CARD1:INIT

7. Calibrate the Model 7700 with the following command:
   :CAL:PROT:CARD1:STEP0 <temp>
   Here <temp> is the cold calibration temperature (°C) measured in Step 3.

8. Send the following commands to save calibration and lock out calibration:
   :CAL:PROT:CARD1:SAVE
   :CAL:PROT:CARD1:LOCK
3

Routine Maintenance
Introduction

The information in this section deals with routine type maintenance and includes procedures for setting the line voltage, replacing the Model 2701 line and front terminal AMPS fuses, and replacing the amps fuses for the Model 7700 plug-in module. Replacement of the Model 2701 non-volatile RAM battery and module relay closure count is also covered.

Setting the line voltage and replacing the line fuse

**WARNING**  Disconnect the line cord at the rear panel and remove all test leads connected to the instrument (front and rear) before replacing the line fuse.

The power line fuse is located in the power module next to the AC power receptacle (see Figure 3-1). If the line voltage must be changed or if the line fuse requires replacement, perform the following steps:

1. Place the tip of a flat-blade screwdriver into the power module by the fuse holder assembly (see Figure 3-1). Gently push in and to the left. Release pressure on the assembly and its internal spring will push it out of the power module.

2. Remove the fuse and replace it with the type listed in Table 3-1.

**CAUTION**  For continued protection against fire or instrument damage, replace the fuse only with the type and rating listed. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

3. If configuring the instrument for a different line voltage, remove the line voltage selector from the assembly and rotate it to the proper position. When the selector is installed into the fuse holder assembly, the correct line voltage appears inverted in the window.

**CAUTION**  Operating the Model 2701 on the wrong line voltage may result in instrument damage.

4. Install the fuse holder assembly into the power module by pushing it in until it locks in place.
Figure 3-1
Power module

Model 2701

![Diagram of Model 2701 Power Module]

WARNING: NO INTERNAL OPERATOR SERVICABLE PARTS. SERVICE BY QUALIFIED PERSONNEL ONLY.

CAUTION: FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH SAME TYPE AND RATING.

Table 3-1
Power line fuse

<table>
<thead>
<tr>
<th>Line Voltage</th>
<th>Rating</th>
<th>Keithley Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100/120V</td>
<td>0.630A, 250V, 5 × 20 mm, slow-blow</td>
<td>FU-106-.630</td>
</tr>
<tr>
<td>200/240V</td>
<td>0.315A, 250V, 5 × 20 mm, slow-blow</td>
<td>FU-106-.315</td>
</tr>
</tbody>
</table>
Replacing the front terminal AMPS fuse

The front terminal AMPS fuse protects the Model 2701 current input from an over-current condition. Follow the steps below to replace the AMPS fuse.

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

1. Turn off the power and disconnect the power line and test leads.
2. From the front panel, gently push in the AMPS jack with your thumb and rotate the fuse carrier one-quarter turn counterclockwise. (See Figure 3-2.) Release pressure on the jack and its internal spring will push the fuse carrier out of the socket.
3. Remove the fuse and replace it with the same type: 3A, 250V, fast-blow, Keithley part number FU-99-1.

**CAUTION** Do not use a fuse with a higher current rating than specified or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

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

*Figure 3-2*
*Front terminal AMPS fuse*
Replacing Model 7700 plug-in module amps fuses

**WARNING** The information in this section is intended only for qualified service personnel. Do not perform these procedures unless you are qualified to do so. Make sure that all plug-in module connections are de-energized and disconnected before replacing module amps fuses.

1. Turn off the power and disconnect the power line and external connections from the Model 7700.
2. Open the Model 7700 top cover.
3. Locate the amps fuses for CH21 and CH22 (see Figure 3-3).
4. Remove the circuit board from the bottom plastic housing by removing the two bottom screws.

**Figure 3-3**
Model 7700 amps fuses

5. De-solder the blown CH21 or CH22 fuse as required, taking care not to damage the circuit board or spread solder flux around the board.

**CAUTION** Do not use a fuse with a higher current rating than specified or module damage may occur.

7. Solder the new fuse in place using organic (OA based) flux solder, again taking care not to damage the circuit board or spread solder flux around the board.
8. Carefully clean the repaired area of the circuit board with a foam tipped swab or brush dipped in pure water, then blow dry the board with dry nitrogen gas. Allow the board to dry for several hours in a 50°C low-humidity environment before use.
9. Re-install the circuit board into the plastic housing, then close the top cover.

Replacing non-volatile RAM battery

The Model 2701 has a rechargeable lithium ion battery for non-volatile RAM. Use the procedure below to replace the battery, if required. Refer to the disassembly procedures in Section 5 and the parts list and component layout drawings at the end of Section 6 for more information.

**WARNING** There is a danger of explosion if the battery is incorrectly replaced. Replace only with the part designated by the corresponding Keithley part number. Dispose of used batteries according to the manufacturer's instructions.

The following procedure is intended only for qualified service personnel. Do not perform this procedure unless you are qualified to do so.

Disconnect the line cord and all connecting wires from the Model 2701 before removing the top cover.

**WARNING** The precautions below must be followed to avoid personal injury.

- Wear safety glasses or goggles when working with lithium ion batteries.
- Do not short the battery terminals together.
- Keep lithium ion batteries away from all liquids.
- Observe proper polarity when installing the battery.
- Do not incinerate or otherwise expose the battery to excessive heat (>60°C).
- Bulk quantities of lithium ion batteries should be disposed of as hazardous waste.

1. Before replacing the battery, refer to the troubleshooting procedures in Table 4-4 in Section 4 to determine if the battery requires replacement
2. Remove the Model 2701 top cover and motherboard using the disassembly procedures in Section 5.
3. Remove the battery from its holder on the bottom of the case near the front panel.
4. Install a new battery, Keithley part number BA-52.
5. Re-install the motherboard and top cover by following the disassembly procedures in Section 5 in reverse order. Be sure to plug in all cables including the cable that connects the battery to the motherboard at J900.
Plug-in module relay closure count

The Model 2701 keeps an internal count of the number of times each module relay has been closed. This count will help you determine if and when any relays require replacement (see module contact life specifications). The count can be read or reset only via remote as outlined below.

Closure count commands

Table 3-2 summarizes closure count commands.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>:ROUTe</td>
<td>Route subsystem.</td>
</tr>
<tr>
<td>:CLOSe</td>
<td>Path to CLOSe commands.</td>
</tr>
<tr>
<td>:COUNT? (@clist)</td>
<td>Query count for channels in clist (channel list).</td>
</tr>
<tr>
<td>:INTerval &lt; NRf&gt;</td>
<td>Set count update interval in minutes (1 to 1440).</td>
</tr>
<tr>
<td>:RCOunt (@clist)</td>
<td>Reset count for channels in clist.*</td>
</tr>
</tbody>
</table>

* Unit must be in manufacturing calibration mode. See text below.

Reading relay closure count

To determine the closure count of specific channels, send this query via remote:

:ROUTe:CLOSe:COUNT? (@clist)

Here, clist is the summary of channels. For example, to determine the closure count of channels 1 and 4 of a module in slot 1, the following query would be sent:

:ROUT:CLOS:COUN? (@101,104)

The following query would determine the closure count of slot 1 module channels 1 through 10:

Resetting relay closure count

NOTE The Model 2701 must be in the manufacturing calibration mode to reset the closure count. To do so, press and hold the OPEN key while turning on the power, then send the :CAL:PROT:CODE "code" to unlock calibration (default code: KI002701). After resetting relay counts, send :CAL:PROT:LOCK to lock out calibration.

To reset the relay closure count of specific channels to 0, send this command via remote:

:ROUTE:CLOSE:RCOUNT (@clist)

Again clist is the summary of channels to be reset. For example, the following command resets channels 2 and 7 of a module in slot 1 to 0:

:ROUTE:CLOS:RCO (@102,107)

The following command resets the count of slot 1 module channels 1 through 10:

:ROUTE:CLOS:RCO (@101:110)

Setting count update interval

Relay closure counts are updated in temporary RAM every time a channel is closed regardless of how it was closed: by a SCPI command, front panel control, or during a scan. These counts are permanently written to the EEPROM on the card only at a user-settable time interval (which has a factory default of 15 minutes) or whenever the counts are queried. Valid intervals (set in integer number of minutes) are between 1 and 1440 minutes (24 hrs). Relay closures are counted only when a relay cycles from open to closed state. If you send multiple close commands to the same channel without sending an open command, only the first closure will be counted.

The lower the interval, the less chance there is of losing relay counts due to power failures. However, writing to the EEPROM more often may reduce scanning throughput. The higher the interval, the less scanning throughput is reduced, but more relay counts may be lost in the event of a power failure.

To set the count update interval, send this command:

:ROUTE:CLOSE:COUN:INTerval <interval>

For example, to set the interval to 30 minutes, send this command:

:ROUTE:CLOS:COUN:INT 30
Troubleshooting
Introduction

This section of the manual will assist you in troubleshooting and repairing the Model 2701. Included are self-tests, test procedures, troubleshooting tables, and circuit descriptions. It is left to the discretion of the repair technician to select the appropriate tests and documentation needed to troubleshoot the instrument. Refer to the disassembly procedures in Section 5 and the parts lists in Section 6 for further information.

WARNING The information in this section is intended only for qualified service personnel. Do not perform these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages that could cause personal injury or death. Use caution when working with hazardous voltages.

Repair considerations

Before making any repairs to the Model 2701, be sure to read the following considerations.

CAUTION The PC boards are built using surface mount techniques and require specialized equipment and skills for repair. If you are not equipped and/or qualified, it is strongly recommended that you send the unit back to the factory for repairs or limit repairs to the PC board replacement level. Without proper equipment and training, you could damage a PC board beyond repair.

- Repairs will require various degrees of disassembly. However, it is recommended that the Front Panel Tests be performed prior to any disassembly. The disassembly instructions for the Model 2701 are contained in Section 5 of this manual.
- Do not make repairs to surface mount PC boards unless equipped and qualified to do so (see previous CAUTION).
- When working inside the unit and replacing parts, be sure to adhere to the handling precautions and cleaning procedures explained in Section 5.
- Many CMOS devices are installed in the Model 2701. These static-sensitive devices require special handling as explained in Section 5.
- Whenever a circuit board is removed or a component is replaced, the Model 2701 must be recalibrated. See Section 2 for details on calibrating the unit.
Power-on self-tests

RAM and EPROM tests

During the power-on sequence, the Model 2701 will perform a checksum test on its EPROM and test its RAM. If the RAM tests fails, the instrument will lock up.

Flash memory tests

After the RAM and EPROM tests, the instrument will perform a checksum test on flash memory. If a failure occurs, the unit will perform the comprehensive tests summarized in Table 4-1. If a failure occurs, an error message will be displayed, and the unit will automatically enter the firmware upgrade mode (as indicated by “FW UPGRADE” message). Depending on the failure mode, firmware upgrades can be performed through the port(s) listed in the table. You can also force the unit into the firmware upgrade mode by holding in the STEP key during power-up.

Table 4-1
Flash memory failure modes

<table>
<thead>
<tr>
<th>Flash memory code sections¹</th>
<th>Status and error messages</th>
<th>Firmware upgrade port³</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPGA</td>
<td>LOADING FPGA</td>
<td>RS-232</td>
</tr>
<tr>
<td></td>
<td>FPGA CHKSUM²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FPGA TIMEOUT²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FPGA COMMERR²</td>
<td></td>
</tr>
<tr>
<td>Ethernet</td>
<td>LOAD ETHERNET</td>
<td>RS-232</td>
</tr>
<tr>
<td></td>
<td>ETHER CHKSUM²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ETHER TIMEOUT²</td>
<td></td>
</tr>
<tr>
<td>Main code</td>
<td>LOADING MAIN</td>
<td>RS-232 or Ethernet</td>
</tr>
<tr>
<td></td>
<td>MAIN CHKSUM²</td>
<td></td>
</tr>
</tbody>
</table>

1. Code sections tested in sequence shown.
2. Error message displayed only on failure of specific test.
3. Firmware upgrade can be performed only through indicated port(s) depending on failure mode.
Front panel tests

There are two front panel tests: one to test the functionality of the front panel keys and one to test the display. In the event of a test failure, refer to “Display board checks” on page 4-13 for details on troubleshooting the display board.

KEY test

The KEY test allows you to check the functionality of each front panel key. Perform the following steps to run the KEY test:

1. Press SHIFT and then TEST to access the self-test options.
2. Use the up or down RANGE key to display “TEST: KEY.”
3. Press ENTER to start the test. When a key is pressed, the label name for that key is displayed to indicate that it is functioning properly. When the key is released, the message “NO KEY PRESS” is displayed.
4. Pressing EXIT tests the EXIT key. However, the second consecutive press of EXIT aborts the test and returns the instrument to normal operation.

DISP test

The display test allows you to verify that each segment and annunciator in the vacuum fluorescent display is working properly. Perform the following steps to run the display test:

1. Press SHIFT and then TEST to access the self-test options.
2. Use the up or down RANGE key to display “TEST: DISP.”
3. Press ENTER to start the test. There are four parts to the display test. Each time ENTER is pressed, the next part of the test sequence is selected. The four parts of the test sequence are as follows:
   a. All annunciators are displayed.
   b. The segments of each digit are sequentially displayed.
   c. The 12 digits (and annunciators) are sequentially displayed.
   d. The annunciators located at either end of the display are sequentially displayed.
4. When finished, abort the display test by pressing EXIT. The instrument returns to normal operation.
Principles of operation

The following information is provided to support the troubleshooting tests and procedures covered in this section of the manual. Refer to the following block diagrams:

- **Figure 4-1** — Power supply block diagram
- **Figure 4-2** — Digital circuitry block diagram
- **Figure 4-3** — Analog circuitry block diagram
- **Figure 4-4** — Ohms open-lead sense detection block diagram

**Power supply**

The following information provides some basic circuit theory that can be used as an aid to troubleshoot the power supply. A block diagram of the power supply is shown in **Figure 4-1**.

**Figure 4-1**
*Power supply block diagram*
AC power is applied to the AC power module receptacle. Power is routed through the line fuse and line voltage selection switch of the power module to the power transformer. The power transformer has a total of four secondary windings for the various supplies.

AC voltage for the display filaments is taken from a power transformer secondary at F1 and F2, then routed to the display board.

Each DC supply uses a rectifier and a capacitive filter, and many supplies use an IC regulator. Table 4-2 summarizes rectifier, filter, and regulator circuits for the various DC supplies.

<table>
<thead>
<tr>
<th>Supply</th>
<th>Rectifier</th>
<th>Filter</th>
<th>Regulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5VD</td>
<td>CR104</td>
<td>C156, C273, C274, C281</td>
<td>U144</td>
</tr>
<tr>
<td>+3.3VD</td>
<td>-</td>
<td>C66</td>
<td>U18</td>
</tr>
<tr>
<td>+2.5VD</td>
<td>-</td>
<td>C205</td>
<td>U25</td>
</tr>
<tr>
<td>+1.8VD</td>
<td>-</td>
<td>C214</td>
<td>U19</td>
</tr>
<tr>
<td>+37V</td>
<td>CR115, CR117</td>
<td>C104</td>
<td>U101</td>
</tr>
<tr>
<td>+15V</td>
<td>CR102</td>
<td>C148</td>
<td>U125</td>
</tr>
<tr>
<td>-15V</td>
<td>CR102</td>
<td>C131</td>
<td>U119</td>
</tr>
<tr>
<td>+5V, +5VRL, +5V2</td>
<td>CR103</td>
<td>C146</td>
<td>U124</td>
</tr>
<tr>
<td>+18V</td>
<td>CR102</td>
<td>C148</td>
<td>-</td>
</tr>
<tr>
<td>-18V</td>
<td>CR102</td>
<td>C131</td>
<td>-</td>
</tr>
</tbody>
</table>

**Display board**

Display board components are shown in the digital circuitry block diagram in Figure 4-2.

**Microcontroller**

U401 is the display board microcontroller that controls the display and interprets key data. The microcontroller uses three internal peripheral I/O ports for the various control and read functions.

Display data is serially transmitted to the microcontroller from the digital section via the TXB line to the microcontroller RDI terminal. In a similar manner, key data is serially sent back to the digital section through the RXB line via TDO. The 4MHz clock for the microcontroller is generated by crystal Y401.
**Figure 4-2**

*Digital circuitry block diagram*
Display

DS401 is the display module, which can display up to 12 alpha-numeric characters and includes the various annunciators.

The display uses a common multiplexing scheme with each character refreshed in sequence. U402 and U403 are the drivers for the display characters and annunciators. Note that data for the drivers are serially transmitted from the microcontroller (MOSI and PC1).

Filament voltage for the display is derived from the power supply transformer (F1 and F2). The display drivers require +37VDC and +5VDC, which are supplied by U144 (+5VD) and U101 (+37V).

Key matrix

The front panel keys (S401-S430) are organized into a row-column matrix to minimize the number of microcontroller peripheral lines required to read the keyboard. A key is read by strobing the columns and reading all rows for each strobed column. Key-down data is interpreted by the display microcontroller and sent back to the main microprocessor using proprietary encoding schemes.

Digital circuitry

Refer to Figure 4-2 for the following discussion on digital circuitry.

Main microprocessor

U1 is an MCF5407 microprocessor that oversees all operating aspects of the instrument except the Ethernet interface (see below). The MPU has a 32-bit data bus and provides a 24-bit address bus. It also has integrated peripheral support such as 16-bit I/O, an integral DRAM controller with SDRAM support, and UARTs, one of which is used for the RS-232 interface.

The MPU clock frequency of 50MHz is controlled by crystal Y1. MPU RESET is performed momentarily on power-up.

Memory circuits

U6 is the flash memory that stores the firmware code for instrument operation and SDRAM U3 provides temporary storage for the MPU. A battery watchdog control automatically senses when the +5VD supply is being powered down and then switches to the lithium ion battery for power. Battery charge is maintained by U4 and associate components.

Real time clock

U7 is the real time clock. The clock runs from main power and switches to two 0.33F capacitors (C43, C44) on power down and can hold the time for up to six months.
RS-232 interface

Serial data transmission and reception is performed by the TXD and RXD lines of the MPU. U15 provides the necessary voltage level conversion for the RS-232 interface port.

Trigger circuits

Buffering for Trigger Link input and output is performed by U14 and U20. Trigger input and output is controlled by FPGA U9 under MPU supervision.

Digital I/O

U23 and U24 make up the digital input/output. Digital I/O is controlled by the FPGA U9 under MPU supervision.

Module slot control

U13 and U21 make up the control circuitry that allows communication of relay data to Slot 1 or Slot 2.

Ethernet interface

U10 is a NET+ARM 32-bit RISC processor that supervises Ethernet port operation. This IC includes an integrated 10/100BaseT MAC as well as numerous other features such as two serial ports, DMA controller, and general-purpose I/O lines. U1 is the ARM processor memory IC, while U12 provides Ethernet port I/O buffering and drive capabilities.
Analog circuitry

Refer to Figure 4-3 for the following discussion on analog circuitry.

**INPUT HI**

INPUT HI protection is provided by the SSP (Solid State Protection) circuit. The SSP is primarily made up of Q101 and Q102. An overload condition opens Q101 and Q102, which disconnects the analog input signal from the rest of the analog circuit.

Note that for the 100VDC and 1000VDC ranges, Q101 and Q102 of the SSP are open. The DC voltage signal is routed through the DCV Divider (Q114 and Q136) to the DCV switching circuit.

**AMPS input**

The ACA or DCA input signal is applied to the Current Shunt circuit, which is made up of K103, R158, R205, and R338. For the 20mA DC range, 5.1Ω (R205/[R338 + R158]) is shunted across the input. Relay K103 is energized (set state) to select the shunts. For all other DCA ranges and all ACA ranges, 0.1Ω (R158) is shunted across the input (K103 reset).

The ACA signal is then sent to the AC Switching & Gain circuit, while the DCA signal is routed directly to the A/D MUX & Gain circuit.

**Signal switching**

Signal switching for DCV and OHMS is done by the DCV & Ohms Switching circuit. FETs Q113, Q105, Q104, and Q108 connect the DCV or ohms signal to the X1 buffer (U113).

Note that the reference current for OHMS is generated by the Ohms I-Source circuit. For 4-wire ohms measurements, SENSE LO is connected to U126.

Signal switching and gain for ACV, FREQ and ACA is done by the AC Switching & Gain circuit, which is primarily made up of K102, U102, U103, U105, U112, U118, U111, and U110. Note that U111 is used for frequency adjustment. The states of these analog switches vary from unit to unit.

**Multiplexer and A/D converter**

All input signals, except FREQ, are routed to the A/D MUX & Gain circuit. The multiplexer (U163) switches the various signals for measurement. In addition to the input signal, the multiplexer also switches among reference and zero signals at various phases of the measurement cycle.

When the input signal is selected by the MUX, it is amplified by U132 and U166. Gain is controlled by switches in U129 and associated resistors.

The multiplexed signals of the measurement cycle are routed to the A/D Converter (U165) where it converts the analog signals to digital form. The digital signals are then routed through an opto-isolator to the MPU to calculate a reading.
Figure 4-3
Analog circuitry block diagram
Ohms open-lead sense detection

There are two types of open sense lead detect (Figure 4-4). The first is for the INPUT HI and INPUT LO leads. For these leads, the open sense detection is implemented in hardware. A comparator circuit monitors the voltage at the INPUT HI lead output and will trip the OVLD detect circuit when the voltage level exceeds an appropriate value for the particular range. This circuit operates because the INPUT HI lead output is connected to a current source. If the lead is disconnected, it will quickly charge the output to the current source maximum voltage level. This level depends on the range and is documented in the specifications in Appendix A. When the open sense lead is detected, the front panel will display OVRFLW.

The second type of open sense lead detection is implemented in software. This function works for the SENSE HI and SENSE LO leads. The SENSE HI and SENSE LO leads will drift negative when disconnected due to small leakage currents. These leads, when operating properly, will always have a positive voltage on them; and when disconnected, they will drift to negative voltages. The open lead sense software monitors the voltage at these inputs and will trip the open sense detect when the inputs drift to -15mV. When the open sense condition is detected, the front panel will display OVRFLW.

Figure 4-4
Ohms open-lead sense detection block diagram

Scanner card signals

Scanner card input signals are connected directly to installed scanner cards. Scanner card output signals are routed internally to the INPUTS switch, which selects between the front panel terminals and the scanner card outputs.
Troubleshooting

Troubleshooting information for the various circuits is summarized below. See “Principles of operation” on page 4-5 for circuit theory.

Display board checks

If the front panel DISP tests show a failure, troubleshoot the display board using Table 4-3.

Table 4-3
Display board checks

<table>
<thead>
<tr>
<th>Step</th>
<th>Item/component</th>
<th>Required condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front panel DISP test</td>
<td>Verify that all segments operate.</td>
<td>Use front panel display test.</td>
</tr>
<tr>
<td>2</td>
<td>P1005, pin 5</td>
<td>+5V ±5%</td>
<td>Digital +5V supply.</td>
</tr>
<tr>
<td>3</td>
<td>P1005, pin 9</td>
<td>+37V ±5%</td>
<td>Display +37V supply.</td>
</tr>
<tr>
<td>4</td>
<td>U401, pin 1</td>
<td>Goes low briefly on power up, then goes high.</td>
<td>Microcontroller RESET.</td>
</tr>
<tr>
<td>5</td>
<td>U401, pin 43</td>
<td>4MHz square wave.</td>
<td>Controller 4MHz clock.</td>
</tr>
<tr>
<td>6</td>
<td>U401, pin 32</td>
<td>Pulse train every 1msec.</td>
<td>Control from main processor.</td>
</tr>
<tr>
<td>7</td>
<td>U401, pin 33</td>
<td>Brief pulse train when front panel key is pressed.</td>
<td>Key down data sent to main processor.</td>
</tr>
</tbody>
</table>

Power supply checks

Power supply problems can be checked using Table 4-4.

Table 4-4
Power supply checks

<table>
<thead>
<tr>
<th>Step</th>
<th>Item/component</th>
<th>Required condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Line fuse</td>
<td>Check continuity.</td>
<td>Remove to check.</td>
</tr>
<tr>
<td>2</td>
<td>Line voltage</td>
<td>120V/240V as required.</td>
<td>Check power module position.</td>
</tr>
<tr>
<td>3</td>
<td>Line power</td>
<td>Plugged into live receptacle, power on.</td>
<td>Check for correct power-up sequence.</td>
</tr>
<tr>
<td>4</td>
<td>+5VD pad</td>
<td>+5V ±5%</td>
<td>+5VD, referenced to Common D.¹</td>
</tr>
<tr>
<td>5</td>
<td>+3.3VD pad</td>
<td>+3.3V ±5%</td>
<td>+3.3VD, referenced to Common D.¹</td>
</tr>
<tr>
<td>6</td>
<td>+2.5VD pad</td>
<td>+2.5V ±5%</td>
<td>+2.5VD, referenced to Common D.¹</td>
</tr>
<tr>
<td>7</td>
<td>+1.8VD pad</td>
<td>+1.8V ±5%</td>
<td>+1.8VD, referenced to Common D.¹</td>
</tr>
<tr>
<td>8</td>
<td>U101, pin 7</td>
<td>+37V ±5%</td>
<td>+37V, referenced to Common D.¹</td>
</tr>
<tr>
<td>9</td>
<td>U125, pin 3</td>
<td>+15V ±5%</td>
<td>+15V, referenced to Common A.²</td>
</tr>
<tr>
<td>10</td>
<td>U119, pin 3</td>
<td>-15V ±5%</td>
<td>-15V, referenced to Common A.²</td>
</tr>
<tr>
<td>11</td>
<td>U124, pin 3</td>
<td>+5V ±5%</td>
<td>+5VRL, referenced to Common A.²</td>
</tr>
</tbody>
</table>

¹ U144, pin 2
² C293 negative terminal
Digital circuitry checks

Digital circuit problems can be checked using Table 4-5.

Table 4-5
Digital circuitry checks

<table>
<thead>
<tr>
<th>Step</th>
<th>Item/component</th>
<th>Required condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power-on test</td>
<td>RAM OK, ROM OK.</td>
<td>Verify that RAM and ROM are functional.</td>
</tr>
<tr>
<td>2</td>
<td>J1, pin 3</td>
<td>Digital common.</td>
<td>All signals referenced to digital common.</td>
</tr>
<tr>
<td>3</td>
<td>J1, pin 9</td>
<td>+3.3V (+3.3VD supply)</td>
<td>MPU supply voltage.</td>
</tr>
<tr>
<td>4</td>
<td>U4, pin 9</td>
<td>+4.2V</td>
<td>Battery backed memory charge voltage.</td>
</tr>
<tr>
<td>5</td>
<td>J900, pin 1</td>
<td>+4.2V</td>
<td>Battery voltage (BA-52).</td>
</tr>
<tr>
<td>6</td>
<td>U1, pin 149</td>
<td>Low on power-up, then goes high.</td>
<td>MPU RESET line.</td>
</tr>
<tr>
<td>7</td>
<td>U1, lines A0-A24</td>
<td>Check for stuck bits.</td>
<td>MPU address bus.</td>
</tr>
<tr>
<td>8</td>
<td>U1, lines D0-D31</td>
<td>Check for stuck bits.</td>
<td>MPU data bus.</td>
</tr>
<tr>
<td>9</td>
<td>U1, pin 174</td>
<td>50MHz</td>
<td>MPU clock.</td>
</tr>
<tr>
<td>10</td>
<td>U15, pin 13</td>
<td>Pulse train during RS-232 I/O.</td>
<td>RS-232 RX line.</td>
</tr>
<tr>
<td>11</td>
<td>U15, pin 14</td>
<td>Pulse train during RS-232 I/O.</td>
<td>RS-232 TX line.</td>
</tr>
<tr>
<td>12</td>
<td>TP8</td>
<td>500Hz signal.</td>
<td>Signal present if main code is running properly.</td>
</tr>
</tbody>
</table>

Analog signal switching states

Table 4-6 through Table 4-12 provide switching states of the various relays, FETs, and analog switches for the basic measurement functions and ranges. These tables can be used to assist in tracing an analog signal from the input to the A/D multiplexer.

Table 4-6
DCV signal switching

<table>
<thead>
<tr>
<th>Range</th>
<th>Q101</th>
<th>Q102</th>
<th>Q114</th>
<th>Q136</th>
<th>Q109</th>
<th>K101*</th>
<th>Q113</th>
<th>Q105</th>
<th>Q104</th>
<th>Q108</th>
<th>Q14/ Q13</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mV</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>1V</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>10V</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>100V</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>1000V</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>

* K101 set states:  Pin 8 switched to Pin 7
                  Pin 3 switched to Pin 4
### Table 4-7
**ACV and FREQ signal switching**

<table>
<thead>
<tr>
<th>Range</th>
<th>Q101</th>
<th>Q102</th>
<th>K101*</th>
<th>K102*</th>
<th>U103 pin 8</th>
<th>U103 pin 9</th>
<th>U105 pin 8</th>
<th>U105 pin 9</th>
<th>U103 pin 16</th>
<th>U105 pin 1</th>
<th>U111 pin 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mV</td>
<td>ON</td>
<td>ON</td>
<td>RESET</td>
<td>RESET</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>1V</td>
<td>ON</td>
<td>ON</td>
<td>RESET</td>
<td>RESET</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>10V</td>
<td>ON</td>
<td>ON</td>
<td>RESET</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>100V</td>
<td>ON</td>
<td>ON</td>
<td>RESET</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>750V</td>
<td>ON</td>
<td>ON</td>
<td>RESET</td>
<td>SET</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
</tbody>
</table>

* K101 and K102 reset states: Pin 8 switched to Pin 9<br>Pin 3 switched to Pin 2

K101 and K102 set states: Pin 8 switched to Pin 7<br>Pin 3 switched to Pin 4

### Table 4-8
**Ω2 signal switching**

<table>
<thead>
<tr>
<th>Range</th>
<th>Q101</th>
<th>Q102</th>
<th>Q114</th>
<th>Q136</th>
<th>Q109</th>
<th>K101*</th>
<th>K102*</th>
<th>Q113</th>
<th>Q105</th>
<th>Q104</th>
<th>Q108</th>
<th>Q11</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Ω</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>RESET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>1kΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>RESET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>10kΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>RESET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>100kΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>RESET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>1MΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>RESET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>10MΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>RESET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>100MΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>RESET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>

* K101 set states: Pin 8 switched to Pin 7<br>Pin 3 switched to Pin 4

K102 reset states: Pin 8 switched to Pin 9<br>Pin 3 switched to Pin 2
### Table 4-9
**Ω4 signal switching**

<table>
<thead>
<tr>
<th>Range</th>
<th>Q101</th>
<th>Q102</th>
<th>Q114</th>
<th>Q136</th>
<th>Q109</th>
<th>K101*</th>
<th>Q113</th>
<th>Q105</th>
<th>Q104</th>
<th>Q108</th>
<th>Q11</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Ω</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>1kΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>10kΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>100kΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>1MΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>10MΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>100MΩ</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>SET</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>

* K101 set states:
  - Pin 8 switched to Pin 7
  - Pin 3 switched to Pin 4

### Table 4-10
**Ω2/Ω4 reference switching**

<table>
<thead>
<tr>
<th>Range</th>
<th>U133/0.7V</th>
<th>U133/7V</th>
<th>Q123</th>
<th>Q125</th>
<th>Q124</th>
<th>Q126</th>
<th>Q120</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Ω</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>1kΩ</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>10kΩ</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>100kΩ</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>1MΩ</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>10MΩ</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>100MΩ</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
</tr>
</tbody>
</table>

### Table 4-11
**DCA signal switching**

<table>
<thead>
<tr>
<th>Range</th>
<th>K103*</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mA</td>
<td>Set</td>
</tr>
<tr>
<td>100mA</td>
<td>Reset</td>
</tr>
<tr>
<td>1A</td>
<td>Reset</td>
</tr>
<tr>
<td>3A</td>
<td>Reset</td>
</tr>
</tbody>
</table>

* K103 set states:
  - Pin 8 to 7
  - Pin 3 to 4
* K103 reset states:
  - Pin 8 to 9
  - Pin 3 to 2
Table 4-12
ACA signal switching

<table>
<thead>
<tr>
<th>Range</th>
<th>K103*</th>
<th>U105 pin 16</th>
<th>U105 pin 1</th>
<th>U111 pin 16</th>
<th>U105 pin 8</th>
<th>U103 pin 16</th>
<th>U103 pin 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Reset</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>3A</td>
<td>Reset</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
</tbody>
</table>

* K103 set states:  Pin 8 to 7
  Pin 3 to 4
K103 reset states:  Pin 8 to 9
  Pin 3 to 2

Table 4-13 through Table 4-17 can be used to trace the analog signal through the A/D multiplexer (U163) to the final amplifier stage. These tables show the MUX lines (S3, S4, S6, S7) that are selected for measurement during the SIGNAL phase of the multiplexing cycle. Also included are switching states of analog switches (U129) that set up the gain for the final amplifier stage (U166).

Table 4-13
DCV signal multiplexing and gain

<table>
<thead>
<tr>
<th>Range</th>
<th>Signal (U163)</th>
<th>U129 pin 1</th>
<th>U129 pin 8</th>
<th>U129 pin 9</th>
<th>Gain (U166)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mV</td>
<td>S4</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>×100</td>
</tr>
<tr>
<td>1V</td>
<td>S4</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>10V</td>
<td>S4</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
<tr>
<td>100V</td>
<td>S4</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>1000V</td>
<td>S4</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
</tbody>
</table>

Table 4-14
ACV and ACA signal multiplexing and gain

<table>
<thead>
<tr>
<th>Range</th>
<th>Signal (U163)</th>
<th>U129 pin 1</th>
<th>U129 pin 8</th>
<th>U129 pin 9</th>
<th>Gain (U166)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>S3</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
</tbody>
</table>
### Table 4-15

**DCA signal multiplexing and gain**

<table>
<thead>
<tr>
<th>Range</th>
<th>Signal (U163)</th>
<th>U129 pin 1</th>
<th>U129 pin 8</th>
<th>U129 pin 9</th>
<th>Gain (U166)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mA</td>
<td>S6</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>×100</td>
</tr>
<tr>
<td>100mA</td>
<td>S6</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>×100</td>
</tr>
<tr>
<td>1A</td>
<td>S6</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>×100</td>
</tr>
<tr>
<td>3A</td>
<td>S6</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
</tbody>
</table>

### Table 4-16

**Ω2 signal multiplexing and gain**

<table>
<thead>
<tr>
<th>Range</th>
<th>Signal (U163)</th>
<th>U129 pin 1</th>
<th>U129 pin 8</th>
<th>U129 pin 9</th>
<th>Gain (U166)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Ω</td>
<td>S4</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>×100</td>
</tr>
<tr>
<td>1kΩ</td>
<td>S4</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>10kΩ</td>
<td>S4</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>100kΩ</td>
<td>S4</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>1MΩ</td>
<td>S4</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
<tr>
<td>10MΩ</td>
<td>S4</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
<tr>
<td>100MΩ</td>
<td>S4</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
</tbody>
</table>

### Table 4-17

**Ω4 signal multiplexing and gain**

<table>
<thead>
<tr>
<th>Range</th>
<th>Signal (U163)</th>
<th>U129 pin 1</th>
<th>U129 pin 8</th>
<th>U129 pin 9</th>
<th>Gain (U166)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Ω</td>
<td>S4 then S7</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>×100</td>
</tr>
<tr>
<td>1kΩ</td>
<td>S4 then S7</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>10kΩ</td>
<td>S4 then S7</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>100kΩ</td>
<td>S4 then S7</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×10</td>
</tr>
<tr>
<td>1MΩ</td>
<td>S4 then S7</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>×1</td>
</tr>
<tr>
<td>10MΩ</td>
<td>S4 then S7</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
<tr>
<td>100MΩ</td>
<td>S4 then S7</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>×1</td>
</tr>
</tbody>
</table>
Figure 4-3 provides a block diagram of the analog circuitry. Table 4-18 shows where the various switching devices are located in the block diagram.

**Table 4-18**  
*Switching device locations*

<table>
<thead>
<tr>
<th>Switching devices</th>
<th>Analog circuit section (see Figure 4-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q101, Q102</td>
<td>SSP (Solid State Protection)</td>
</tr>
<tr>
<td>Q114, Q136, Q109</td>
<td>DCV Divider</td>
</tr>
<tr>
<td>K101, Q113, Q105, Q104, Q108</td>
<td>DCV and Ohms Switching</td>
</tr>
<tr>
<td>Q121</td>
<td>Sense LO</td>
</tr>
<tr>
<td>K102, U103, U105, U111</td>
<td>AC switching and Gain</td>
</tr>
<tr>
<td>U133, Q119, Q123, Q124, Q125, Q126</td>
<td>Ohms I-Source</td>
</tr>
<tr>
<td>K103</td>
<td>Current Shunts</td>
</tr>
<tr>
<td>U129, U163</td>
<td>A/D Mux and Gain</td>
</tr>
</tbody>
</table>
5

Disassembly
Introduction

This section explains how to handle, clean, and disassemble the Model 2701 Ethernet Multimeter/Data Acquisition System. Disassembly drawings are located at the end of this section.

Handling and cleaning

To avoid contaminating PC board traces with body oil or other foreign matter, avoid touching the PC board traces while you are repairing the instrument. Some circuit board areas, especially those under the motherboard shield, have high-impedance devices or sensitive circuitry where contamination could cause degraded performance.

Handling PC boards

Observe the following precautions when handling PC boards:

• Wear cotton gloves.
• Only handle PC boards by the edges and shields.
• Do not touch any board traces or components not associated with repair.
• Do not touch areas adjacent to electrical contacts.
• Use dry nitrogen gas to clean dust off PC boards.

Solder repairs

Observe the following precautions when soldering a circuit board:

• Use an OA-based (organic activated) flux and take care not to spread the flux to other areas of the circuit board.
• Remove the flux from the work area when you have finished the repair by using pure water with clean, foam-tipped swabs or a clean, soft brush.
• Once you have removed the flux, swab only the repair area with methanol, then blow dry the board with dry nitrogen gas.
• After cleaning, allow the board to dry in a 50°C, low-humidity environment for several hours.
Static sensitive devices

CMOS devices operate at very high impedance levels. Therefore, any static that builds up on you or your clothing may be sufficient to destroy these devices if they are not handled properly. Use the following precautions to avoid damaging them:

**CAUTION** Many CMOS devices are installed in the Model 2701. Handle all semiconductor devices as being static sensitive.

- Transport and handle ICs only in containers specially designed to prevent static build-up. Typically, you will receive these parts in anti-static containers made of plastic or foam. Keep these devices in their original containers until ready for installation.
- Remove the devices from their protective containers only at a properly grounded workstation. Also, ground yourself with a suitable wrist strap.
- Handle the devices only by the body; do not touch the pins.
- Ground any printed circuit board into which a semiconductor device is to be inserted to the bench or table.
- Use only anti-static type desoldering tools.
- Use only grounded-tip soldering irons.
- Once the device is installed in the PC board, it is normally adequately protected, and you can handle the boards normally.

Assembly drawings

Use the following assembly drawings to assist you as you disassemble and reassemble the Model 2701. Also, refer to these drawings for information about the Keithley part numbers of most mechanical parts in the unit. The drawings are located at the end of this section.

- Front Panel Assembly — 2701-040
- Card Cage/Power Module Assembly — 2701-050
- Power Module/Transformer/Chassis Assembly — 2701-051
- Front Panel/Card Cage/Chassis Assembly — 2701-052
- Chassis Assembly — 2701-053, 2701-054
- Final Inspection — 2701-080
Disassembly procedures

Case cover removal

Follow the steps below to remove the case cover to gain access to internal parts.

**WARNING** Before removing the case cover, disconnect the line cord and any test leads from the instrument.

1. Remove Handle — The handle serves as an adjustable tilt-bail. Adjust its position by gently pulling it away from the sides of the instrument case and swinging it up or down. To remove the handle, swing the handle below the bottom surface of the case and back until the orientation arrows on the handles line up with the orientation arrows on the mounting ears. With the arrows lined up, pull the ends of the handle away from the case.
2. Remove Mounting Ears — Remove the screw that secures each mounting ear. Pull down and out on each mounting ear.

**NOTE** When re-installing the mounting ears, make sure to mount the right ear to the right side of the chassis and the left ear to the left side of the chassis. Each ear is marked “RIGHT” or “LEFT” on its inside surface.

3. Remove Rear Bezel — To remove the rear bezel, loosen the two captive screws that secure the rear bezel to the chassis. Pull the bezel away from the case.
4. Removing Bottom Screws — Remove the four bottom screws that secure the case to the chassis.
5. Remove Cover — To remove the case, grasp the front bezel of the instrument and carefully slide the chassis forward. Slide the chassis out of the metal case.

Motherboard removal

Perform the following steps to remove the motherboard. This procedure assumes that the case cover is already removed.

1. Remove the RS-232 and Digital I/O fasteners. The RS-232 and Digital I/O connectors each have two nuts that secure the connectors to the rear panel. Remove these nuts.
2. Remove the front/rear inputs switch rod. At the switch, place the edge of a flat-blade screwdriver in the notch on the pushrod. Gently twist the screwdriver while pulling the rod from the shaft.
3. Disconnect the front input terminals. You must disconnect these input terminal connections:
   - INPUT HI and LO
   - SENSE HI and LO
   - AMPS
Remove all the connections except the front AMPS connection by pulling the wires off the pin connectors. To remove the front panel AMPS input wire (white), first remove the AMPS fuse holder, then use needle-nose pliers to grasp the AMPS wire near the fuse housing. Push the wire forward and down to snap the spring out of the fuse housing. Carefully pull the spring and contact tip out of the housing.

4. Unplug cables:
   • Unplug the display board ribbon cable from connector J1014.
   • Unplug the transformer cables from connectors J1002 and J6.
   • Unplug scanner slots ribbon cable from connector J1012.
   • Unplug analog backplane connections J1008 and J1010.
   • Unplug the battery cable from J1017.
   • Unplug the fan cable from J1018.

5. Remove the fastening screws that secure the motherboard to the chassis. One of these screws is located along the left side of the unit towards the middle and it also secures U144. One screw is located at the right center of the chassis near the front/rear switch, S101, and another screw is behind the AC shield. The final screw is near the rear panel next to J5.

   During re-assembly, replace the board and start the RS-232 and Digital I/O connector nuts and the mounting screw. Tighten all the fasteners once they are all in place and the board is correctly aligned.

6. Remove the motherboard, which is held in place by edge guides on one side, by sliding it forward until the board edges clear the guides. Carefully pull the motherboard from the chassis.

Card cage removal

After the motherboard has been removed, the card cage that holds plug-in modules can be removed simply by removing the screws that attach the card cage to the case bottom and removing it.

Front panel disassembly

Use the following procedures to remove the display board and/or the pushbutton switch pad:

**NOTE** You must first remove the case cover, the front/rear input switch, and the front input terminal wires as described earlier in this section.

1. Unplug the display board ribbon cable from connector J1014.
2. Remove the front panel assembly.

   This assembly has four retaining clips that snap onto the chassis over four pem nut studs. Two retaining clips are located on each side of the front panel. Pull the retaining clips outward and, at the same time, pull the front panel assembly forward until it separates from the chassis.
3. Using a thin-bladed screwdriver, pry the plastic PC board stop (located at the bottom of the display board) until the bar separates from the casing. Pull the display board from the front panel.
4. Remove the switch pad by pulling it from the front panel.

Removing power components

The following procedures to remove the power transformer, power module, and fan require that the case cover and motherboard be removed, as previously explained.

Power transformer removal

Perform the following steps to remove the power transformer:
1. Remove the motherboard.
2. Remove the two nuts that secure the transformer to the side of the chassis.
3. Pull the black ground wire off the threaded stud and remove the power transformer from the chassis.

Power module removal

Perform the following steps to remove the power module:
1. Remove the motherboard.
2. Remove the POWER switch rod.
3. Remove the card cage. (See “Card cage removal” on page 5-5.)
4. Disconnect the power module’s ground wire. This green and yellow wire connects to a threaded stud on the chassis with a kep nut.
5. Squeeze the latches on either side of the power module while pushing the module from the access hole.

Fan removal

Perform the following steps to remove the fan:
1. Remove the motherboard.
2. Remove the four screws that secure the fan to the bottom of the chassis.
3. Remove the fan from the chassis.
Instrument reassembly

Reassemble the instrument by reversing the previous disassembly procedures. Make sure that all parts are properly seated and secured, and that all connections are properly made. To ensure proper operation, replace and securely fasten the shield.

**WARNING**  To ensure continued protection against electrical shock, verify that power line ground (green and yellow wire attached to the power module) and the power transformer ground (black wire) are connected to the chassis. When installing the power transformer, be sure to reconnect the black ground wire to the mounting stud on side of the chassis. Be sure to install the bottom case screws to assure a good case-to-chassis ground connection.

Input terminal wire connections

During reassembly, use the information in Table 5-1 to connect input terminal wires.

**Table 5-1**

*Input terminal wire colors*

<table>
<thead>
<tr>
<th>Input terminal</th>
<th>Wire color</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT HI</td>
<td>Red</td>
</tr>
<tr>
<td>INPUT LO</td>
<td>Black</td>
</tr>
<tr>
<td>SENSE HI</td>
<td>Yellow</td>
</tr>
<tr>
<td>SENSE LO</td>
<td>Gray</td>
</tr>
<tr>
<td>AMPS</td>
<td>White</td>
</tr>
</tbody>
</table>

Power module wire connections

Use the information in Table 5-2 and DETAIL B of drawing 2701-050 to connect power module wires.

**Table 5-2**

*Power module wire colors*

<table>
<thead>
<tr>
<th>Location</th>
<th>Wire color</th>
</tr>
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<tbody>
<tr>
<td>Right side</td>
<td>Gray</td>
</tr>
<tr>
<td>Right top</td>
<td>Violet</td>
</tr>
<tr>
<td>Left top</td>
<td>White</td>
</tr>
<tr>
<td>Right bottom</td>
<td>Red</td>
</tr>
<tr>
<td>Left bottom</td>
<td>Blue</td>
</tr>
</tbody>
</table>
STEP 1

2701-310 STAGING, FRONT PANEL
(REF 2701-308A, FRONT PANEL)

2700-313A, OVERLAY

STEP 2

2700-110H, DISPLAY BOARD ASSEMBLY
SNAP TOP OF BOARD INTO FRONT PANEL

REF: FRONT PANEL

2701-311A, DISPLAY LENS
DO NOT REMOVE GREEN MASK FROM THE LENS
USE T-1186

2001-310A, CONDUCTIVE RUBBER SWITCH

2001-371A, P.C. BOARD STOP
(2 REQ'D)
PLACE ON FRONT PANEL TABS AND SLIDE TOWARDS OUTSIDE EDGE OF PANEL

PART NUMBER QTY DESCRIPTION
2701-310 1 STAGING, FRONT PANEL REF 2701-308A
2700-110H 1 DISPLAY BOARD ASSEMBLY
2700-313A 1 OVERLAY
2701-311A 1 DISPLAY LENS
2000-310A 1 CONDUCTIVE RUBBER SWITCH
2001-371A 2 P.C. BOARD STOP

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES

X: ± .015
Y: ± .005
TOTAL: ± .064

SURFACE FINISH

KEITHLEY Instruments Inc.
Cleveland, Ohio 44134

DATE 10 Dec-01
SCALE  ---- TITILE
90
ENG APPR
LS

MATERIAL

FINISH

USED ON

MODEL NEXT ASSEMBLY NEXT PROCESS STEP QTY
2701 2701-051 FP|Chassis Assembly 1

FRONT PANEL ASSEMBLY OP6

B 2701-040
BEFORE INSTALLING COVER, REMOVE PAPER
FROM TOP OF BEEPER ON BOARD AND CHECK
ALL WIRE CONNECTIONS.
THEN POWER UP UNIT TO LOOK AT FAN TO SEE
IF OPERATIONAL.

DETAIL A
SEE RECOMMENDED PROCESS

PART NUMBER QTY DESCRIPTION
2701-055 1 TECH CHASSIS ASSEMBLY
2700-307B 1 COVER
4-40X1/4FFHUC 4 PHIL FLAT HEAD UNDERCUT SCREW
428-303D 4 REAR BEZEL
FA-232-1C 2 CAPTIVE PANEL SCREW
CS-725 4 SCREWLOCK FEMALE
4-40X3/16FFP 2 PHIL PAN HEAD SCREW
4-40X5/16PPHSEM 2 PHIL PAN HEAD SEMS SCREW
2700-319A 1 FRONT/REAR SWITCH ROD

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES
UNLESS OTHERWISE SPECIFIED

DATE 05-JUL-02

SCALE - - - -

TITLE

KEITHLEY Instruments Inc.
Cleveland, Ohio 44130

KEITHLEY

Material: 
Finish: 
Surface Max. 

Chassis Assembly QP6

2701-055 Final Chassis Assembly 1
2701 Tech 1
MODEL NEXT ASSEMBLY NEXT PROCESS STEP QTY

2701 2701-055 2701-055 2701-055
1 1 1

ENG APPR LS

NO. 2701-054
**Recommended Procedure**

1. **Beep Intensity Test**
   - **Step 1:**
     - Turn Unit ON, listen for beep.
     - Verify readings are:
       - Loading FG1A
       - Load Ethernet
       - Loading Main
       - Displays all segments
       - Ethernet:
         - XXX XXX XXX XXX
       - I: None, Z: None
       - XXX XXX
     - Place certificate of calibration on top of unit, then place into P0-14-4, chiploc bag and send with W.O. shipping kit items to audit.

2. **Step 2:**
   - Call stockroom for work order shipping kit before sending to audit.
   - Place certificate of calibration on top of unit, then place into P0-14-4, chiploc bag and send with W.O. shipping kit items to audit.
   - Remove fuse holder from unit pull fuse block section out and rotate until proper voltages will be shown in window.
   - Place certificate of calibration on top of unit, then place into P0-14-4, chiploc bag and send with W.O. shipping kit items to audit.

**Part Number**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Qty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2701-055</td>
<td>1</td>
<td>Chassis Assembly</td>
</tr>
<tr>
<td>P0-14-4</td>
<td>1</td>
<td>Chiploc Bag</td>
</tr>
<tr>
<td>CA-180-3</td>
<td>1</td>
<td>Cable - W.O. Shipping Kit</td>
</tr>
<tr>
<td>DMN-950-08*</td>
<td>1</td>
<td>Co Manual Package - W.O. Shipping Kit</td>
</tr>
<tr>
<td>PA-804</td>
<td>1</td>
<td>Packing List - W.O. Shipping Kit</td>
</tr>
<tr>
<td>PA-854</td>
<td>1</td>
<td>Packing List - W.O. Shipping Kit</td>
</tr>
<tr>
<td>CO-7</td>
<td>1</td>
<td>Line Cord - W.O. Shipping Kit</td>
</tr>
<tr>
<td>CA-22</td>
<td>1</td>
<td>Test Leads - W.O. Shipping Kit</td>
</tr>
<tr>
<td>4-40X1/4PH</td>
<td>1</td>
<td>Cert. of Cal. (PA-21A Printed in Prod)</td>
</tr>
<tr>
<td>2750-329</td>
<td>1</td>
<td>2 Phil Pan Head Screw</td>
</tr>
<tr>
<td>428-329</td>
<td>1</td>
<td>Handle</td>
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**For Europe**

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<th>Qty</th>
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<tr>
<td>2701-04-08*</td>
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<td>Manual Package - W.O. Shipping Kit</td>
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<tr>
<td>2100-B5</td>
<td>1</td>
<td>Software - W.O. Shipping Kit</td>
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</table>

**For Japan**

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<th>Qty</th>
<th>Description</th>
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<tr>
<td>FU-105-315</td>
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<td>Fuse</td>
</tr>
<tr>
<td>CO-76</td>
<td>1</td>
<td>Line Cord</td>
</tr>
<tr>
<td>CO-35</td>
<td>1</td>
<td>Line Cord</td>
</tr>
</tbody>
</table>

**Perform Hipot Test**

PER MS-1537 TO IEC Voltage Spec

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Fuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>100V</td>
</tr>
<tr>
<td>Domestic</td>
<td>120V</td>
</tr>
<tr>
<td>Europe</td>
<td>220V</td>
</tr>
</tbody>
</table>

**Keithley Instruments Inc., Cleveland, Ohio 44130**

**Final Inspection**

<table>
<thead>
<tr>
<th>Model</th>
<th>Next Assembly</th>
<th>Next Process Step</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>2701</td>
<td>Audit</td>
<td>Audit</td>
<td>1</td>
</tr>
</tbody>
</table>

**Dimensions**

<table>
<thead>
<tr>
<th>Dimensional Tolerances</th>
<th>Unless Otherwise Specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT: ±.015</td>
<td>ANG: ±.5</td>
</tr>
<tr>
<td>XXY: ±.005</td>
<td>FRA: ±.004</td>
</tr>
</tbody>
</table>
6
Replaceable Parts
Introduction

This section contains replacement parts information and component layout drawings for the Model 2701 and Model 7700.

Parts lists

Both electrical and mechanical parts for the Model 2701 are listed in Table 6-1 through Table 6-4 on the following pages. Parts for the Model 7700 plug-in module are listed in Table 6-5. For additional information on mechanical parts, see the assembly drawings provided at the end of Section 5.

Ordering information

To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see inside front cover for addresses). When ordering parts, be sure to include the following information:

- Instrument model number (Model 2701)
- Instrument serial number
- Part description
- Component designation (if applicable)
- Keithley part number

Factory service

If the instrument is to be returned to Keithley Instruments for repair, perform the following:

- Call the Repair Department at 1-888-KEITHLEY for a Return Material Authorization (RMA) number.
- Complete the service form at the back of this manual and include it with the instrument.
- Carefully pack the instrument in its original packing carton.
- Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label.

Component layouts

Component layouts for the various circuit boards are provided on the following pages.
Table 6-1
Model 2701 motherboard parts list

<table>
<thead>
<tr>
<th>Circuit designation</th>
<th>Description</th>
<th>Keithley part no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1, C3, C6, C8, C10, C11, C13, C14, C16-C25, C27</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C102</td>
<td>CAP .01UF, 10%, 1000V, CERAMIC</td>
<td>C-64-.01</td>
</tr>
<tr>
<td>C103, C111, C191, C196, C256, C257, C263, C269</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C104</td>
<td>CAP 100UF, 20%, 63V, ALUM ELEC</td>
<td>C-403-100</td>
</tr>
<tr>
<td>C105</td>
<td>CAP .22UF, 20%, 400V, FILM</td>
<td>C-513-.22</td>
</tr>
<tr>
<td>C106</td>
<td>CAP .1UF, 20%, 100V, CERAMIC</td>
<td>C-512-15P</td>
</tr>
<tr>
<td>C107</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-436-.1</td>
</tr>
<tr>
<td>C108</td>
<td>CAP 2.2UF, 20%, 63V, POLYCARB</td>
<td>C-480-2.2</td>
</tr>
<tr>
<td>C109</td>
<td>CAP 47P, 5%, 100V, CERAMIC</td>
<td>C-465-47P</td>
</tr>
<tr>
<td>C110, C226, C254</td>
<td>CAP .01, 5%, 50V, NPO</td>
<td>C-514-.01</td>
</tr>
<tr>
<td>C112, C248</td>
<td>CAP 1000P, 10%, 100V, CERAMIC</td>
<td>C-451-1000P</td>
</tr>
<tr>
<td>C113, C114, C119, C126</td>
<td>CAP .33UF, 20%, 63V, POLYCARBONE</td>
<td>C-482-.33</td>
</tr>
<tr>
<td>C115</td>
<td>CAP 270PF, 5%, 100V, CERAMIC</td>
<td>C-465-270P</td>
</tr>
<tr>
<td>C116, C188</td>
<td>CAP 47PF, 10%, 100V, CERAMIC</td>
<td>C-451-47P</td>
</tr>
<tr>
<td>C117, C134, C140, C181, C251, C265</td>
<td>CAP 1000P, 10%, 100V, CERAMIC</td>
<td>C-451-1000P</td>
</tr>
<tr>
<td>C123, C245</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C127-C130, C133, C135, C136, C138, C139, C142</td>
<td>CAP 1000UF, ±20%, 16V, ALUMINUM</td>
<td>C-488-1000</td>
</tr>
<tr>
<td>C131, C148</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
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<tr>
<td>C132</td>
<td>CAP 47PF, 10%, 100V, CERAMIC</td>
<td>C-451-47P</td>
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<tr>
<td>C137</td>
<td>CAP 330PF, 5%, 100V, CERAMIC</td>
<td>C-465-33P</td>
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<tr>
<td>C141, C158, C176, C195, C219, C220, C222, C261</td>
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<td>C-465-47P</td>
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<tr>
<td>C143, C144, C151, C159, C160, C258, C260</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C145, C240</td>
<td>CAP 1000PF, 20%, 50V, CERAMIC</td>
<td>C-418-1000P</td>
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<tr>
<td>C146</td>
<td>CAP 1000UF, ±20%, 16V, ALUMINUM</td>
<td>C-488-1000</td>
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<tr>
<td>C147, C149, C152-C155, C161-C170, C172-C174</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
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<tr>
<td>C150, C218, C285, C286, C288, C289, C39, C412</td>
<td>CAP 47PF, 10%, 100V, CERAMIC</td>
<td>C-451-47P</td>
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<td>C156, C273, C274, C281</td>
<td>CAP 1000UF, ±20%, 16V, ALUMINUM</td>
<td>C-488-1000</td>
</tr>
<tr>
<td>C157</td>
<td>CAP .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C171, C177</td>
<td>CAP 47PF, 10%, 100V, CERAMIC</td>
<td>C-451-47P</td>
</tr>
<tr>
<td>C175, C209</td>
<td>CAP 330PF, 5%, 100V, CERAMIC</td>
<td>C-592-3300</td>
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<tr>
<td>C178, C180, C182-C185, C187, C194</td>
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<td>C-465-100P</td>
</tr>
<tr>
<td>C179, C266</td>
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<td>C-418-.01</td>
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<tr>
<td>C197-C199, C201-C204, C206, C210, C213, C216</td>
<td>CAP 10UF, 20%, 16V, TANTALUM</td>
<td>C-546-10</td>
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<tr>
<td>C2, C4, C45, C72, C87, C90, C217, C229, C235</td>
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<td>C-418-4700P</td>
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<td>C207</td>
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<td>C-519-1</td>
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<td>C-418-.1</td>
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<td>C221, C223-C225, C227, C232-C234, C237, C250</td>
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<td>C-418-.15</td>
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<tr>
<td>C230</td>
<td>CAP 10UF, 20%, 16V, TANTALUM</td>
<td>C-546-10</td>
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<tr>
<td>Circuit designation</td>
<td>Description</td>
<td>Keithley part no.</td>
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<td>C-451-22P</td>
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<td>C255</td>
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<td>C-573-100</td>
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<tr>
<td>C262,C268,C468</td>
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<td>C-465-47P</td>
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<td>C283,C284,C5,C192,C200,C242,C243</td>
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<td>R304</td>
<td>RES, 20K, 1%, 100MW, THICK FILM</td>
<td>R-418-20K</td>
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<tr>
<td>R308</td>
<td>RES, 100, 1%, 100MW, THICK FILM</td>
<td>R-418-100</td>
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<tr>
<td>R309</td>
<td>RES, 1K, .1%, 1/10W, METAL FILM</td>
<td>R-263-1K</td>
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<tr>
<td>R310</td>
<td>RES, 9.09K, .1%, 1/10W, METAL FILM</td>
<td>R-263-9.09K</td>
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<tr>
<td>R311</td>
<td>RES, 392, 1%, 100MW, THICK FILM</td>
<td>R-418-392</td>
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<tr>
<td>R312,R313</td>
<td>RES, 332K,1%, 100MW, THICK FILM</td>
<td>R-418-332K</td>
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<td>R315</td>
<td>RES, 100K, 1%, 100MW, THICK FILM</td>
<td>R-418-100K</td>
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<tr>
<td>R318</td>
<td>RES, 7.32K, 1%, 100MW, THICK FILM</td>
<td>R-418-7.32K</td>
</tr>
<tr>
<td>R323</td>
<td>RES, 150, 1%, 100MV, THIN FILM</td>
<td>R-438-150</td>
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<tr>
<td>R341</td>
<td>RES, 1K, 1%, 100MW, THICK FILM</td>
<td>R-418-1K</td>
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<tr>
<td>R350</td>
<td>RES, 6.04K, 1%, 125MW, THIN FILM</td>
<td>R-423-6.04K</td>
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### Table 6-1 (Continued)
#### Model 2701 motherboard parts list

<table>
<thead>
<tr>
<th>Circuit designation</th>
<th>Description</th>
<th>Keithley part no.</th>
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<tbody>
<tr>
<td>R352</td>
<td>RES NET 50K, 1%, 1/2W, THICK FILM</td>
<td>TF-243-50K</td>
</tr>
<tr>
<td>R353</td>
<td>RESISTOR NETWORK, 10K-10K</td>
<td>TF-236</td>
</tr>
<tr>
<td>R354</td>
<td>RES NET, 5K, 1%, .668A</td>
<td>TF-243-5K</td>
</tr>
<tr>
<td>R38,R95,R97-R100,R111,R118,R122,R127</td>
<td>RES, 1K, 1%, 100MW, THICK FILM</td>
<td>R-418-1K</td>
</tr>
<tr>
<td>R382,R419,R801,R168,R69,R73,R74,R77,R79</td>
<td>RES, 10K, 1%, 100MW, THICK FILM</td>
<td>R-418-10K</td>
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<tr>
<td>R394,R22,R54,R89,R90</td>
<td>RES, 1K, 1%, 100MW, THICK FILM</td>
<td>R-418-1K</td>
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<td>R4,R6</td>
<td>RES, 10K, 1%, 100MW, THICK FILM</td>
<td>R-418-10K</td>
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<tr>
<td>R46,R131,R227,R229,R276,R282,R344,R345</td>
<td>RES, 10K, 1%, 100MW, THICK FILM</td>
<td>R-418-10K</td>
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<tr>
<td>R5</td>
<td>RES, 10, 10%, 100MW, THICK FILM</td>
<td>R-418-10</td>
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<tr>
<td>R50</td>
<td>RES, 5.11K, 1%, 100MW, THICK FILM</td>
<td>R-418-5.11K</td>
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<tr>
<td>R52,R58,R63,R65,R144,R84,R85</td>
<td>RES, .0499, 1%, 100MW, THICK FILM</td>
<td>R-418-.0499</td>
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<td>R55</td>
<td>RES, 5.49K, 1%, 100MW, THICK FILM</td>
<td>R-418-5.49K</td>
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<td>R66,R67</td>
<td>RES, 12.4, 10%, 100MW, THICK FILM</td>
<td>R-418-12.4</td>
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<td>R7</td>
<td>RES CAP NET, 50 OHM, 10%, 100-20%, 1W</td>
<td>TF-286-50-100P</td>
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<td>R72</td>
<td>RES, 3.01K, 1%, 100MW, THICK FILM</td>
<td>R-418-3.01K</td>
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<td>R75,R78,R80,R81,R130,R154,R177,R183,R186</td>
<td>RES, 100K, 1%, 100MW, THICK FILM</td>
<td>R-418-100K</td>
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<td>R8,R13-R21,R25-R33,R35,R41-R45,R47-R49</td>
<td>RES, 4.75K, 1%, 100MW, THICK FILM</td>
<td>R-418-4.75K</td>
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<td>R86,R82,R83,R92-R94,R155,R162,R203,R207</td>
<td>RES, 4.75K, 1%, 100MW, THICK FILM</td>
<td>R-418-4.75K</td>
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<td>R9,R10,R34</td>
<td>RES, 200, 1%, 100MW, THICK FILM</td>
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<td>R91</td>
<td>RES, 56.2 1%.1W, THICK FILM</td>
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<td>R96</td>
<td>RES, 56.2 1%.1W, THICK FILM</td>
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<td>RV1</td>
<td>TRANSIENT VOLTAGE SUPPRESSOR</td>
<td>VR-25</td>
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<td>RV101,RV102</td>
<td>VAR, 576V METAL OXIDE, 510L40</td>
<td>VR-5</td>
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<tr>
<td>RV104,RV105</td>
<td>BIDIRECTIONAL TRANSIENT VOLT SUPPRESSOR</td>
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<td>S101</td>
<td>SWITCH, PUSHBUTTON, 8 POLE</td>
<td>SW-468</td>
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<td>SA101</td>
<td>SURGE ARRESTER, CG3-1.5AL</td>
<td>SA-4</td>
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<td>SA102,SA103</td>
<td>SURGE ARRESTER</td>
<td>SA-8</td>
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<td>TP102,TP105,TP107</td>
<td>CONN, TEST POINT</td>
<td>CS-553</td>
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<td>TP103,TP104,DGND</td>
<td>SURFACE MOUNT PCB TEST POINT</td>
<td>CS-1026</td>
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<td>U1</td>
<td>IC, COLDFIRE MICROPROCESSOR</td>
<td>LSI-286</td>
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<td>U10</td>
<td>IC, 32 BIT RISC PROCESSOR</td>
<td>LSI-285</td>
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<td>U101</td>
<td>IC, VOLTAGE REG, LM317M</td>
<td>IC-846</td>
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<td>U102,U118</td>
<td>IC, J-FET, OP-AMP, TLE2081CD</td>
<td>IC-967</td>
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<tr>
<td>U103,U105,U111,U129</td>
<td>IC, CMOS ANALOG SWITCH, DG211DY</td>
<td>IC-768</td>
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<td>U104</td>
<td>IC, IRED AND PHOTO DIODE ARRAY</td>
<td>IC-1468</td>
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<tr>
<td>U106,U109,U121,U130,U134</td>
<td>IC, 8 STAGE SHIFT/STORE, MC14094BD</td>
<td>IC-722</td>
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<td>U107,U108</td>
<td>IC, PHOTO DARLINGTON TRANS, PS2706-1</td>
<td>IC-1467</td>
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<td>U110</td>
<td>IC, TRMS TO DC CONVERTER, 637JR</td>
<td>IC-796</td>
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### Table 6-1 (Continued)
#### Model 2701 motherboard parts list

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<th>Description</th>
<th>Keithley part no.</th>
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<tr>
<td>U112</td>
<td>IC, LOW COST HIGH SPEED JFET AMP</td>
<td>IC-1526</td>
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<tr>
<td>U113, U126</td>
<td>IC, OP-AMP, LTC1050CS8</td>
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<td>U114, U167</td>
<td>IC, DUAL J-FET OP-AMP, OP-282GS,</td>
<td>IC-968</td>
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<td>U115</td>
<td>IC, QUAD COMPARATOR, LM339D</td>
<td>IC-774</td>
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<td>U116</td>
<td>IC, DARLINGTON ARRAY, ULN2003L</td>
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<td>U117, U145</td>
<td>IC, VOLT. COMPARATOR, LM311M</td>
<td>IC-776</td>
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<td>U119</td>
<td>IC, -15V, VOLTAGE REGULATOR</td>
<td>IC-1334</td>
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<td>U12</td>
<td>IC, 10/100 ETHERNET TRANSCEIVER</td>
<td>LSI-263</td>
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<td>U120, U131, U169, U186, U30</td>
<td>IC, VOLT COMP ARATOR, LM393D</td>
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<td>U123</td>
<td>IC, DUAL PICOAMP OP-AMP, AD706JR</td>
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<td>U124</td>
<td>IC, VOLTAGE REGULATOR</td>
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<td>U125</td>
<td>IC, +15V, VOLTAGE REGULATOR</td>
<td>IC-1241</td>
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<td>U13</td>
<td>IC, OCTAL BUFFER</td>
<td>IC-1308</td>
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<td>U132, U138, U139, U190</td>
<td>IC, OPA177GS</td>
<td>IC-960</td>
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<td>U133</td>
<td>IC, CMOS ANAL SWITCH, DG444DY,</td>
<td>IC-866</td>
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<td>U137, U166</td>
<td>IC, HI-SPEED BIFET OP-AMP, AD711JR</td>
<td>IC-894</td>
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<td>U14, U20, U29</td>
<td>IC, DUAL BUFFER W/OPEN DRAIN OUTPUT</td>
<td>IC-1479</td>
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<td>U141</td>
<td>IC, PRECISION REFERENCE, LM399</td>
<td>196-600A</td>
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<td>U142</td>
<td>IC, OP-AMP, NE5534D</td>
<td>IC-802</td>
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<td>U144</td>
<td>IC, 5V, 3.0A, LOW-DROPOUT REGULATOR</td>
<td>IC-1519</td>
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<td>U148, U153</td>
<td>IC, QUAD 2 IN NOR, 74HCT02</td>
<td>IC-809</td>
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<td>U149</td>
<td>IC, NCHAN LAT DMOS QUADFET, SD5400CY</td>
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<td>U15</td>
<td>IC, +3.3V, RS232 TRANSEIVER</td>
<td>IC-1420</td>
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<td>U150</td>
<td>IC, OPTOCOUPLE, 2611</td>
<td>IC-690</td>
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<tr>
<td>U154</td>
<td>IC, QUAD D FLIP FLOP W/CLK,RESET 74HC175</td>
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<td>U155</td>
<td>IC, OPTOCOUPLE, 2601</td>
<td>IC-239</td>
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<td>U16</td>
<td>IC, 300MA, DUAL SMART BATT BACK UP REG</td>
<td>IC-1528</td>
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<td>U163</td>
<td>IC, 8-CHAN ANA MULTIPLEXER, DG408DY</td>
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<td>U165</td>
<td>PROGRAM</td>
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<td>U168</td>
<td>IC, DUAL D-TYPE F/F, 74HC74</td>
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<td>U17</td>
<td>IC, HEX SCHMITT INVERTER</td>
<td>IC-1368</td>
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<td>U175</td>
<td>IC, DUAL HIGH CMR/SPEED OPTO, HCPL-2631</td>
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<td>U18</td>
<td>IC, 1.5A, SWITCHING REGULATOR</td>
<td>IC-1426</td>
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<td>U19</td>
<td>INTEGRATED CIRCUIT SMT</td>
<td>IC-1532</td>
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<tr>
<td>U2, U21, U22, U26, U28, U31-U34, U801-U803</td>
<td>UHS CONFIGURABLE 2-INPUT GATE</td>
<td>IC-1492</td>
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<td>U23, U24</td>
<td>IC, PROTECTED QUAD POWER DRIVERS</td>
<td>IC-1212</td>
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### Table 6-1 (Continued)

*Model 2701 motherboard parts list*

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<th>Description</th>
<th>Keithley part no.</th>
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<tr>
<td>U25</td>
<td>IC, 2.5V, 1.5A, SWITCHING REGULATOR</td>
<td>IC-1505</td>
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<td>U27</td>
<td>INTERGRATED CIRCUIT SMT</td>
<td>IC-1423</td>
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<td>U3,U11</td>
<td>IC, 512K X 32 X 4 BANKS SDRAM</td>
<td>LSI-266-2</td>
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<td>U35</td>
<td>UHS CONFIGURABLE 2-INPUT GATE</td>
<td>IC-1493</td>
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<td>U4</td>
<td>IC, LITHIUM ION BATTERY CHARGER</td>
<td>IC-1530</td>
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<td>U427</td>
<td>INTERGRATED CIRCUIT SMT</td>
<td>IC-1529</td>
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<td>U5</td>
<td>OCTAL BUFFERS/DRIVERS, 3-ST OUT</td>
<td>IC-1488</td>
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<td>U6</td>
<td>IC, 3V, ADV BOOT BLOCK FLASH MEM</td>
<td>LSI-257-1</td>
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<td>U7</td>
<td>INTERGRATED CIRCUIT SMT</td>
<td>IC-1524</td>
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<td>U8</td>
<td>IC, 32K X8 BIT, 70NS 3.3V FRAM</td>
<td>LSI-291-1</td>
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<td>U805-U807</td>
<td>UHS CONFIGURABLE 2-INPUT GATE</td>
<td>IC-1492</td>
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<td>U9</td>
<td>FPGA, 2.5V</td>
<td>LSI-292-1</td>
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<td>VR102</td>
<td>DIODE, ZENER, 6.0V, BZX84B6V2</td>
<td>DZ-87</td>
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<td>VR103,VR104</td>
<td>DIODE, ZENER, 6.8V, MMSZ5235BT1</td>
<td>DZ-100</td>
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<td>VR105,VR106,VR124,VR125</td>
<td>DIODE, ZENER, 11V, MMSZ11T1</td>
<td>DZ-103</td>
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<td>VR107,VR108,VR110,VR122,VR123</td>
<td>DIODE, ZENER, 5.1V, BZX84C5V1</td>
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<td>VR109</td>
<td>DIODE, ZENER, 17V, MMBZ5247BL</td>
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<td>VR112,VR113</td>
<td>DIODE, ZENER, 6.2V, MMSZ6V2</td>
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<td>VR119,VR120</td>
<td>DIODE, ZENER, 12V, MMSZ12T1</td>
<td>DZ-112</td>
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<td>Y1</td>
<td>CRYSTAL OSCILLATOR, 50M</td>
<td>CR-73-4</td>
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<td>Y102</td>
<td>CRYSTAL OSCILLATOR, 12M</td>
<td>CR-75-1</td>
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<td>Y2</td>
<td>CRYSTAL, FSM327</td>
<td>CR-41</td>
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### Table 6-2

**Model 2701 display board parts list**

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<tr>
<th>Circuit designation</th>
<th>Description</th>
<th>Keithley part no.</th>
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<tr>
<td>C401, C402, C411, C403, C404, C405, C407, C409</td>
<td>CAP, .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C406, C408</td>
<td>CAP, 33PF, 10%, 100V, CERAMIC</td>
<td>C-451-33P</td>
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<tr>
<td>C410, C412</td>
<td>CAP, .1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
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<tr>
<td>C413</td>
<td>CAP, 22UF, 20%, 6.3, TANTALUM</td>
<td>C-417-22</td>
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<tr>
<td>C414</td>
<td>CAP, 47PF, 10%, 100V, CERAMIC</td>
<td>C-451-47P</td>
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<td>CR401, CR402</td>
<td>DIODE, MBR0520LT1</td>
<td>RF-103</td>
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<td>DS401</td>
<td>DISPLAY</td>
<td>DD-61</td>
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<td>P1014</td>
<td>CABLE ASSEMBLY</td>
<td>CA-123-16A</td>
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<td>R401–R404, R406, R409, R411, R414–R418</td>
<td>RES, 15k, 1%, 100MW, THICK FILM</td>
<td>R-418-15K</td>
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<tr>
<td>R405, R408, R410, R412</td>
<td>RES, 12.1, 1%, 1/4W, METAL FILM</td>
<td>R-391-12.1</td>
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<td>R413</td>
<td>RES, 13k, 1%, 100MW, THICK FILM</td>
<td>R-418-13K</td>
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<td>R419</td>
<td>RES, 10M, 5%, 125MW, METAL FILM</td>
<td>R-375-10M</td>
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<td>R420, R421</td>
<td>RES, 10k, 1%, 100MW, THICK FILM</td>
<td>R-418-10K</td>
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<td>U401</td>
<td>PROGRAMMED ROM</td>
<td>2000-800A02</td>
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<td>U402, U403</td>
<td>IC, LATCHED DRIVERS, UCN-5812EPF-1</td>
<td>IC-732</td>
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<td>Y401</td>
<td>CRYSTAL, 4MHZ</td>
<td>CR-36-4M</td>
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### Table 6-3

**Model 2701 backplane board parts list**

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<tr>
<td>J1, J2</td>
<td>CONN 2 ROWS OF 16 PINS</td>
<td>CS-736-4</td>
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<td>J3</td>
<td>CONN, RT ANGLE HEADER</td>
<td>CS-1066-1</td>
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<tr>
<td>J4, J5</td>
<td>CONN, FEMALE, 8 PIN</td>
<td>CS-612-8</td>
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<tr>
<td>J6, J7</td>
<td>CONN, MALE, 3 PIN</td>
<td>CS-612-1</td>
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<tr>
<td>L1, L2</td>
<td>FERRITE CHIP, 600 OHM, BLM32A07</td>
<td>CH-62</td>
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<tr>
<td>R1, R3</td>
<td>RES, 4.75K, 1%, 100MW, THICK FILM</td>
<td>R-418-4.75K</td>
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<tr>
<td>R2, R4-R13</td>
<td>RES, 475, 1%, 1/4W, METAL FILM</td>
<td>R-391-475</td>
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<tr>
<td>Quantity</td>
<td>Description</td>
<td>Keithley part no.</td>
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<td>HANDLE</td>
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<td>FAN</td>
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<td>CHASSIS</td>
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<td>1</td>
<td>REAR PANEL</td>
<td>2701-303A</td>
</tr>
<tr>
<td>1</td>
<td>FRONT PANEL</td>
<td>2701-308A</td>
</tr>
<tr>
<td>1</td>
<td>FRONT PANEL</td>
<td>2001-302H</td>
</tr>
<tr>
<td>1</td>
<td>DISPLAY LENS</td>
<td>2701-311A</td>
</tr>
<tr>
<td>1</td>
<td>SLOT COVER</td>
<td>2750-321A</td>
</tr>
<tr>
<td>1</td>
<td>BEZEL, REAR</td>
<td>428-303D</td>
</tr>
<tr>
<td>2</td>
<td>FOOT</td>
<td>428-319A</td>
</tr>
<tr>
<td>1</td>
<td>MOUNTING EAR, RIGHT</td>
<td>428-328E</td>
</tr>
<tr>
<td>1</td>
<td>MOUNTING EAR, LEFT</td>
<td>428-338B</td>
</tr>
<tr>
<td>1</td>
<td>POWER ROD</td>
<td>704-313A</td>
</tr>
<tr>
<td>1</td>
<td>BATTERY, LITHIUM ION</td>
<td>BA-52</td>
</tr>
<tr>
<td>2</td>
<td>BANANA JACK, PUSH-IN BLACK</td>
<td>BJ-14-0</td>
</tr>
<tr>
<td>2</td>
<td>BANANA JACK, PUSH-IN RED</td>
<td>BJ-14-2</td>
</tr>
<tr>
<td>2</td>
<td>FOOT, EXTRUDED</td>
<td>FE-22A</td>
</tr>
<tr>
<td>2</td>
<td>FOOT, RUBBER</td>
<td>FE-6</td>
</tr>
<tr>
<td>1</td>
<td>FUSE HOLDER</td>
<td>FH-35-1</td>
</tr>
<tr>
<td>1</td>
<td>FUSE, .630A, 250V, SLO BLO FUSE</td>
<td>FU-106-.630</td>
</tr>
<tr>
<td>1</td>
<td>FUSE, 3A, 250</td>
<td>FU-99-1</td>
</tr>
<tr>
<td>1</td>
<td>LINE MODULE</td>
<td>PM-1-1B</td>
</tr>
<tr>
<td>1</td>
<td>TRANSFORMER</td>
<td>TR-361A</td>
</tr>
<tr>
<td>1</td>
<td>TEST LEADS</td>
<td>CA-22</td>
</tr>
<tr>
<td>1</td>
<td>LINE CORD</td>
<td>CO-7</td>
</tr>
</tbody>
</table>
## Table 6-5

**Model 7700 parts list**

<table>
<thead>
<tr>
<th>Circuit designation</th>
<th>Description</th>
<th>Keithley part no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1,C9,C10,C11,C14,C15,C22,C4</td>
<td>CAP, 0.1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C16</td>
<td>CAP, 220U, 20%, 10V, TANTALUM</td>
<td>C-558-220</td>
</tr>
<tr>
<td>C17,C18,C19,C21,C25,C26,C23,C24,C15</td>
<td>CAP, 47P, 5%, 100V, CERAMIC</td>
<td>C-465-47P</td>
</tr>
<tr>
<td>C2,C6,C7,C8,C12,C13,C20,C27,C28,C31</td>
<td>CAP, 0.1UF, 20%, 50V, CERAMIC</td>
<td>C-418-.1</td>
</tr>
<tr>
<td>C29,C32,C33,C34</td>
<td>CAP, 47P, 5%, 100V, CERAMIC</td>
<td>C-465-47P</td>
</tr>
<tr>
<td>C30</td>
<td>CAP, 4.7U, 10%, 35V, TANTALUM</td>
<td>C-476-4.7</td>
</tr>
<tr>
<td>CR1,CR22</td>
<td>DIODE, DUAL SWITCHING, BAV99L</td>
<td>RF-82</td>
</tr>
<tr>
<td>CR23,CR24,CR26,CR27</td>
<td>DIODE, SWITCHING, MMBD914</td>
<td>RF-83</td>
</tr>
<tr>
<td>CR2-CR21,CR25</td>
<td>DIODE, DUAL SWITCHING, BAV99L</td>
<td>RF-82</td>
</tr>
<tr>
<td>F1,F2</td>
<td>FUSE, 3A</td>
<td>FU-107-1</td>
</tr>
<tr>
<td>J1</td>
<td>CONN, RT ANGLE DUAL ROW RECEPT</td>
<td>CS-1065-1</td>
</tr>
<tr>
<td>J2</td>
<td>SINGLE COIL LATCH RELAY</td>
<td>RL-225</td>
</tr>
<tr>
<td>K1-K21,K24,K25,K26,K27</td>
<td>NON LATCHING RELAY</td>
<td>RL-242</td>
</tr>
<tr>
<td>Q1</td>
<td>N-CHANNEL/P-CHANNEL POWER MOSFET</td>
<td>TG-360</td>
</tr>
<tr>
<td>Q2,Q4</td>
<td>TRANS, PNP SILICON</td>
<td>TG-388</td>
</tr>
<tr>
<td>Q3,Q6,Q49,Q50</td>
<td>TRANS, NPN SILICON</td>
<td>TG-389</td>
</tr>
<tr>
<td>Q34,36,40,42,44,46,7</td>
<td>TRANS, PNP SILICON</td>
<td>TG-388</td>
</tr>
<tr>
<td>Q35,37,41,43,45,47,48</td>
<td>TRANS, NPN SILICON</td>
<td>TG-389</td>
</tr>
<tr>
<td>Q5</td>
<td>P CHANNEL TMOSFET</td>
<td>TG-392</td>
</tr>
<tr>
<td>Q8,10,12,14,16,18,20,22,24,26,28,30,32</td>
<td>TRANS, PNP SILICON</td>
<td>TG-388</td>
</tr>
<tr>
<td>Q9,11,13,15,17,19,21,23,25,27,29,31,33</td>
<td>TRANS, NPN SILICON</td>
<td>TG-389</td>
</tr>
<tr>
<td>R1</td>
<td>RES, 69.8K, 1%, 1W, THICK FILM</td>
<td>R-418-69.8K</td>
</tr>
<tr>
<td>R10,R11,R12</td>
<td>RES, 4.7K, 5%, 125MW, METAL FILM</td>
<td>R-375-4.7K</td>
</tr>
<tr>
<td>R108,R109,R110,R111,R3,R150</td>
<td>RES, 1K, 1%, 100MW, THICK FILM</td>
<td>R-418-1K</td>
</tr>
<tr>
<td>R13,R14</td>
<td>RES, 3.01K, 1%, 125MW, METAL FILM</td>
<td>R-391-3.01K</td>
</tr>
<tr>
<td>R15-R54,R58,R59</td>
<td>RES, 4.22K, 1%, 125MW, METAL FILM</td>
<td>R-391-4.22K</td>
</tr>
<tr>
<td>R2</td>
<td>RES, 10K, 1%, 100MW, THICK FILM</td>
<td>R-418-10K</td>
</tr>
<tr>
<td>R4,R5,R6,R7</td>
<td>RES, 2.21K, 1%, 125MW, METAL FILM</td>
<td>R-391-2.21K</td>
</tr>
<tr>
<td>R8</td>
<td>RES, 1K, 5%, 125MW, METAL FILM</td>
<td>R-375-1K</td>
</tr>
<tr>
<td>R9</td>
<td>RES, 1K, 5%, 125MW, METAL FILM</td>
<td>R-375-1K</td>
</tr>
<tr>
<td>R55,R56,R57</td>
<td>RES, 470, 5%, 125MW, METAL FILM</td>
<td>R-375-470</td>
</tr>
<tr>
<td>R60,R61</td>
<td>RES, 4.22K, 1%, 125MW, METAL FILM</td>
<td>R-391-4.22K</td>
</tr>
<tr>
<td>R62,R63</td>
<td>RES, 137, 1%, 125MW, METAL FILM</td>
<td>R-391-137</td>
</tr>
<tr>
<td>R64,R65,R66,R67,R68,R69,R70,R71</td>
<td>RES, 499, 1%, 100MW, THICK FILM</td>
<td>R-418-499</td>
</tr>
<tr>
<td>TE101-TE110,TE122</td>
<td>CONN, 4-PIN, JOLO BB-125-04</td>
<td>TE-115-4</td>
</tr>
<tr>
<td>TE-121</td>
<td>CONN, 6-PIN</td>
<td>TE-115-6</td>
</tr>
<tr>
<td>U1,U2,U3,U4,U8</td>
<td>IC, 8 STAGE SHIFT/STORE, MC14094BD</td>
<td>IC-772</td>
</tr>
<tr>
<td>U11,U12,U13,U15,U17,U18</td>
<td>IC, CENTIGRADE TEMP SENSOR, LM35DM</td>
<td>IC-906</td>
</tr>
<tr>
<td>U14</td>
<td>IC, RETRIG., MULTIVIB, 74HC123AM</td>
<td>IC-788</td>
</tr>
</tbody>
</table>
### Table 6-5 (Continued)
*Model 7700 parts list*

<table>
<thead>
<tr>
<th>Circuit designation</th>
<th>Description</th>
<th>Keithley part no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>U16, U24, U6, U7, U25, U9, U10</td>
<td>IC, 2.5V, CASCADABLE SERIAL EEPROM&lt;br&gt;IC, QUAD 2 IN AND, 74HCT08&lt;br&gt;IC, 8-CHAN ANA MULTIPLEXER, DG408DY&lt;br&gt;IC, POS NAND GATES/INV, 74HCT14&lt;br&gt;IC, DUAL OPTO&lt;br&gt;TOP COVER HEAT STAKE ASSEMBLY&lt;br&gt;BOTTOM CARD COVER&lt;br&gt;COMPRESSION SPRING</td>
<td>LSI-212&lt;br&gt;IC-837&lt;br&gt;IC-844&lt;br&gt;IC-656&lt;br&gt;IC-1358&lt;br&gt;7700-302A&lt;br&gt;7702-301C&lt;br&gt;SP-7-3</td>
</tr>
</tbody>
</table>
PRIMARY SIDE COMPONENTS (SIDE-04)

MC-612

NOTE: FOR FURTHER COMPONENT INFORMATION REFER TO 2750 PRODUCT STRUCTURE.
# 2701 Ethernet Multimeter/Data Acquisition System

## DC CHARACTERISTICS

**CONDITIONS:** MED (1 PLC) or 10 PLC or MED (1 PLC) with Digital Filter of 10

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>RANGE</th>
<th>RESOLUTION</th>
<th>TEST CURRENT ±5% OR BURDEN VOLTAGE</th>
<th>INPUT RESISTANCE OR OPEN CKC</th>
<th>VOLTAGE</th>
<th>ACCURACY: ±(ppm of reading + ppm of range) (ppm + parts per million) (e.g., 10ppm = 0.001%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage 11</td>
<td>0.00000 mV</td>
<td>0.1 µV</td>
<td>&gt;10 GΩ</td>
<td>±15</td>
<td>25 x 35</td>
<td>30 x 35 (1 ± 5°C)</td>
</tr>
<tr>
<td></td>
<td>1.00000 V</td>
<td>0.1 µV</td>
<td>&gt;10 GΩ</td>
<td>±15</td>
<td>25 x 37</td>
<td>30 x 7 (1 ± 5°C)</td>
</tr>
<tr>
<td></td>
<td>10.0000 V</td>
<td>10 µV</td>
<td>&gt;10 GΩ</td>
<td>±15</td>
<td>20 x 5</td>
<td>30 x 5 (1 ± 5°C)</td>
</tr>
<tr>
<td></td>
<td>100.000 V</td>
<td>100 µV</td>
<td>&gt;10 MΩ</td>
<td>±15</td>
<td>35 x 9</td>
<td>45 x 9 (5 ± 1°C)</td>
</tr>
<tr>
<td></td>
<td>1000.00 V</td>
<td>1 mV</td>
<td>&gt;10 GΩ</td>
<td>±20</td>
<td>35 x 9</td>
<td>50 x 9 (5 ± 1°C)</td>
</tr>
</tbody>
</table>

**Resistance 4, 8**

<table>
<thead>
<tr>
<th>Resistance</th>
<th>20 x 20</th>
<th>80 x 20</th>
<th>100 x 20</th>
<th>±5% 100 µV</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.000 Ω</td>
<td>6.9 V</td>
<td>6.9 V</td>
<td>6.9 V</td>
<td>±20 + 0.01%</td>
</tr>
<tr>
<td>1000.00 Ω</td>
<td>6.9 V</td>
<td>6.9 V</td>
<td>6.9 V</td>
<td>±80 + 0.01%</td>
</tr>
<tr>
<td>10000.0 Ω</td>
<td>12.8 V</td>
<td>12.8 V</td>
<td>12.8 V</td>
<td>±200 + 0.01%</td>
</tr>
<tr>
<td>100000.0 Ω</td>
<td>70.6 V</td>
<td>70.6 V</td>
<td>70.6 V</td>
<td>±2000 + 0.01%</td>
</tr>
</tbody>
</table>

**TEMPERATURE 19**

*(Displayed in °C, °F, or K. Exclusive of probe errors.)*

<table>
<thead>
<tr>
<th>Thermocouples (Accuracy based on ITS-90.)</th>
<th>90 Day</th>
<th>1 Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>J –200 to +760 °C</td>
<td>0.001°C</td>
<td>0.2°C</td>
</tr>
<tr>
<td>K –200 to +1372°C</td>
<td>0.001°C</td>
<td>0.2°C</td>
</tr>
<tr>
<td>N –200 to +1300°C</td>
<td>0.001°C</td>
<td>0.2°C</td>
</tr>
<tr>
<td>T –200 to +400°C</td>
<td>0.001°C</td>
<td>0.2°C</td>
</tr>
<tr>
<td>E –200 to +1000°C</td>
<td>0.001°C</td>
<td>0.2°C</td>
</tr>
<tr>
<td>R 0 to +1372°C</td>
<td>0.1°C</td>
<td>0.6°C</td>
</tr>
<tr>
<td>S 0 to +1768°C</td>
<td>0.1°C</td>
<td>0.6°C</td>
</tr>
<tr>
<td>B +350 to +1820°C</td>
<td>0.1°C</td>
<td>0.6°C</td>
</tr>
</tbody>
</table>

**DC MEASUREMENT SPEEDS**

**Single Channel, 60Hz (50Hz) Operation**

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>DIGITS</th>
<th>READINGS/s</th>
<th>PLCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCV, DCI, Ω (10M)</td>
<td>5</td>
<td>(4)</td>
<td>10</td>
</tr>
<tr>
<td>Thermocouple, Thermistor</td>
<td>5</td>
<td>(4)</td>
<td>1</td>
</tr>
<tr>
<td>Channel (Ratio)</td>
<td>5</td>
<td>(4)</td>
<td>10</td>
</tr>
<tr>
<td>Channel (AVG)</td>
<td>5</td>
<td>(4)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Multiple Channels Into Memory**

<table>
<thead>
<tr>
<th>Channels/s</th>
<th>7710 Scanning DCV</th>
<th>7703 Scanning DCV</th>
<th>7703 Scanning DCV with Limits or Time Stamp On</th>
<th>7703 Scanning DCV alternating 2W</th>
</tr>
</thead>
<tbody>
<tr>
<td>7702 Scanning DCV</td>
<td>75</td>
<td>(5)</td>
<td>200</td>
<td>(100)</td>
</tr>
<tr>
<td>7700 and 7708 Scanning Temperature (T/C)</td>
<td>75</td>
<td>(5)</td>
<td>200</td>
<td>(100)</td>
</tr>
</tbody>
</table>

**Multiple Channels, Into and Out of Memory**

<table>
<thead>
<tr>
<th>Channels/s</th>
<th>7710 Scanning DCV</th>
<th>7703 Scanning DCV</th>
<th>7703 Scanning DCV with Limits or Time Stamp On</th>
<th>7703 Scanning DCV alternating 2W</th>
</tr>
</thead>
<tbody>
<tr>
<td>7700 and 7708 Scanning Temperature (T/C)</td>
<td>75</td>
<td>(5)</td>
<td>200</td>
<td>(100)</td>
</tr>
</tbody>
</table>

---

**DC SYSTEM SPEEDS**

**RANGE CHANGES**% 50/±42/s (excludes 4 Wire Ohms).

**FUNCTION CHANGES**% 50/±42/s.

**AI TORANGE TIME**% <30ms.

**ASCII READINGS TO RS-232 (115.2k BAUD)**: 300/s.

**MAX. EXTERNAL TRIGGER RATE**: 2000/s.

---

**2701 Ethernet Multimeter/Data Acquisition System**
**DC SPEED vs. NOISE REJECTION**

<table>
<thead>
<tr>
<th>Rate</th>
<th>Filter</th>
<th>RMS Noise</th>
<th>NMRR</th>
<th>CMRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Off</td>
<td>0.1 (0.08)</td>
<td>6.5</td>
<td>&lt;2.5 µV</td>
</tr>
<tr>
<td>1</td>
<td>Off</td>
<td>13 (12)</td>
<td>5.5</td>
<td>&lt;6 µV</td>
</tr>
<tr>
<td>0.1</td>
<td>Off</td>
<td>509 (400)</td>
<td>5.5</td>
<td>&lt;40 µV</td>
</tr>
<tr>
<td>0.006</td>
<td>Off</td>
<td>3000 (3000)</td>
<td>4.5</td>
<td>&lt;300 µV</td>
</tr>
<tr>
<td>0.002</td>
<td>Off</td>
<td>3500 (3500)</td>
<td>3.5</td>
<td>&lt;1 mV</td>
</tr>
</tbody>
</table>

**DC MEASUREMENT CHARACTERISTICS**

**DC Volts**

- **A-D LINEARITY:** 2.0 ppm of reading ± 0.01 ppm of range.
- **INPUT IMPEDANCE:** 100MΩ-10GΩ: Selectable >10GΩ // with <400Ω or 10MΩ ±1%, 100V, 1000V: 10MΩ ±1%.

**EARTH ISOLATION:** 500V peak, >10GΩ any terminal to chassis.

**OUTPUT BIAS CURRENT:** <75pA at 23°C.

**INPUT PROTECTION:** 1000V, all Source Inputs, 350V Sense Inputs. 300V

**REFERENCE JUNCTION:** ITS-90.

**CONVERSION:** Thermocouples

- 100mA–3A, 0.1

**SHUNT RESISTORS:**

- **DC Current**
  - SHUNT Resistors: 100mA–3A, 0.1Ω, 20mA, 5Ω.
  - INPUT PROTECTION: 3A, 250V fuse.

**Thermocouples**

- **CONVERSION:** ITS-90.
- **REFERENCE JUNCTION:** Internal, External, or Simulated (Fixed).
- **OPEN CIRCUIT CHECK:** Selectable per channel. Open >11.4k ± 200Ω:

**AC SPECIFICATIONS**

1. **Function**: Voltage, Current, Resistance
2. **Range**: 100.0000 mV, 1.000000 V, 10.000000 V, 100.00000 V, 1000.0000 V, 7.50000 V
3. **Calibration Cycle**: 90 Days, 1 Year (all ranges)
4. **Accuracy**: ±(% of reading ± % of range), 23°C ± 5°C

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Resolution</th>
<th>Calibration Cycle</th>
<th>3 Hz–10 Hz</th>
<th>10 Hz–20 kHz</th>
<th>20 kHz–50 kHz</th>
<th>50 kHz–100 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.0000 mV</td>
<td>0.1 µV</td>
<td>90 Days</td>
<td>0.35 ± 0.03</td>
<td>0.05 ± 0.03</td>
<td>0.11 ± 0.05</td>
<td>0.6 ± 0.08</td>
</tr>
<tr>
<td>1.000000 V</td>
<td>1.0 µV</td>
<td>(all ranges)</td>
<td>0.35 ± 0.03</td>
<td>0.06 ± 0.03</td>
<td>0.12 ± 0.05</td>
<td>0.6 ± 0.08</td>
</tr>
<tr>
<td>10.00000 V</td>
<td>10 µV</td>
<td>1 Year</td>
<td>0.35 ± 0.03</td>
<td>0.06 ± 0.03</td>
<td>0.12 ± 0.05</td>
<td>0.6 ± 0.08</td>
</tr>
<tr>
<td>100.0000 V</td>
<td>100 µV</td>
<td>(all ranges)</td>
<td>0.35 ± 0.03</td>
<td>0.06 ± 0.03</td>
<td>0.12 ± 0.05</td>
<td>0.6 ± 0.08</td>
</tr>
<tr>
<td>750.000 V</td>
<td>5.0 kΩ</td>
<td>(all ranges)</td>
<td>0.35 ± 0.03</td>
<td>0.06 ± 0.03</td>
<td>0.12 ± 0.05</td>
<td>0.6 ± 0.08</td>
</tr>
</tbody>
</table>

**Frequency and Period**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Resolution</th>
<th>Calibration Cycle</th>
<th>Accuracy (ppm of reading + ppm of range) (3 Hz–500 kHz) (333 ms–2 s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mV</td>
<td>0.333 ppm</td>
<td>90 Days / 1 Year</td>
<td>100 ppm + 0.333 ppm (SWL, 1s gate) 100 ppm + 3.333 ppm (MED, 10ms gates)</td>
</tr>
<tr>
<td>3.00000 A</td>
<td>10 µA</td>
<td>90 Days / 1 Year</td>
<td>100 ppm + 0.333 ppm (SWL, 1s gate) 100 ppm + 3.333 ppm (MED, 10ms gates)</td>
</tr>
</tbody>
</table>

**ACCURACY**

- Add ±2% (measured with 10MΩ input resistance. DMM, >10GΩ DMM on 10MΩ and 100MΩ ranges).

**EARTH ISOLATION**

- Add 1.0V when used with plug-in modules.

**OFFSET COMPENSATION**

- Add the following to "ppm of range" uncertainty when using plug-in modules:
  - 10. For RATIO, DCV only. For AVERAGE, DCV and Thermocouples only. Available with plug-in modules only.
  - 11. Add 6µV to "of range" uncertainty when using Models 7701, 7703, and 7707, and 3µV for Models 7706 and 7709.

**INPUT PROTECTION**

- Add 1.0V when used with plug-in modules.

**INPUT PROTECTION**

- Add 20% overrange except on 1000V and 3A.

**OFFSET COMPENSATION**

- Add the following to "ppm of range" uncertainty:
  - 100mV: 15ppm; 1V and 100V: 2ppm; 100V and 1000V: 1ppm.

**INPUT PROTECTION**

- Add 1.0V when used with plug-in modules.

**INPUT PROTECTION**

- Add the following to "ppm of range" uncertainty:
  - 100mV: 15ppm; 1V and 100V: 2ppm; 100V and 1000V: 1ppm.

**OFFSET COMPENSATION**

- Add the following to "ppm of range" uncertainty:
  - 100mV: 15ppm; 1V and 100V: 2ppm; 100V and 1000V: 1ppm.

**INPUT PROTECTION**

- Add 1.0V when used with plug-in modules.

**INPUT PROTECTION**

- Add the following to "ppm of range" uncertainty:
  - 100mV: 15ppm; 1V and 100V: 2ppm; 100V and 1000V: 1ppm.

**OFFSET COMPENSATION**

- Add the following to "ppm of range" uncertainty:
  - 100mV: 15ppm; 1V and 100V: 2ppm; 100V and 1000V: 1ppm.

**INPUT PROTECTION**

- Add 1.0V when used with plug-in modules.

**INPUT PROTECTION**

- Add the following to "ppm of range" uncertainty:
  - 100mV: 15ppm; 1V and 100V: 2ppm; 100V and 1000V: 1ppm.

**OFFSET COMPENSATION**

**INPUT PROTECTION**

- Add 1.0V when used with plug-in modules.
2701 Ethernet Multimeter/Data Acquisition System

**AC Volt**
- **MEASUREMENT METHOD:** AC-coupled, True RMS.
- **INPUT IMPEDANCE:** 1MΩ ± 2% // by <100pF.
- **INPUT PROTECTION:** 1kV, 400VDC, 300Vrms with plug in modules.

**AC Current**
- **MEASUREMENT METHOD:** AC-coupled, True RMS.
- **SHAUT RESISTANCE:** 0.1Ω.
- **BURDEN VOLTAGE:** 1A <0.5Vrms, 3A <1.5Vrms. Add 1.5Vrms when used with plug in modules.
- **INPUT PROTECTION:** 3A, 250V fuse.

**Frequency and Period**
- **MEASUREMENT METHOD:** Reciprocal Counting technique.
- **GATE TIME:** SLOW 1s, MED 100ms, and FAST 10ms.

**AC General**
- **AC CMRR:** 50dB.
- **VOLT Hertz PRODUCT:** 8/s (3/s).

**AC MEASUREMENT CHARACTERISTICS**

**AC Notes**
- Includes measurement and data transfer over ethernet (Reading Element only).
- Includes measurement and data transfer over ethernet (Reading Element only).

**GENERAL SPECIFICATIONS:**

**EXPANSION SLOTS:** 2.
- **POWER SUPPLY:** 100V / 120V / 220V / 240V ±10%.
- **LINE FREQUENCY:** 55Hz to 66Hz and 360Hz to 440Hz, automatically sensed at power-up.
- **POWER CONSUMPTION:** 80VA.
- **OPERATING ENVIRONMENT:** Specified for 0°C to 50°C. Altitude <2000m above Sea Level.
- **STORAGE ENVIRONMENT:** -40°C to 70°C.
- **BATTERY:** Lithium ion battery-backed memory. 30 days of buffer storage @ 23°C and >4 hours charge time. Battery lifetime: 3 years @ 23°C, 1.5 years @ 50°C.
- **WARRANTY:** 3 years, excludes battery.
- **VIBRATION:** MIL-PRF-28800F Class 3, Random.
- **WARM-UP:** 2 hours to rated accuracy.

**DIMENSIONS:**
- **Rack Mounting:** 8mm high x 213mm wide x 370mm deep (3.5 in x 8.375 in x 14.563 in).
- **Benck Configuration (with handle and feet):** 184mm high x 238mm wide x 370mm deep (7 in x 9.375 in x 14.563 in).
- **Shipping Weight:** 4.75kg (10 lbs).
- **Software Development Package**
- **Password Protection:** 11 characters.
- **Software:** Windows 98, NT, 2000, ME, and XP compatible, Internet Explorer 5.0 or higher.

**AC System Speeds**
- **Range Changes**
  - 4/3 (3/s).
- **Function Changes**
  - 4/3 (3/s).
- **Autorange Time:** ≤ 3s.
- **ASCI Readings to RS-232 (11.2k baud):** 300/s.
- **Max. External Trigger Rate:** 2000/s.

Specifications are subject to change without notice.
7700 20-Channel Differential Multiplexer w/Automatic CJC

**GENERAL**

20 CHANNELS: 20 channels of 2-pole relay input. All channels configurable to 4-pole.

2 CHANNELS: 2 channels of current only input.

RELAY TYPE: Latching electromechanical.

ACTUATION TIME: <3ms.

**CAPABILITIES**

CHANNELS 1-20: Multiplex one of 20 2-pole or one of 10 4-pole signals into DMM.

CHANNELS 21-22: Multiplex one of 2 2-pole current signals into DMM.

**INPUTS**

MAXIMUM SIGNAL LEVEL:

Channels (1-20): 300V DC or rms, 1A switched, 60W, 125VA maximum.

Channels (21-22): 60V DC or 30V rms, 3A switched, 60W, 125VA maximum.

CONTACT LIFE (typ): >10^6 operations at max signal level.

>10^8 operations cold switching.

CONTACT RESISTANCE: <1Ω at end of contact life.

CONTACT POTENTIAL: <±500nV typical per contact, 1µV max.

<±500nV typical per contact pair, 1µV max.

OFFSET CURRENT: <100pA.

CONNECTOR TYPE: Screw terminal, #20 AWG wire size.

ISOLATION BETWEEN ANY TWO TERMINALS: >10^6Ω, <100pF.

ISOLATION BETWEEN ANY TERMINAL AND EARTH: >10^9Ω, <200pF.

CROSS TALK (50Ω Source, 50Ω Load): <0.1dB below 1MHz.

<3dB below 2MHz.

COMMON MODE VOLTAGE: 300V between any terminal and chassis.

T/C COLD JUNCTION:

1.0°C (18°–28°C Mainframe Temp)

1.5°C (0°–18°C & 28°–50°C Mainframe Temp).

**ENVIRONMENTAL**

OPERATING ENVIRONMENT: Specified for 0°C to 50°C.

Specified to 80% R.H. at 35°C.

STORAGE ENVIRONMENT: –25°C to 65°C.

WEIGHT: 0.45kg (1 lb).
Accuracy calculations

The information below discusses how to calculate accuracy for both DC and AC characteristics.

Calculating DC characteristics accuracy

DC characteristics accuracy is calculated as follows:

\[ \text{Accuracy} = \pm (\text{ppm of reading} + \text{ppm of range}) \]

(\text{ppm} = \text{parts per million and } 10\text{ppm} = 0.001\%)

As an example of how to calculate the actual reading limits, assume that you are measuring 5V on the 10V range. You can compute the reading limit range from one-year DCV accuracy specifications as follows:

\[ \text{Accuracy} = \pm (30\text{ppm of reading} + 5\text{ppm of range}) \]
\[ = \pm [(30\text{ppm} \times 5V) + (5\text{ppm} \times 10V)] \]
\[ = \pm (150\mu V + 50\mu V) \]
\[ = \pm 200\mu V \]

Thus, the actual reading range is: 5V ± 200µV or from 4.9998V to 5.0002V.

DC current and resistance calculations are performed in exactly the same manner using the pertinent specifications, ranges, and input signal values.

Calculating AC characteristics accuracy

AC characteristics accuracy is calculated similarly, except that AC specifications are given as follows:

\[ \text{Accuracy} = \pm (% \text{ of reading} + \% \text{ of range}) \]

As an example of how to calculate the actual reading limits, assume that you are measuring 120V, 60Hz on the 750V range. You can compute the reading limit range from ACV one-year accuracy specifications as follows:

\[ \text{Accuracy} = \pm (0.06\% \text{ of reading} + 0.03\% \text{ of range}) \]
\[ = \pm [(0.0006 \times 120V) + (0.0003 \times 750V)] \]
\[ = \pm (0.072V + 0.225V) \]
\[ = \pm 0.297V \]

In this case, the actual reading range is: 120V ± 0.297V or from 119.703V to 120.297V.

AC current calculations are performed in exactly the same manner using the pertinent specifications, ranges, and input signal values.
Calculating dBm characteristics accuracy

As an example of how to calculate the actual reading limits for a 13dBm measurement with a reference impedance of 50Ω, assume an applied signal 0.998815V. The relationship between voltage and dBm is as follows:

$$\text{dBm} = 10 \log \left( \frac{V_{IN}^2}{R_{REF}} \right) / \text{1mW}$$

From the previous example on calculating DC characteristics accuracy, it can be shown that a measurement of 0.998815V on the 1V range has an uncertainty of ±36.9644mV or 0.998778V to 0.998852V, using one-year specifications.

Expressing 0.998778V as dBm:

$$\text{dBm} = 10 \log \left( \frac{(0.998778V)^2}{50\Omega} \right) / \text{1mW} = 12.9968\text{dBm}$$

and expressing 0.998852V as dBm:

$$\text{dBm} = 10 \log \left( \frac{(0.998852V)^2}{50\Omega} \right) / \text{1mW} = 13.00032\text{dBm}$$

Thus, the actual reading range is 13dBm ±0.00032dBm.

dBm and dB for other voltage inputs can be calculated in exactly the same manner using pertinent specifications, ranges, and reference impedances.
Calculating dB characteristics accuracy

The relationship between voltage and dB is as follows:

\[ dB = 20 \log \frac{V_{IN}}{V_{REF}} \]

As an example of how to calculate the actual readings limits for dB, with a user-defined VREF of 10V, you must calculate the voltage accuracy and apply it to the above equation.

To calculate a -60dB measurement, assume 10mV RMS for a VREF of 10V. Using the 100mV range, one-year, 10Hz - 20kHz frequency band, and SLOW rate, the voltage limits are as follows:

\[
\text{Accuracy} = \pm[(0.06\% \text{ of reading}) + (0.03\% \text{ of range})] \\
\pm[(0.0006 \times 10\text{mV}) + (0.0003 \times 100\text{mV})] \\
\pm[6\mu\text{V} + 30\mu\text{V}] \\
\pm36\mu\text{V}
\]

Thus, the actual reading accuracy is 10mV ±36mV or 10.036mV to 9.964mV. Applying the voltage reading accuracy into the dB equation yields:

\[
\text{dBm} = 20 \log \frac{10.036\text{mV}}{10\text{V}} = -59.96879\text{dB}
\]

\[
\text{dBm} = 20 \log \frac{9.964\text{mV}}{10\text{V}} = -60.03133\text{dB}
\]

Thus, the actual reading accuracy is -60dB + 0.031213dB to -60dB - 0.031326dB.

dBm and dB for other voltage inputs can be calculated in exactly the same manner using pertinent specifications, ranges, and other reference voltages.

Additional derating factors

In some cases, additional derating factors must be applied to calculate certain accuracy values. For example, an additional derating factor of 0.02ppm/V must be added to DCV specifications for voltages over 500V. Before calculating accuracy, study the associated specifications very carefully to see if any derating factors apply.
Optimizing measurement accuracy

The configurations listed below assume that the multimeter has had factory setups restored.

**DC voltage, DC current, and resistance:**
- Select 6½ digits, 10 PLC, filter ON (up to 100 readings), fixed range.
- Use REL on DC voltage and 2-wire resistance measurements.
- Use 4-wire resistance measurements for best accuracy.

**AC voltage and AC current:**
- Select 6½ digits, 10 PLC, filter ON (up to 100 readings), fixed range.

**Temperature:**
- Select 6½ digits, 10 PLC, filter ON (up to 100 readings).

Optimizing measurement speed

The configurations listed below assume that the multimeter has had factory setups restored.

**DC voltage, DC current, and resistance:**
- Select 3½ digits, 0.01 PLC, filter OFF, fixed range.

**AC voltage and AC current:**
- Select 3½ digits, 0.01 PLC, filter OFF, fixed range.

**Temperature:**
- Select 3½ digits, 0.01 PLC, filter OFF.

For all functions, turn off the display and autozero, and set the trigger delay to zero. Use the :SAMPle:COUNT and READ? bus commands.
Calibration Reference
## Introduction

This appendix contains detailed information about the various Model 2701 remote calibration commands. Section 2 of this manual covers detailed calibration procedures. For information about additional commands to control other instrument functions, refer to the Model 2701 User’s Manual.

## Command summary

Table B-1 summarizes Model 2701 calibration commands.

<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 calibration lock (except queries and :CODE).</td>
</tr>
<tr>
<td>:CODE &lt;up to 8 char. string&gt;</td>
<td>Calibration code or password (default: KI002701).</td>
</tr>
<tr>
<td>:COUNt?</td>
<td>Request the number of times the unit has been calibrated.</td>
</tr>
<tr>
<td>:INITiate</td>
<td>Initiate calibration.</td>
</tr>
<tr>
<td>:LOCK</td>
<td>Lock out calibration (opposite of enabling cal with :CODE command).</td>
</tr>
<tr>
<td>:LOCK?</td>
<td>Request comprehensive cal lock state (0 = locked; 1 = unlocked).</td>
</tr>
<tr>
<td>:SAVE</td>
<td>Save cal constants to EEROM.</td>
</tr>
<tr>
<td>:DATE &lt;year&gt;, &lt;month&gt;, &lt;day&gt;</td>
<td>Send cal date to 2701.</td>
</tr>
<tr>
<td>:DATE?</td>
<td>Request cal date from 2701.</td>
</tr>
<tr>
<td>:NDUE &lt;year&gt;, &lt;month&gt;, &lt;day&gt;</td>
<td>Send next due cal date to 2701.</td>
</tr>
<tr>
<td>:NDUE?</td>
<td>Request next due cal date from 2701.</td>
</tr>
<tr>
<td>:DATA?</td>
<td>Request calibration constants data.</td>
</tr>
<tr>
<td>:DC</td>
<td>DC cal steps.</td>
</tr>
<tr>
<td>:STEP0</td>
<td>Rear scanner terminals short step(^1).</td>
</tr>
<tr>
<td>:STEP1</td>
<td>Front terminal short circuit.</td>
</tr>
<tr>
<td>:STEP2</td>
<td>Open circuit.</td>
</tr>
<tr>
<td>:STEP3 &lt;NRf&gt;</td>
<td>10V DC step.</td>
</tr>
<tr>
<td>:STEP4 &lt;NRf&gt;</td>
<td>–10V DC step.</td>
</tr>
<tr>
<td>:STEP5 &lt;NRf&gt;</td>
<td>100V DC step.</td>
</tr>
<tr>
<td>:STEP6 &lt;NRf&gt;</td>
<td>1k(\Omega) 4-wire step.</td>
</tr>
<tr>
<td>:STEP7 &lt;NRf&gt;</td>
<td>10k(\Omega) 4-wire step.</td>
</tr>
<tr>
<td>:STEP8 &lt;NRf&gt;</td>
<td>100k(\Omega) 4-wire step.</td>
</tr>
</tbody>
</table>
**Table B-1 (Continued)**

Remote calibration command summary

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>:CALibration</td>
<td></td>
</tr>
<tr>
<td>:PROTected</td>
<td></td>
</tr>
<tr>
<td>:DC</td>
<td></td>
</tr>
<tr>
<td>:STEP9 &lt;NRf&gt;</td>
<td>1MΩ 4-wire step.</td>
</tr>
<tr>
<td>:STEP10 &lt;NRf&gt;</td>
<td>10mA DC step.</td>
</tr>
<tr>
<td>:STEP11 &lt;NRf&gt;</td>
<td>100mA DC step.</td>
</tr>
<tr>
<td>:STEP12 &lt;NRf&gt;</td>
<td>1A DC step.</td>
</tr>
<tr>
<td>:AC</td>
<td>AC cal steps.</td>
</tr>
<tr>
<td>:STEP1</td>
<td>10mV AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP2</td>
<td>100mV AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP3</td>
<td>100mV AC at 50kHz step.</td>
</tr>
<tr>
<td>:STEP4</td>
<td>1V AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP5</td>
<td>1V AC at 50kHz step.</td>
</tr>
<tr>
<td>:STEP6</td>
<td>10V AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP7</td>
<td>10V AC at 50kHz step.</td>
</tr>
<tr>
<td>:STEP8</td>
<td>100V AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP9</td>
<td>100V AC at 50kHz step.</td>
</tr>
<tr>
<td>:STEP10</td>
<td>700V AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP11</td>
<td>100mA AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP12</td>
<td>1A AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP13</td>
<td>2A AC at 1kHz step.</td>
</tr>
<tr>
<td>:STEP14</td>
<td>1V AC at 3Hz step(^1).</td>
</tr>
<tr>
<td>:STEP15</td>
<td>1V AC at 1kHz step(^1).</td>
</tr>
</tbody>
</table>

**NOTE:** Upper-case letters indicated short form of each command. For example, instead of sending "`:CALibration:PROTected:INITiate,`” you can send "`:CAL:PROT:INIT.`”

\(^1\) DC:STEP0, AC:STEP14, and AC:STEP15 are one-time factory calibration points and are valid only in manufacturing calibration mode.
Miscellaneous calibration commands

Miscellaneous commands perform miscellaneous calibration functions such as programming the calibration code and date. These commands are discussed in detail in the following paragraphs.

:CODE

(:CALibration:PROTected:CODE)

Purpose To program the calibration code or password so that you can perform the calibration procedures.

Format :cal:prot:code '<char_string>'

Parameter Up to a 8-character string including letters and numbers.

Description The :CODE command enables the Model 2701 calibration procedures when performing these procedures over the bus. In general, this command must be sent to the unit before sending any other comprehensive or manufacturing calibration command. The default calibration code is KI002701.

NOTES The :CODE command should be sent only once before performing either the comprehensive or factory calibration. Do not send :CODE before each calibration step.

To change the code, first send the present code, then send the new code.

The code parameter must be enclosed in single quotes.

Example :CAL:PROT:CODE 'KI002701' Send default code of KI002701.

:COUNt?

(:CALibration:PROTected:COUNt?)

Purpose To determine how many times the Model 2701 has been calibrated.

Format :cal:prot:coun?

Response <n> Calibration count.

Description The :COUNt? command allows you to determine how many times the Model 2701 has been calibrated.

NOTE Use the :COUNt? command to help you monitor for unauthorized calibration procedures.

:INIT

(:CALibration:PROTected:INITiate)

Purpose
To initiate comprehensive and factory calibration procedures.

Format
:cal:prot:init

Parameter
None

Description
The :INIT command enables Model 2701 calibration when performing these procedures over the bus. This command must be sent to the unit after sending the :CODE command, but before sending any other calibration command.

NOTE
The :INIT command should be sent only once before performing either DC, AC, or factory calibration. Do not send :INIT before each calibration step.

Example
:CAL:PROT:INIT
Initiate calibration.

:LOCK

(:CALibration:PROTected:LOCK)

Purpose
To lock out comprehensive or manufacturing calibration.

Format
:cal:prot:lock

Parameter
None

Description
The :LOCK command allows you to lock out both comprehensive and manufacturing calibration after completing those procedures. Thus, :LOCK performs the opposite of enabling calibration with the :CODE command.

NOTE
To unlock comprehensive calibration, send the :CODE command. To unlock manufacturing calibration, hold in the OPEN key while turning on the power.

Example
:CAL:PROT:LOCK
Lock out calibration.
:LOCK?

(:CALibration:PROTected:LOCK?)

**Purpose**
To read comprehensive calibration lock status.

**Format**
:cal:prot:lock?

**Response**
0  Comprehensive calibration locked.
1  Comprehensive calibration unlocked.

**Description**
The :LOCK? query requests status from the Model 2701 on calibration locked/unlocked state. Calibration must be enabled sending the :CODE command before calibration can be performed.

**Example**

:SAVE

(:CALibration:PROTected:SAVE)

**Purpose**
To save calibration constants in EEROM after the calibration procedure.

**Format**
:cal:prot:save

**Parameter**
None

**Description**
The :SAVE command stores internally calculated calibration constants derived during both comprehensive and manufacturing calibration in EEROM. (EEROM is non-volatile memory.) Calibration constants will be retained indefinitely once saved. Generally, :SAVE is sent after all other calibration steps (except for :LOCK).

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

**Example**
:CAL:PROT:SAVE  Save calibration constants.
:DATE

(:CALibration:PROTected:DATE)

Purpose To send the calibration date to the instrument.

Format :cal:prot:date <year>, <month>, <day>

Parameter <year> = 1999 to 2098
<month> = 1 to 12
<day> = 1 to 31

Query format :cal:prot:date?

Response <year>,<month>,<day>

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 the CALIBRATION selection in the front panel CAL menu.

NOTE The year, month, and day parameters must be delimited by commas.

Example :CAL:PROT:DATE 1999,12,16 Send cal date (12/16/1999).

:NDUE

(:CALibration:PROTected:NDUE)

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

Format :cal:prot:ndue <year>, <month>, <day>

Parameter <year> = 1999 to 2098
<month> = 1 to 12
<day> = 1 to 31

Query format :cal:prot:ndue?

Response <year>,<month>,<day>

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 the front panel CAL menu.

NOTE The next due date parameters must be delimited by commas.

Example :CAL:PROT:NDUE 2000,12,16 Send due date (12/16/2000).
### :DATA?

(:CALibration:PROTected:DATA?)

<table>
<thead>
<tr>
<th>Purpose</th>
<th>To read calibration constants data.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Format</td>
<td>:cal:prot:data?</td>
</tr>
<tr>
<td>Response</td>
<td>Floating-point, ASCII values separated by commas.</td>
</tr>
<tr>
<td>Description</td>
<td>The :DATA? query requests all the calibration constants. Values are returned in one string of ASCII floating-point values delimited by commands.</td>
</tr>
</tbody>
</table>
**DC calibration commands**

The :DC commands perform calibration of the DCV, DCI, and ohms functions. Table B-2 summarizes these calibration commands along with parameter limits.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
<th>Parameter limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>:STEP1</td>
<td>Front terminal short circuit.</td>
<td>9 to 11</td>
</tr>
<tr>
<td>:STEP2</td>
<td>Open circuit.</td>
<td></td>
</tr>
<tr>
<td>:STEP3 &lt;NRf&gt;</td>
<td>10V DC calibration step.</td>
<td>-9 to -11</td>
</tr>
<tr>
<td>:STEP4 &lt;NRf&gt;</td>
<td>-10V DC calibration step.</td>
<td></td>
</tr>
<tr>
<td>:STEP5 &lt;NRf&gt;</td>
<td>100V DC calibration step.</td>
<td>90 to 110</td>
</tr>
<tr>
<td>:STEP6 &lt;NRf&gt;</td>
<td>1kΩ 4-wire calibration step.</td>
<td>900 to 1.1E3</td>
</tr>
<tr>
<td>:STEP7 &lt;NRf&gt;</td>
<td>10kΩ 4-wire calibration step.</td>
<td>9E3 to 11E3</td>
</tr>
<tr>
<td>:STEP8 &lt;NRf&gt;</td>
<td>100kΩ 4-wire calibration step.</td>
<td>90E3 to 110E3</td>
</tr>
<tr>
<td>:STEP9 &lt;NRf&gt;</td>
<td>1MΩ 4-wire calibration step.</td>
<td>900E3 to 1.1E6</td>
</tr>
<tr>
<td>:STEP10 &lt;NRf&gt;</td>
<td>10mA DC calibration step.</td>
<td>9E-3 to 11E-3</td>
</tr>
<tr>
<td>:STEP11 &lt;NRf&gt;</td>
<td>100mA DC calibration step.</td>
<td>90E-3 to 110E-3</td>
</tr>
<tr>
<td>:STEP12 &lt;NRf&gt;</td>
<td>1A DC calibration step.</td>
<td>0.9 to 1.1</td>
</tr>
</tbody>
</table>

### :STEP1

 (:CALibration:PROTected:DC:STEP1)

**Purpose**
To perform front terminal short-circuit calibration.

**Format**
:cal:prot:dc:step1

**Parameter**
None

**Description**
:STEP1 performs the short-circuit calibration step in the comprehensive calibration procedure. Connect a low-thermal short (Model 8610) to the front panel input jacks before sending this command.

**Example**
:CAL:PROT:DC:STEP1
Perform short-circuit calibration.
:STEP2

(:CALibration:PROTected:DC:STEP2)

**Purpose**
To perform front terminal open-circuit calibration.

**Format**
:cal:prot:dc:step2

**Parameter**
None

**Description**
:STEP2 performs the open-circuit calibration step in the comprehensive calibration procedure. Disconnect all cables and accessories from the input jacks before sending this command.

**Example**

:STEP3

(:CALibration:PROTected:DC:STEP3)

**Purpose**
To program the +10V comprehensive calibration step.

**Format**
:cal:prot:dc:step3 <Cal_voltage>

**Parameter**
<Cal_voltage> = 9 to 11 [V]

**Description**
:STEP3 programs the +10V DC comprehensive calibration step. The allowable range of the calibration voltage parameter is from 9 to 11, but 10 is recommended for best results.

**Example**

:STEP4

(:CALibration:PROTected:DC:STEP4)

**Purpose**
To program the -10V DC comprehensive calibration step.

**Format**
:cal:prot:dc:step4 <Cal_voltage>

**Parameter**
<Cal_voltage> = -9 to -11 [V]

**Description**
:STEP4 programs the -10V DC comprehensive calibration step. The allowable range of the calibration voltage parameter is from -9 to -11, but -10 is recommended for best results.

**Example**
:CAL:PROT:DC:STEP4 -10  Program -10V step.
:STEP5

(:CALibration:PROTected:DC:STEP5)
Purpose        To program the 100V DC comprehensive calibration step.
Format         :cal:prot:dc:step5 <Cal_voltage>
Parameter      <Cal_voltage> = 90 to 110 [V]
Description    :STEP5 programs the 100V DC comprehensive calibration step. The allowable range of the calibration voltage parameter is from 90 to 110, but 100 is recommended for best results.
Example        :CAL:PROT:DC:STEP5 100          Program 100V step.

:STEP6

(:CALibration:PROTected:DC:STEP6)
Purpose        To program the 1kΩ 4-wire comprehensive calibration step.
Format         :cal:prot:dc:step6 <Cal_resistance>
Parameter      <Cal_resistance> = 900 to 1.1E3 [Ω]
Description    :STEP6 programs the 1kΩ 4-wire resistance comprehensive calibration step. The allowable range of the calibration resistance parameter is from 900 to 1.1E3, but 1E3 is recommended for best results.
Example        :CAL:PROT:DC:STEP6 1E3             Program 1kΩ step.

:STEP7

(:CALibration:PROTected:DC:STEP7)
Purpose        To program the 10kΩ 4-wire comprehensive calibration step.
Format         :cal:prot:dc:step7 <Cal_resistance>
Parameter      <Cal_resistance> = 9E3 to 11E3 [Ω]
Description    :STEP7 programs the 10kΩ 4-wire resistance comprehensive calibration step. The allowable range of the calibration resistance parameter is from 9E3 to 11E3, but 10E3 is recommended for best results.
Example        :CAL:PROT:DC:STEP7 10E3           Program 10kΩ step.
:STEP8

(:CALibration:PROTected:DC:STEP8)

Purpose To program the 100kΩ 4-wire comprehensive calibration step.
Format :cal:prot:dc:step8 <Cal_resistance>
Parameter <Cal_resistance> = 90E3 to 110E3 [Ω]
Description :STEP8 programs the 100kΩ 4-wire resistance comprehensive calibration step. The allowable range of the calibration resistance parameter is from 90E3 to 110E3, but 100E3 is recommended for best results.
Example :CAL:PROT:DC:STEP8 100E3 Program 100kΩ step.

:STEP9

(CALibration:PROTected:DC:STEP9)

Purpose To program the 1MΩ comprehensive calibration step.
Parameter <Cal_resistance> = 900E3 to 1.1E6 [Ω]
Description :STEP9 programs the 1MΩ comprehensive calibration step. The allowable range of the calibration resistance parameter is from 900E3 to 1.1E6. Use the 1E6 value whenever possible or the closest possible value.
Example :CAL:PROT:DC:STEP9 1E6 Program 1MΩ calibration step.

:STEP10

(CALibration:PROTected:DC:STEP10)

Purpose To program the 10mA comprehensive calibration step.
Format :cal:prot:dc:step10 <Cal_current>
Parameter <Cal_current> = 9E-3 to 11E-3 [A]
Description :STEP10 programs the 10mA comprehensive calibration step. The allowable range of the calibration current parameter is from 9E-3 to 11E-3. Use the 10E-3 value whenever possible for best results.
Example :CAL:PROT:DC:STEP10 10E-3 Program 10mA step.
:STEP11

(CALibration:PROTected:DC:STEP11)

Purpose  To program the 100mA comprehensive calibration step.
Format    :cal:prot:dc:step11 <Cal_current>
Parameter <Cal_current> = 90E-3 to 110E-3 [A]
Description :STEP11 programs the 100mA comprehensive calibration step. The allowable range of the calibration current parameter is from 90E-3 to 110E-3. Use the 100E-3 value whenever possible for best results.
Example   :CAL:PROT:DC:STEP11 100E-3    Program 100mA step.

:STEP12

(CALibration:PROTected:DC:STEP12)

Purpose  To program the 1A comprehensive calibration step.
Format    :cal:prot:dc:step12 <Cal_current>
Parameter <Cal_current> = 0.9 to 1.1 [A]
Description :STEP12 programs the 1A comprehensive calibration step. The allowable range of the calibration current parameter is from 0.9 to 1.1. Use a value of 1 whenever possible for best results.
Example   :CAL:PROT:DC:STEP12 1        Program 1A step.
AC calibration commands

The :AC commands perform comprehensive (user) calibration of the ACV and ACI functions. Table B-3 summarizes these calibration commands.

Table B-3
AC calibration commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>:CALibration</td>
<td></td>
</tr>
<tr>
<td>:PROTected</td>
<td></td>
</tr>
<tr>
<td>:AC</td>
<td></td>
</tr>
<tr>
<td>:STEP1</td>
<td>10mV AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP2</td>
<td>100mV AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP3</td>
<td>100mV AC at 50kHz calibration step.</td>
</tr>
<tr>
<td>:STEP4</td>
<td>1V AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP5</td>
<td>1V AC at 50kHz calibration step.</td>
</tr>
<tr>
<td>:STEP6</td>
<td>10V AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP7</td>
<td>10V AC at 50kHz calibration step.</td>
</tr>
<tr>
<td>:STEP8</td>
<td>100V AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP9</td>
<td>100V AC at 50kHz calibration step.</td>
</tr>
<tr>
<td>:STEP10</td>
<td>700V AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP11</td>
<td>100mA AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP12</td>
<td>1A AC at 1kHz calibration step.</td>
</tr>
<tr>
<td>:STEP13</td>
<td>2A AC at 1kHz calibration step.</td>
</tr>
</tbody>
</table>
:AC:STEP<n>

(CALibration:PROTected:AC:STEP<n>)

Purpose To program individual AC calibration steps.

Format :cal:prot:ac:step<n>

Parameter

1  10mV AC at 1kHz calibration step.
2  100mV AC at 1kHz calibration step.
3  100mV AC at 50kHz calibration step.
4  1V AC at 1kHz calibration step.
5  1V AC at 50kHz calibration step.
6  10V AC at 1kHz calibration step.
7  10V AC at 50kHz calibration step.
8  100V AC at 1kHz calibration step.
9  100V AC at 50kHz calibration step.
10 700V AC at 1kHz calibration step.
11 100mA AC at 1kHz calibration step.
12 1A AC at 1kHz calibration step.
13 2A AC at 1kHz calibration step.

Description The :AC:STEP command programs the 13 individual AC 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.

Example :CAL:PROT:AC:STEP7 Program 10V, 50kHz step.
Manufacturing calibration commands

Three calibration steps are only performed at the factory or when the unit has been repaired:

:CALibration:PROTected:AC:STEP14 1V AC at 3Hz
:CALibration:PROTected:AC:STEP15 1V AC at 1kHz
:CALibration:PROTected:DC:STEP0 Rear scanner terminal short circuit

:AC:STEP<14|15>

(CALibration:PROTected:AC:STEP<14|15>)

Purpose  To program individual AC manufacturing calibration steps.
Format  :cal:prot:ac:step14 <Cal_voltage>
        :cal:prot:ac:step15 <Cal_frequency>
Parameter  <Cal_voltage> = 1 [1V nominal]
           <Cal_frequency = 1E3 [1kHz nominal]
Description  The :AC:STEP14 and :AC:STEP15 commands program the two manufacturing AC calibration steps. The appropriate signal must be connected to the instrument when programming each step, as summarized by the parameters listed above.

:DC:STEP0

(CALibration:PROTected:DC:STEP0)

Purpose  To perform rear scanner terminal short-circuit calibration.
Format  :cal:prot:dc:step0
Parameter  None
Description  :STEP0 performs the rear scanner terminal short-circuit calibration step in the manufacturing calibration procedure. Install an extender card with low-thermal shorts on the output terminals installed in Slot 1 and select the rear scanner inputs before sending this command.
Model 7700 calibration commands

Table B-4 summarizes calibration commands for the Model 7700 plug-in module. Note that CARD1 commands calibrate the card in Slot 1, while CARD2 commands request calibration count and date information from a card in Slot 2.

**NOTE**  A Model 7700 must be installed in Slot 1 through a Model 7797 Calibration System card to be calibrated. See “Model 7700 calibration” in Section 2.

<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 calibration lock (except queries and :CODE).</td>
</tr>
<tr>
<td>:CODE 'up to 8 char. string'</td>
<td>Send calibration code. (Default KI002701.)</td>
</tr>
<tr>
<td>:CARD1</td>
<td>Path to card in slot 1.</td>
</tr>
<tr>
<td>:INITiate</td>
<td>Initiate card calibration.</td>
</tr>
<tr>
<td>:COUNt?</td>
<td>Request number of times card had been calibrated.</td>
</tr>
<tr>
<td>:RCOunt</td>
<td>Reset card calibration count to 0.</td>
</tr>
<tr>
<td>:DATE?</td>
<td>Request card cal date.</td>
</tr>
<tr>
<td>:SAVE</td>
<td>Save cal constants to card EEPROM.</td>
</tr>
<tr>
<td>:LOCK</td>
<td>Lock out calibration.</td>
</tr>
<tr>
<td>:LOCK?</td>
<td>Request cal lock state. (0 = locked, 1 = unlocked.)</td>
</tr>
<tr>
<td>:STEP0 &lt;NRf&gt;</td>
<td>Temperature sensor cold calibration (&lt;NRf&gt; = temperature, °C).</td>
</tr>
<tr>
<td>:CARD2</td>
<td>Path to card in slot 2.</td>
</tr>
<tr>
<td>:COUNt?</td>
<td>Request number of times card has been calibrated.</td>
</tr>
<tr>
<td>:DATE?</td>
<td>Request card calibration date.</td>
</tr>
</tbody>
</table>
:CODE

(:CALibration:PROTected:CODE)

Purpose  To program the calibration code or password so that you can perform the
         Model 7700 calibration procedures.

Format    :cal:prot:code 'char_string'

Parameter  Up to a 8-character string including letters and numbers.

Description  The :CODE command enables the Model 2701 calibration procedures when
              performing these procedures over the bus. This command must be sent to
              the unit before sending any other Model 7700 calibration command. The
              default calibration code is KI002701.

NOTES   The :CODE command should be sent only once before performing calibration. Do
        not send :CODE before each calibration step.

        The code parameter must be enclosed in single quotes.

Example  :CAL:PROT:CODE 'KI002701'    Send default code of KI002701.

:COUNT?

(:CALibration:PROTected:CARD1:COUNt?)
(:CALibration:PROTected:CARD2:COUNt?)

Purpose  To determine how many times a Model 7700 has been calibrated.

Format    :cal:prot:card1:coun?
          :cal:prot:card2:coun?

Response  <n> Calibration count.

Description  The :CARD1:COUNt? and :CARD2:COUNt? commands allow you to
t          determine how many times a Model 7700 in Slot 1 and Slot 2 respectively
          has been calibrated.

NOTE    Use the :COUNt? command to help you monitor for unauthorized calibration
        procedures.

:DATE?

(*CALibration:PROTected:CAR1:DATE?*)
(*CALibration:PROTected:CAR2:DATE?)

**Purpose**
To request the Model 7700 calibration date.

**Format**
:cal:prot:card1:date?
:cal:prot:card2:date?

**Response**
<year>,<month>,<day>

**Description**
The :CARD1:DATE? and :CARD2:DATE? queries allow you to read back the calibration date from a Model 7700 in Slot 1 and Slot 2, respectively.

*NOTE*  The card calibration date is automatically set to the Model 2701 real time clock date when the card is calibrated.

**Example**

:INIT

(*CALibration:PROTected:CAR1:INITiate*)

**Purpose**
To initiate Model 7700 calibration procedures.

**Format**
:cal:prot:card1:init

**Parameter**
None

**Description**
The :INIT command enables Model 7700 calibration when performing these procedures over the bus. This command must be sent to the unit after sending the :CODE command, but before performing Model 7700 calibration.

**Example**
:CAL:PROT:CAR1:INIT  Initiate 7700 calibration.
**:LOCK**

(:CALibration:PROTected:CARd1:LOCK)

**Purpose**
To lock out Model 7700 calibration.

**Format**
:cal:prot:card1:lock

**Parameter**
None

**Description**
The :LOCK command allows you to lock out Model 7700 calibration after completing the procedure. Thus, :LOCK performs the opposite of enabling calibration with the :CODE command.

**Example**
:CAL:PROT:CARD1:LOCK  Lock out card 1 calibration.

**:LOCK?**

(:CALibration:PROTected:CARd1:LOCK?)

**Purpose**
To read Model 7700 calibration lock status.

**Format**
:cal:prot:card1:lock?

**Response**
0  Calibration locked.
1  Calibration unlocked.

**Description**
The :LOCK? query requests status from the Model 2701 on Model 7700 calibration locked/unlocked state. Calibration must be enabled sending the :CODE command before calibration can be performed.

**Example**

**:RCOunt**

(:CALibration:PROTected:CARd1:RCOunt)

**Purpose**
To reset card calibration count to 0.

**Format**
:cal:prot:card1:rco

**Parameter**
None

**Description**
The :RCOunt command resets the card calibration count reported by :COUNT? to 0.

**Example**
:CAL:PROT:CARD1:RCO  Rest card calibration count.
SAVE

(:CALibration:PROTected:CARD1:SAVE)

Purpose  To save calibration constants in card EEROM after the calibration procedure.

Format    :cal:prot:card1:save

Parameter  None

Description  The :SAVE command stores calculated calibration constants derived during Model 7700 calibration in card EEROM. (EEROM is non-volatile memory.) Calibration constants will be retained indefinitely once saved. Generally, :SAVE is sent after all other calibration steps (except for :LOCK).

NOTE  Card calibration will be only temporary unless the :SAVE command is sent to permanently store calibration constants.

Example  :CAL:PROT:CARD1:SAVE  Save card calibration constants.

STEP0

(:CALibration:PROTected:CARD1:STEP0)

Purpose  To perform Model 7700 calibration.

Format    :cal:prot:card1:step0 <temp>

Parameter  <temp> = Cold calibration temperature (°C)

Description  :STEP0 performs temperature sensor calibration of the Model 7700. The card must be allowed to cool down to ambient temperature before calibration. The cold temperature of the card must be measured and sent as the <temp> parameter during calibration.

NOTE  Before calibrating the Model 7700, make sure that power has been removed from the card for at least two hours to allow card circuitry to cool down. After turning on the power during the calibration procedure, complete the procedure as quickly as possible to minimize card heating that could affect calibration accuracy.

Example  :CAL:PROT:CARD1:STEP0 23  Perform 7700 calibration.
Remote error reporting

Methods to detect and determine the nature of calibration errors are discussed in the following paragraphs. See the Model 2701 User’s Manual for details on status register operation.

Error summary

Table B-5 summarizes Model 2701 calibration errors.

Table B-5
Calibration error summary

<table>
<thead>
<tr>
<th>Error number and description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+400, &quot;10 vdc zero error&quot;</td>
</tr>
<tr>
<td>+401, &quot;100 vdc zero error&quot;</td>
</tr>
<tr>
<td>+402, &quot;10 vdc full scale error&quot;</td>
</tr>
<tr>
<td>+403, &quot;-10 vdc full scale error&quot;</td>
</tr>
<tr>
<td>+404, &quot;100 vdc full scale error&quot;</td>
</tr>
<tr>
<td>+405, &quot;-100 vdc full scale error&quot;</td>
</tr>
<tr>
<td>+406, &quot;1k 2-w zero error&quot;</td>
</tr>
<tr>
<td>+407, &quot;10k 2-w zero error&quot;</td>
</tr>
<tr>
<td>+408, &quot;100k 2-w zero error&quot;</td>
</tr>
<tr>
<td>+409, &quot;10M 2-w zero error&quot;</td>
</tr>
<tr>
<td>+410, &quot;10M 2-w full scale error&quot;</td>
</tr>
<tr>
<td>+411, &quot;10M 2-w open error&quot;</td>
</tr>
<tr>
<td>+412, &quot;1k 4-w zero error&quot;</td>
</tr>
<tr>
<td>+413, &quot;10k 4-w zero error&quot;</td>
</tr>
<tr>
<td>+414, &quot;100k 4-w zero error&quot;</td>
</tr>
<tr>
<td>+415, &quot;10M 4-w sense lo zero error&quot;</td>
</tr>
<tr>
<td>+416, &quot;1k 4-w full scale error&quot;</td>
</tr>
<tr>
<td>+417, &quot;10k 4-w full scale error&quot;</td>
</tr>
<tr>
<td>+418, &quot;100k 4-w full scale error&quot;</td>
</tr>
<tr>
<td>+419, &quot;1M 4-w full scale error&quot;</td>
</tr>
<tr>
<td>+420, &quot;10M 4-w full scale error&quot;</td>
</tr>
<tr>
<td>+421, &quot;10m adc zero error&quot;</td>
</tr>
<tr>
<td>+422, &quot;100m adc zero error&quot;</td>
</tr>
<tr>
<td>+423, &quot;10m adc full scale error&quot;</td>
</tr>
<tr>
<td>+424, &quot;100m adc full scale error&quot;</td>
</tr>
<tr>
<td>+425, &quot;1 adc full scale error&quot;</td>
</tr>
<tr>
<td>+438, &quot;Date of calibration not set&quot;</td>
</tr>
<tr>
<td>+439, &quot;Next date of calibration not set&quot;</td>
</tr>
<tr>
<td>+450, &quot;100m vac dac error&quot;</td>
</tr>
</tbody>
</table>
### Table B-5 (Continued)
*Calibration error summary*

<table>
<thead>
<tr>
<th>Error number and description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+451, &quot;1 vac dac error&quot;</td>
</tr>
<tr>
<td>+452, &quot;10 vac dac error&quot;</td>
</tr>
<tr>
<td>+453, &quot;100 vac dac error&quot;</td>
</tr>
<tr>
<td>+454, &quot;100m vac zero error&quot;</td>
</tr>
<tr>
<td>+455, &quot;100m vac full scale error&quot;</td>
</tr>
<tr>
<td>+456, &quot;1 vac zero error&quot;</td>
</tr>
<tr>
<td>+457, &quot;1 vac full scale error&quot;</td>
</tr>
<tr>
<td>+458, &quot;1 vac noise error&quot;</td>
</tr>
<tr>
<td>+459, &quot;10 vac zero error&quot;</td>
</tr>
<tr>
<td>+460, &quot;10 vac full scale error&quot;</td>
</tr>
<tr>
<td>+461, &quot;10 vac noise error&quot;</td>
</tr>
<tr>
<td>+462, &quot;100 vac zero error&quot;</td>
</tr>
<tr>
<td>+463, &quot;100 vac full scale error&quot;</td>
</tr>
<tr>
<td>+464, &quot;750 vac zero error&quot;</td>
</tr>
<tr>
<td>+465, &quot;750 vac full scale error&quot;</td>
</tr>
<tr>
<td>+466, &quot;750 vac noise error&quot;</td>
</tr>
<tr>
<td>+467, &quot;Post filter offset error&quot;</td>
</tr>
<tr>
<td>+468, &quot;1 aac zero error&quot;</td>
</tr>
<tr>
<td>+469, &quot;1 aac full scale error&quot;</td>
</tr>
<tr>
<td>+470, &quot;3 aac zero error&quot;</td>
</tr>
<tr>
<td>+471, &quot;3 aac full scale error&quot;</td>
</tr>
<tr>
<td>+472, &quot;Input time constant error&quot;</td>
</tr>
<tr>
<td>+473, &quot;Frequency gain error&quot;</td>
</tr>
<tr>
<td>+474, &quot;1K Ohm Ioff Ocomp FS error&quot;</td>
</tr>
<tr>
<td>+475, &quot;10K Ohm Ioff Ocomp FS error&quot;</td>
</tr>
<tr>
<td>+476, &quot;Temperature Cold Cal error&quot;</td>
</tr>
<tr>
<td>+500, &quot;Calibration data invalid&quot;</td>
</tr>
<tr>
<td>+513, &quot;AC calibration data lost&quot;</td>
</tr>
<tr>
<td>+514, &quot;DC calibration data lost&quot;</td>
</tr>
<tr>
<td>+515, &quot;Calibration dates lost&quot;</td>
</tr>
<tr>
<td>+518, &quot;Card calibration data lost&quot;</td>
</tr>
<tr>
<td>+519, &quot;Card calibration dates lost&quot;</td>
</tr>
<tr>
<td>+610, &quot;Questionable calibration&quot;</td>
</tr>
</tbody>
</table>

*Model 7700 card only.*
Error queue

As with other Model 2701 errors, any calibration error will be reported in the remote error queue. You can read this queue by using the :SYST:ERR? query. The Model 2701 will respond with the appropriate error message, as summarized in Table B-5.

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 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.

Detecting calibration step completion

When sending remote calibration commands, you must wait until the instrument completes the current operation before sending a command. You can use the *OPC? (operation complete) query to help determine when each calibration step is completed.

With the *OPC? query, the instrument will place an ASCII 1 in the output queue when it has completed each step. To use this method, allow a sufficiently long timeout period after sending each calibration command, then test for an ASCII 1 in the output queue by sending *OPC?.
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