

# Models 2510 and 2510-AT TEC SourceMeter®

## Service Manual

2510-902-01 Rev. E / March 2010

**KEITHLEY**

A G R E A T E R M E A S U R E O F C O N F I D E N C E

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# **Models 2510 and 2510-AT TEC SourceMeter®**

## **Service Manual**

All references in this manual to the Model 2510 also apply to the Model 2510-AT unless otherwise specified.

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# Manual Print History

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

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

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

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

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

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

Instrumentation and accessories shall not be connected to humans.

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

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

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

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**1**

# Performance Verification

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# Introduction

Use the procedures in this section to verify that Model 2510 accuracy is within the limits stated in the instrument's one-year accuracy specifications. You can perform these verification procedures:

- When you first receive the instrument to make sure that it was not damaged during shipment.
- To verify that the unit meets factory specifications.
- To determine if calibration is required.
- Following calibration to make sure it was performed properly.

**WARNING**    **The information in this section is intended for qualified service personnel only. Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death if contacted. Use standard safety precautions when working with hazardous voltages.**

**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.*

## 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 test equipment.
- Using the specified output signals and reading limits.

### Environmental conditions

Conduct your performance verification procedures in a test environment with:

- An ambient temperature of 18-28°C (65-82°F).
- A relative humidity of less than 70% unless otherwise noted.

### Warm-up period

Allow the Model 2510 to warm up for at least one hour 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 2510 requires a line voltage of 100 to 240V and a line frequency of 50 or 60Hz. Verification tests must be performed within this range.

## Recommended test equipment

Table 1-1 summarizes recommended verification equipment and pertinent specifications. 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 test equipment uncertainty will add to the uncertainty of each measurement. Generally, test equipment uncertainty should be at least four times better than corresponding Model 2510 specifications.

**Table 1-1**  
*Recommended verification equipment*

| Description                                | Manufacturer/Model    | Specifications  |
|--|-----------------------|---|
| Digital Multimeter                         | Keithley 2002         | DC Voltage <sup>1</sup> 20V: ±6.8ppm<br><br>Resistance <sup>1</sup> 20Ω: ±23ppm<br>200Ω: ±19ppm<br>2kΩ: ±7.4ppm<br>20kΩ: ±7.4ppm<br>200kΩ: ±29.8ppm |
| Resistors <sup>2</sup>                     | Isotec RUG-Z-1R00-0.1 | 1Ω, ±0.1%, 100W<br>100Ω, ±1%<br>1kΩ, ±1%<br>10kΩ, ±1%<br>100kΩ, ±1%   |
| INPUT/OUTPUT Mating Connector <sup>3</sup> | Keithley CS-846       |   |

1. Ninety day, full-range accuracy specification of ranges required for various measurement points.

2. Characterize all resistors using 4-wire ohms function of recommended DMM before use.

3. One connector supplied with Model 2510.

## Resistor characterization

The resistors listed in Table 1-1 must be characterized using the 4-wire ohms function of the recommended DMM before use. Be sure to use the lowest resistance range possible for each measurement for best accuracy. Characterized values can be recorded in Table 1-2.

**Table 1-2**  
*Characterized resistor values*

| Nominal resistance | Characterized resistance* |
|--------------------|---------------------------|
| 1Ω                 | _____Ω                    |
| 100Ω               | _____Ω                    |
| 1kΩ                | _____kΩ                   |
| 10kΩ               | _____kΩ                   |
| 100kΩ              | _____kΩ                   |

\*Characterize value using DMM (see Table 1-1).

## Verification limits

The verification limits stated in this section have been calculated using only the Model 2510 one-year accuracy specifications, and they do not include test equipment uncertainty. If a particular measurement falls outside the allowable range, recalculate new limits based on Model 2510 specifications and corresponding test equipment specifications.

### Example limits calculation

As an example of how verification limits are calculated, assume you are testing the operating voltage function using a 10V value. Using the Model 2510 operating voltage one-year accuracy specification of  $\pm(0.1\%$  of reading + 4mV offset), the calculated output limits are:

$$\text{Limits} = 10\text{V} \pm [(10\text{V} \times 0.1\%) + 4\text{mV}]$$

$$\text{Limits} = 10\text{V} \pm (0.01 + 0.004)$$

$$\text{Limits} = 10\text{V} \pm 0.014\text{V}$$

$$\text{Limits} = 9.986 \text{ to } 10.014\text{V}$$

### Resistance limits calculation

When verifying accuracy for tests using the precision resistors, it will be necessary to recalculate resistance limits based on the actual characterized resistance values. You can calculate resistance reading limits in the same manner described above, but be sure to use the actual characterized resistance values and the Model 2510 one-year accuracy specifications for your calculations (see Appendix A).

## Restoring factory defaults

Before performing the verification procedures, restore the instrument to its factory front panel (BENCH) defaults as follows:

1. Press the MENU key. The instrument will display the following prompt:  
MAIN MENU  
SAVESETUP COMMUNICATION CAL ©
2. Select SAVESETUP, and then press ENTER. The unit then displays:  
SAVESETUP MENU  
SAVE RESTORE POWERON RESET
3. Select RESET, and then press ENTER. The unit displays:  
RESET ORIGINAL DFLTS  
BENCH GPIB
4. Select BENCH, and then press ENTER to restore BENCH defaults.

## Performing the verification test procedures

### Test summary

- Voltage accuracy
- Current accuracy
- AC resistance accuracy
- Sensor measurement accuracy

If the Model 2510 is not within specifications and not under warranty, see the calibration procedures in Section 2 for information on calibrating the unit.

## Test considerations

**WARNING**     **The maximum common-mode voltage (voltage between INPUT/OUTPUT - terminals and chassis ground) is 30V DC. Exceeding this value may cause a shock hazard.**

**CAUTION**     **The maximum voltage between INPUT/OUTPUT sense (S) terminals is 1V. Exceeding this voltage may result in instrument damage.**

When performing the verification procedures:

- Be sure to restore factory front panel defaults as previously outlined.
- Make sure that the test equipment is fully warmed up and properly connected to the Model 2510 INPUT or OUTPUT terminals as required.
- Be sure that the Model 2510 output is turned on before making measurements.
- Be sure the test equipment is set up for the proper function and range.
- Allow the Model 2510 output signal to settle before making a measurement.
- Do not connect test equipment to the Model 2510 through a scanner, multiplexer, or other switching equipment.

## Adjusting setpoints

Before making many verification measurements, you must properly adjust the setpoint as covered below.

1. First select the function to be tested as indicated in the procedure.
2. Press any one of the four EDIT keys (*B*, *C*, *I*, *F*) to enter the setpoint edit mode.
3. Using the EDIT keys, adjust the setpoint to the required value.

# Voltage accuracy

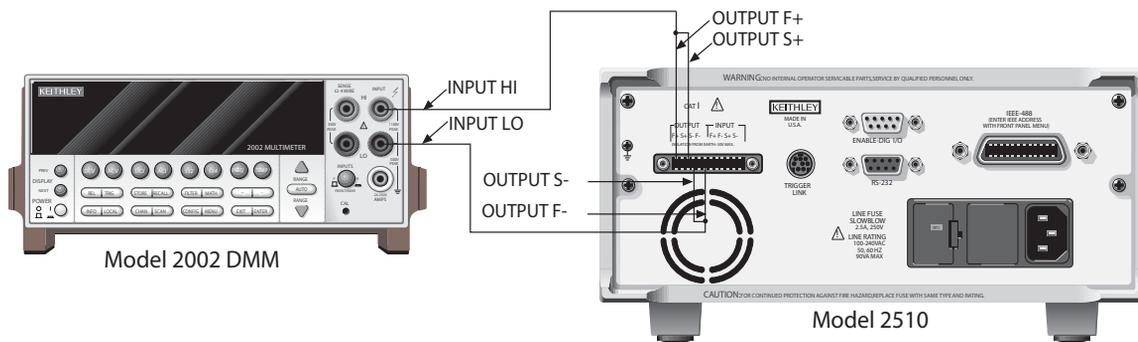
## Output voltage accuracy

Follow the steps below to verify that Model 2510 output voltage accuracy is within specified limits. This test involves setting the output voltage to a specific value and accurately measuring the voltage with a DMM.

1. With the power off, connect the digital multimeter to the Model 2510 OUTPUT terminals, as shown in Figure 1-1.
2. Turn on the Model 2510 and DMM, and allow them to warm up for at least one hour.
3. Select the multimeter DC volts measuring function, and choose the 20V range.
4. Press the Model 2510 V key to select the voltage function, and make sure the source output is turned on.

5. Using the EDIT keys, adjust the Model 2510 voltage setpoint to exactly +9.000V.
6. Verify that the DMM reading is within 8.987 to 9.013V limits.
7. Repeat steps 5 and 6 for a -9.000V output value.
8. Turn off the output when the test is completed.

**Figure 1-1**  
Connections for voltage  
verification tests



## Voltage readback accuracy

Follow the steps below to verify that Model 2510 voltage readback accuracy is within specified limits. This test involves setting the output voltage to a specific value as measured by a DMM and verifying that the Model 2510 voltage readback display reading is within limits.

1. With the power off, connect the digital multimeter to the Model 2510 OUTPUT terminals, as shown in Figure 1-1.
2. Turn on the Model 2510 and DMM, and allow them to warm up for at least one hour.
3. Select the multimeter DC volts measuring function, and choose the 20V range.
4. Press the Model 2510 V key to select the voltage function, and make sure the source output is turned on.
5. Using the EDIT keys, adjust the Model 2510 output voltage as measured by the DMM to +9.000V (or closest possible value).
6. Verify that the Model 2510 readback display (top display line) is within 8.987 to 9.013V limits.
7. Repeat steps 5 and 6 for a -9.000V output value.
8. Turn off the output when the test is completed.

## Voltage limit accuracy

Follow the steps below to verify that Model 2510 voltage limit accuracy is within specified limits. The test involves setting the voltage limit to a specific value and making sure the output voltage is limited to the required value.

1. With the power off, connect the digital multimeter to the Model 2510 OUTPUT terminals, as shown in Figure 1-1.
2. Turn on the Model 2510 and the DMM, and allow them to warm up for one hour.
3. Select the multimeter DC voltage measuring function, and set the unit to the 20V range.
4. Press the Model 2510 V key to select the voltage function.
5. Using the EDIT keys, adjust the Model 2510 voltage setpoint to +10.000V.
6. Press CONFIG then V, select PROTECTION, then set the voltage limit to 9.00V.
7. Turn the source output on.
8. Verify that the “VLIM” message is displayed, then note the DMM voltage reading.
9. Verify that the voltage measured in step 8 is within 8.55 to 9.45V limits.
10. Turn off the output when the test is completed.

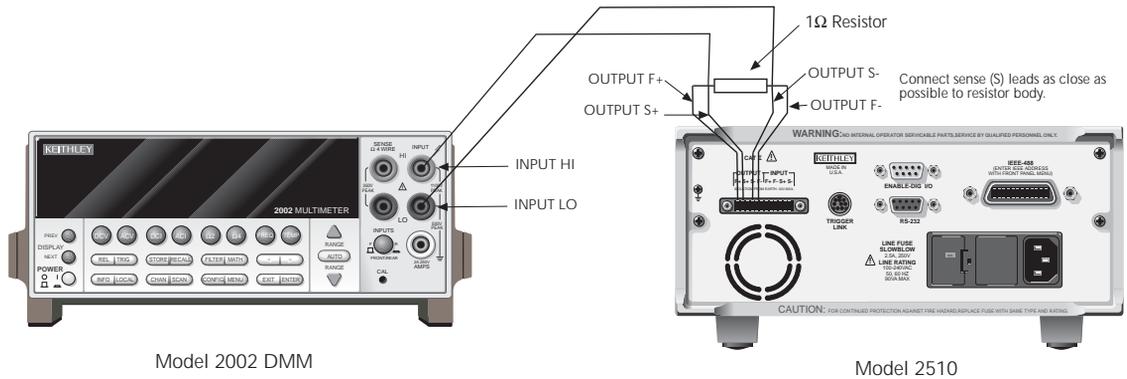
## Current accuracy

### Output current accuracy

Follow the steps below to verify that Model 2510 output current accuracy is within specified limits. The test involves setting the output current to a specific value and measuring the current using a 1 $\Omega$  resistor and a digital multimeter.

1. With the power off, connect the digital multimeter and 1 $\Omega$  resistor to the Model 2510 OUTPUT terminals, as shown in Figure 1-2.
2. Turn on the Model 2510 and the DMM, and allow them to warm up for one hour.
3. Select the multimeter DC voltage measuring function, and set the unit to the 20V range.
4. Press CONFIG then I, choose PROTECTION, then set the current limit to 5.00A.
5. Press the Model 2510 I key to select the current function, and make sure the source output is turned on.
6. Using the EDIT keys, adjust the Model 2510 setpoint to exactly +4.5000A. Compute the current as follows:  $I = V/R$ , where V is the DMM voltage reading, and R is the characterized value of the 1 $\Omega$  resistor.
7. Verify that the current calculated in step 6 is within 4.474 to 4.526A limits.
8. Repeat steps 6 and 7 for an output current of -4.5000A.
9. Turn off the output when the test is completed.

**Figure 1-2**  
Connections for current  
verification tests



## Current readback accuracy

Follow the steps below to verify that Model 2510 current readback accuracy is within specified limits. The test involves setting the output current to a specific value using a 1Ω resistor and a digital multimeter.

1. With the power off, connect the digital multimeter and 1Ω resistor to the Model 2510 OUTPUT terminals, as shown in Figure 1-2.
2. Turn on the Model 2510 and the DMM, and allow them to warm up for one hour.
3. Select the multimeter DC voltage measuring function, and set the unit to the 20V range.
4. Press CONFIG then I, choose PROTECTION, then set the current limit to 5.00A.
5. Press the Model 2510 I key to select the current function, and make sure the source output is turned on.
6. Using the EDIT keys, adjust the Model 2510 output current to +4.5000A, as determined from the DMM voltage reading and resistor value. Compute the current as follows:  

$$I = V/R$$
 where V is the DMM voltage reading, and R is the characterized value of the 1Ω resistor.
7. Verify that the current calculated in step 7 is within 4.474 to 4.526A limits.
8. Repeat steps 6 and 7 for an output current of -4.5000A.

## Current limit accuracy

Follow the steps below to verify that Model 2510 current limit accuracy is within specified limits. The test involves setting the current limit to a specific value and making sure the current is limited to the required value.

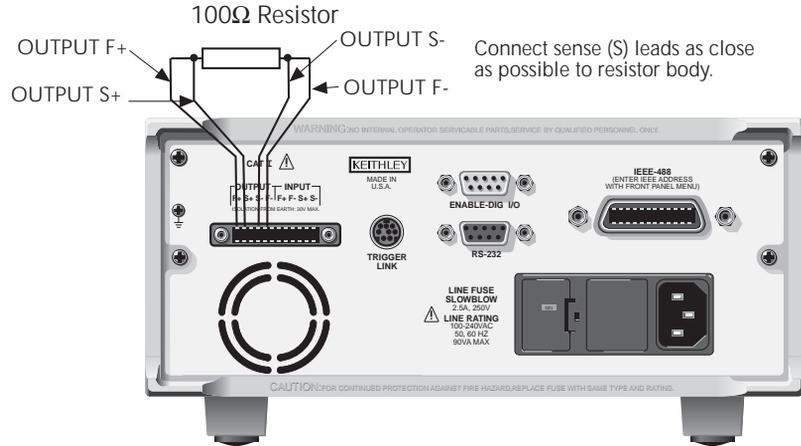
1. With the power off, connect the digital multimeter and 1 $\Omega$  resistor to the Model 2510 OUTPUT terminals, as shown in Figure 1-2.
2. Turn on the Model 2510 and the DMM, and allow them to warm up for one hour.
3. Select the multimeter DC voltage measuring function, and set the unit to the 20V range.
4. Press the Model 2510 V key to select the voltage function.
5. Press CONFIG then I, select PROTECTION, then set the current limit to 4.50A.
6. Make sure the source output is turned on.
7. Using the EDIT keys, adjust the Model 2510 output voltage to +10.000V.
8. Verify that the "ILIM" message is displayed, then measure the output current, as determined from the DMM voltage reading and resistor value. Compute the current as follows:  $I = V/R$ , where V is the DMM voltage reading, and R is the characterized value of the 1 $\Omega$  resistor.
9. Verify that the current calculated in step 9 is within 4.275 to 4.725A limits.
10. Turn off the output when the test is completed.

## AC resistance accuracy

Follow the steps below to verify that Model 2510 AC resistance accuracy is within specified limits. The test involves connecting a 100 $\Omega$  resistor to the OUTPUT terminals and verifying that the Model 2510 AC resistance reading is within limits.

1. With the power off, connect the 100 $\Omega$  resistor to the Model 2510 OUTPUT terminals, as shown in Figure 1-3.
2. Connect the Model 2510 to the serial port or IEEE-488 interface of the computer.
3. Turn on the Model 2510, and allow it to warm up for one hour before testing.
4. Press CONFIG then R.
5. Select AC-OHMS, then press ENTER.
6. Note the reading, and verify that the resistance measurement is within required limits. (Recalculate limits using the characterized resistance value and Model 2510 AC resistance specifications.) For a 100 $\Omega$  resistance, the limits are: 99.88 to 100.12 $\Omega$ .

**Figure 1-3**  
Connections for  
AC resistance  
verification test



Model 2510

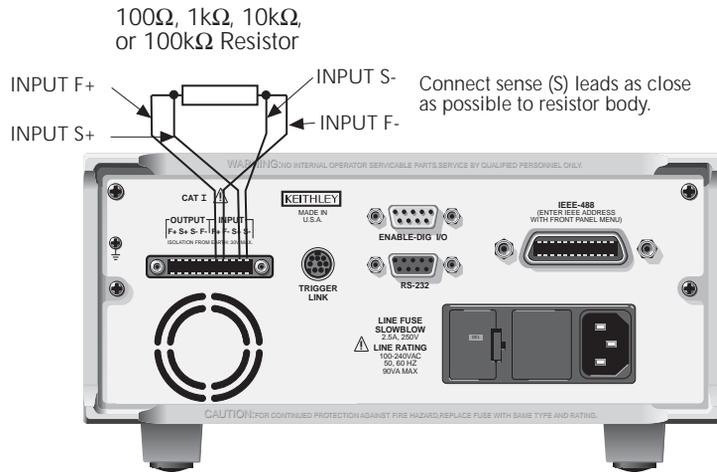
## Sensor measurement accuracy

Use the following steps to verify that Model 2510 temperature sensor measurement accuracy is within specified limits. This procedure involves connecting characterized resistors to the INPUT terminals and verifying sensor resistance readings are within required limits.

**NOTE** The following procedure tests thermistor sensor accuracy and will verify sensor measurement accuracy for all sensor types.

1. With the power off, connect the 100Ω characterized resistor to the Model 2510 INPUT terminals, as shown in Figure 1-4.
2. Turn on the Model 2510, and allow it to warm up for one hour before testing.
3. Select the Model 2510 voltage function by pressing the V key.

**Figure 1-4**  
Connections for sensor  
resistance accuracy  
verification



4. Configure the Model 2510 for thermistor sensor type, resistance range, and 4-wire sense mode as follows:
  - Press CONFIG then T. The instrument will display the following:  
CONFIG TEMPERATURE  
PROTECTION SENSOR-TYPE UNITS PID
  - Select SENSOR-TYPE, and then press ENTER. The following will be displayed:  
SENSOR TYPE  
THERMISTOR RTD I-SS V-SS
  - Select THERMISTOR, and then press ENTER. The following will be displayed:  
THERMISTOR SETTINGS  
RANGE A B C I-SRC ©
  - Select RANGE, then press ENTER. The unit displays:  
THERMISTOR RANGE  
100 1K 10K 100K
  - Select 100, then press ENTER.
  - From the THERMISTOR SETTINGS menu, choose SENSE-MODE, then press ENTER.
  - From the SENSE MODE menu, choose 4-WIRE, then press ENTER.
  - Press EXIT as required to return to normal display.
5. Repeatedly press the DISPLAY TOGGLE key until the sensor resistance (RT) is displayed on the lower display line on the right. For example: RT: +099.98Ω
6. Verify that the sensor reading for the 100Ω resistance in Table 1-3 is within stated limits.

**NOTE** The reading limits in Table 1-3 are based on nominal resistance values. Recalculate new limits based on characterized resistance values and Model 2510 one-year thermistor sensor accuracy specifications (see Appendix A).

- Repeat steps 1 through 5 for the remaining resistance values in Table 1-3. Be sure to select the correct resistance range from the THERMISTOR RANGE menu.

**Table 1-3**

*Sensor resistance measurement accuracy limits*

| Sensor range | Test resistance <sup>1</sup> | Model 2510 sensor reading limits <sup>2</sup><br>(1 year, 18°C-28°C) |
|--------------|------------------------------|--|
| 100Ω         | 100Ω                         | 99.89 to 100.11Ω   |
| 1kΩ          | 1kΩ                          | 0.9992 to 1.0008kΩ   |
| 10kΩ         | 10kΩ                         | 9.995 to 10.005kΩ  |
| 100kΩ        | 100kΩ                        | 99.939 to 100.061kΩ  |

- Nominal resistance values.
- Reading limits based on Model 2510 1-year accuracy specifications and nominal resistance values. Recalculate reading limits using actual characterized resistance values and Model 2510 1-year accuracy specifications. See “Verification limits” earlier in this section for details.



**2**

# Calibration

---

# Introduction

Use the procedures in this section to calibrate the Model 2510. These procedures require accurate test equipment to measure precise DC voltages and resistances. Calibration can be performed either from the front panel or by sending SCPI calibration commands over the IEEE-488 bus or RS-232 port with the aid of a computer.

**WARNING**    **The information in this section is intended for qualified service personnel only. Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages.**

# Environmental conditions

## Temperature and relative humidity

Conduct the calibration procedures at an ambient temperature of 18-28°C (65-82°F) with relative humidity of less than 70% unless otherwise noted.

## Warm-up period

Allow the Model 2510 to warm up for at least one hour before performing calibration.

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.

Allow the test equipment to warm up for the minimum time specified by the manufacturer.

## Line power

The Model 2510 requires a line voltage of 100 to 240V at line frequency of 50 or 60Hz. The instrument must be calibrated while operating from a line voltage within this range.

## Calibration considerations

**WARNING**    **The maximum common-mode voltage (voltage between INPUT/OUTPUT - terminals and chassis ground) is 30V DC. Exceeding this value may cause a shock hazard.**

**CAUTION**    **The maximum voltage between INPUT/OUTPUT sense (S) terminals is 1V. Exceeding this voltage may result in instrument damage.**

When performing the calibration procedures:

- Make sure that the test equipment is properly warmed up and connected to the Model 2510 INPUT or OUTPUT terminals as required.
- Always allow the source signal to settle before calibrating each point.
- Do not connect test equipment to the Model 2510 through a scanner or other switching equipment.
- If an error occurs during calibration, the Model 2510 will generate an appropriate error message. See Appendix B for more information.

### Calibration cycle

Perform calibration at least once a year to ensure the unit meets or exceeds its specifications.

### Recommended calibration equipment

Table 2-1 lists the recommended equipment for the calibration procedures. You can use alternate equipment as long that equipment has specifications at least as good as those listed in the table. For optimum calibration accuracy, test equipment specifications should be at least four times better than corresponding Model 2510 specifications.

**Table 2-1**  
Recommended calibration equipment

| Description                                | Manufacturer/Model    | Specifications   |
|--|-----------------------|--|
| Digital Multimeter                         | Keithley 2002         | DC Voltage <sup>1</sup> 20V: ±6.8ppm<br><br>Resistance <sup>1</sup> 20Ω: ±23ppm<br>200Ω: ±19ppm<br>2kΩ: ±7.4ppm<br>20kΩ ±7.4ppm<br>200kΩ: ±29.8ppm |
| Resistors <sup>2</sup>                     | Isotec RUG-Z-1R00-0.1 | 1Ω ±0.1%, 100W<br>100Ω ±1%<br>1kΩ ±1%<br>10kΩ ±1%<br>100kΩ ±1%   |
| INPUT/OUTPUT Mating Connector <sup>3</sup> | Keithley CS-846       |  |
| Clean Copper Wire                          |                       | #18-22 AWG   |

1. Ninety day, full-range accuracy specification of ranges required for various measurement points.
2. Characterize all resistors using 4-wire ohms function of recommended DMM before use.
3. One connector supplied with Model 2510.

## Resistor characterization

The resistors listed in Table 2-1 must be characterized using the 4-wire ohms function of the recommended DMM before use. Be sure to use the lowest resistance range possible for each measurement for best accuracy. Record the characterized values in Table 2-2.

**Table 2-2**  
Characterized resistor values

| Nominal resistance | Characterized resistance* |
|--------------------|---------------------------|
| 1Ω                 | _____Ω                    |
| 100Ω               | _____Ω                    |
| 1kΩ                | _____kΩ                   |
| 10kΩ               | _____kΩ                   |
| 100kΩ              | _____kΩ                   |

\*Characterize value using DMM (see Table 2-1).

## Calibration menu

Table 2-3 summarizes the main calibration menu selections. To enter the calibration menu, press the MENU key, select CAL, then press ENTER. Use the EDIT keys to move the cursor and scroll through menu selections. Press ENTER to select a MENU item.

**Table 2-3**  
*Calibration menu*

| Menu selection  | Description  |
|-----------------|--|
| UNLOCK          | Unlock calibration using password (default: 002510). |
| EXECUTE         | Execute calibration steps.                           |
| VOLTAGE         | Voltage calibration.                                 |
| CURRENT         | Current calibration.                                 |
| I-PROTECTION    | Current protection calibration.                      |
| TEMPERATURE     | Temperature calibration.                             |
| AC-OHMS         | AC resistance calibration.                           |
| V-SOURCE        | Voltage source calibration.                          |
| VIEW-DATES      | View calibration dates.                              |
| SAVE            | Save calibration constants.                          |
| LOCK            | Lock out calibration.                                |
| CHANGE-PASSWORD | Change calibration password.                         |

## Unlocking calibration

Before performing calibration, you must first unlock calibration by entering or sending the calibration password as explained in the following paragraphs.

### Unlocking calibration from the front panel

- Press the MENU key, choose CAL, and press ENTER. The instrument will display the following:  
CALIBRATION  
UNLOCK EXECUTE VIEW-DATES ©  
β SAVE LOCK CHANGE-PASSWORD
- Select UNLOCK, and then press ENTER. The instrument will display the following:  
PASSWORD:  
Use β, ©, 1, f, ENTER or EXIT.
- Use the 1 and f keys to select the letter or number, and use the β and © arrow keys to choose the position. (Press f for letters; 1 for numbers.) Enter the present password on the display. (Front panel default: 002510.)
- Once the correct password is displayed, press the ENTER key. You can then proceed with the calibration procedure.

## Unlocking calibration by remote

To unlock calibration via remote, send the following command:

```
:CAL:PROT:CODE '<password>'
```

For example, the following command uses the default password:

```
:CAL:PROT:CODE 'KI002510'
```

## Changing the password

The default password (002510) may be changed from the front panel or via remote as discussed.

### Changing the password from the front panel

Follow the steps below to change the password from the front panel:

1. Press the MENU key, choose CAL, and press ENTER. The instrument will display the following:  
CALIBRATION  
UNLOCK EXECUTE VIEW-DATES ©  
B SAVE LOCK CHANGE-PASSWORD
2. Select UNLOCK, then enter the password. (Default: 002510.)
3. Select CHANGE-PASSWORD, and then press ENTER. The instrument will display the following:  
New Pwd: 002510  
Use B, ©, !, f, ENTER or EXIT.
4. Using the EDIT keys, enter the new password on the display.
5. Once the desired password is displayed, press the ENTER key to store the new password.

### Changing the password by remote

To change the calibration password by remote, first send the present password, and then send the new password. For example, the following command sequence changes the password from the 'KI002510' remote default to 'KI\_CAL':

```
:CAL:PROT:CODE 'KI002510'  
:CAL:PROT:CODE 'KI_CAL'
```

You can use any combination of letters and numbers up to a maximum of eight characters.

**NOTE** If you change the first two characters of the password to something other than “KI”, you will not be able to unlock calibration from the front panel.

---

## Resetting the calibration password

If you lose the calibration password, you can unlock calibration by shorting together the CAL pads, which are located on the display board. Doing so will reset the password to the factory default (002510, front panel; KI002510, remote).

See Section 5 for details on disassembling the unit to access the CAL pads. Refer to the display board component layout drawing at the end of Section 6 for the location of the CAL pads.

## Viewing calibration dates and calibration count

When calibration is locked, only the UNLOCK and VIEW-DATES selections will be accessible in the calibration menu. To view calibration dates and calibration count at any time:

1. From normal display, press MENU, select CAL, then press ENTER. The unit will display the following:  
CALIBRATION  
UNLOCK EXECUTE VIEW-DATES ©
2. Select VIEW-DATES, and then press ENTER. The Model 2510 will display the next and last calibration dates and the calibration count as in the following example:  
NEXT CAL: 02/15/2001  
Last calibration: 02/15/2000 Count: 0001

## Calibration errors

The Model 2510 checks for errors after each calibration step, minimizing the possibility that improper calibration may occur due to operator error.

### Front panel error reporting

If an error is detected during comprehensive calibration, the instrument will display an appropriate error message (see Appendix B). The unit will then prompt you to repeat the calibration step that caused the error.

### Remote error reporting

You can detect errors while in remote by testing the state of EAV (Error Available) bit (bit 2) in the status byte. (Use the \*STB? query to request the status byte.) Query the instrument for the type of error by using the :SYST:ERR? query. The Model 2510 will respond with the error number and a text message describing the nature of the error. See Appendix B for details.

## Aborting calibration steps

To abort a calibration step from the front panel, press the EXIT key. To abort a calibration step via remote, send the :ABORt command.

## Front panel calibration

The front panel calibration procedure described below calibrates all functions. Note that each function is separately calibrated, and the procedure must be performed in the order shown.

### Step 1: Prepare the Model 2510 for calibration

1. Turn on the Model 2510 and the digital multimeter, and allow them to warm up for at least one hour before performing calibration.
2. Configure the INPUT terminals for 4-wire sensing as follows:
  - Press CONFIG then T.
  - Select SENSOR-TYPE, then press ENTER.
  - Choose THERMISTOR, then press ENTER.
  - Select SENSE-MODE, then press ENTER.
  - Choose 4-WIRE, then press ENTER.
  - Press EXIT as required to back out of the menu structure and return to normal display.
3. Press the MENU key, choose CAL, and press ENTER. Select UNLOCK, and then press ENTER. The instrument will display the following:  
PASSWORD:  
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
4. Use the  $\uparrow$  and  $f$  keys to select the letter or number, and use the  $\beta$  and  $\odot$  arrow keys to choose the position. (Press  $f$  for letters;  $\uparrow$  for numbers.) Enter the present password on the display. (Front panel default: 002510.)
5. Press ENTER to complete the process.
6. Select EXECUTE, then press ENTER to enter the CAL EXECUTE menu. Table 2-4 summarizes the various menu selections and calibration steps, which are covered in more detail throughout the procedure.

**Table 2-4**  
Calibration step summary

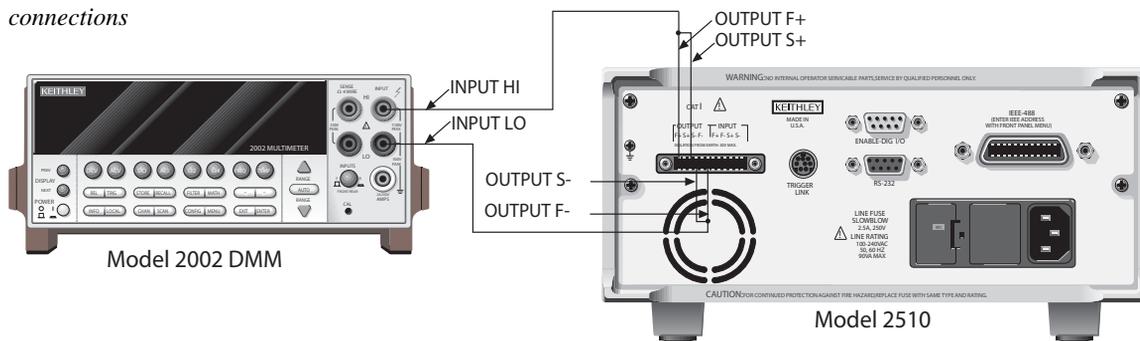
| Function*                 | Calibration step   | Test connections   |
|---------------------------|--|--|
| VOLTAGE                   | Output +8.5V<br>Output 0V<br>Output -8.5V  | DMM to OUTPUT terminals (Figure 2-1)<br>DMM to OUTPUT terminals (Figure 2-1)<br>DMM to OUTPUT terminals (Figure 2-1)   |
| CURRENT                   | 1Ω resistor  | 1Ω resistor to OUTPUT terminals (Figure 2-2)   |
| I-PROTECTION              | 1Ω resistor  | 1Ω resistor to OUTPUT terminals (Figure 2-2)   |
| TEMPERATURE<br>THERMISTOR | 100Ω resistor, short<br>1kΩ resistor, short<br>10kΩ resistor, short<br>100kΩ resistor, short | 100Ω resistor then short to INPUT terminals (Figure 2-3 and Figure 2-4)<br>1kΩ resistor then short to INPUT terminals (Figure 2-3 and Figure 2-4)<br>10kΩ resistor then short to INPUT terminals (Figure 2-3 and Figure 2-4)<br>100kΩ resistor then short to INPUT terminals (Figure 2-3 and Figure 2-4) |
| RTD                       | 100Ω resistor, short<br>1k <sup>3</sup> / <sub>4</sub> resistor, short                       | 100Ω resistor then short to INPUT terminals (Figure 2-3 and Figure 2-4)<br>1k <sup>3</sup> / <sub>4</sub> resistor then short to INPUT terminals (Figure 2-3 and Figure 2-4)   |
| I-SS<br>V-SS              | 1kΩ resistor<br>1kΩ resistor, short  | DMM and 1kΩ resistor to INPUT terminals (Figure 2-5)<br>DMM, 1kΩ resistor; short to INPUT terminals (Figure 2-4 and Figure 2-5)  |
| AC-OHMS                   | 100Ω resistor  | 100Ω resistor to OUTPUT terminals (Figure 2-6)   |
| V-SOURCE                  | Open leads   | None (open OUTPUT terminals)   |

\* CAL EXECUTE menu selections.

### Step 2: Voltage calibration

- From the CAL EXECUTE menu, select VOLTAGE, then press ENTER. The instrument will display the following message:  
VOLTAGE CAL  
Connect only a DMM to Peltier. ©  
8 Then press ENTER.
- Connect the DMM to the Model 2510 OUTPUT terminals, as shown in Figure 2-1.

**Figure 2-1**  
Voltage calibration connections



3. Select the DMM DC voltage function, and enable auto-range.
4. Press ENTER. The unit will then prompt for the +8.5V step:  
VOLTAGE CAL  
Press ENTER to output +8.5V

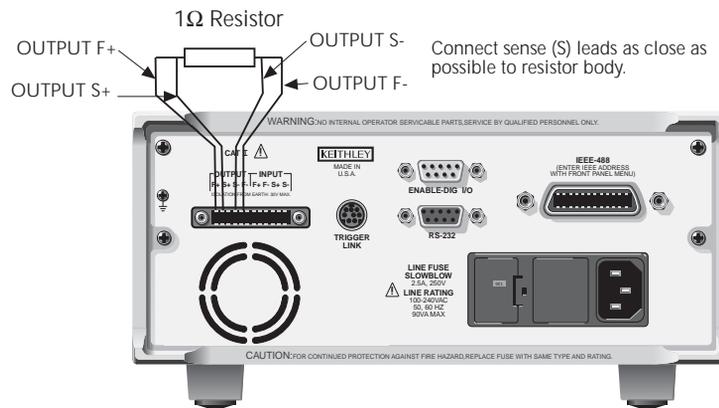
**NOTE** *The output will turn on automatically when you perform the next step.*

5. Press ENTER. The Model 2510 will source +8.5V and simultaneously display the following:  
DMM RDG: +08.50000 V  
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
6. Note and record the DMM reading, and then use the EDIT keys to adjust the Model 2510 display to agree exactly with the actual DMM reading.
7. After adjusting the display to agree with the DMM reading, press ENTER. The instrument will then display the following:  
VOLTAGE CAL  
Press ENTER to output 0.0V
8. Press ENTER. The Model 2510 will source 0V and at the same time display the following:  
DMM RDG: +00.00000 V  
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
9. Note and record the DMM reading, and then adjust the Model 2510 display to agree with that reading.
10. After adjusting the display value to agree with the DMM reading, press ENTER. The unit will then display the following:  
VOLTAGE CAL  
Press ENTER to output -8.5V
11. Press ENTER. The Model 2510 will source -8.5V and display the following:  
DMM RDG: -08.50000 V  
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
12. Note and record the DMM reading, adjust the Model 2510 display to agree with the DMM reading, and press ENTER.
13. Disconnect the DMM from the OUTPUT terminals.

### Step 3: Current and current protection calibration

- From the CAL EXECUTE menu, select CURRENT, then press ENTER. The instrument will display the following message:  
CURRENT CAL  
Connect a 1Ω load to Peltier. ©  
β Then press ENTER.
- Connect the 1Ω resistor to the Model 2510 OUTPUT terminals, as shown in Figure 2-2.

**Figure 2-2**  
Current and current  
protection calibration  
connections



Model 2510

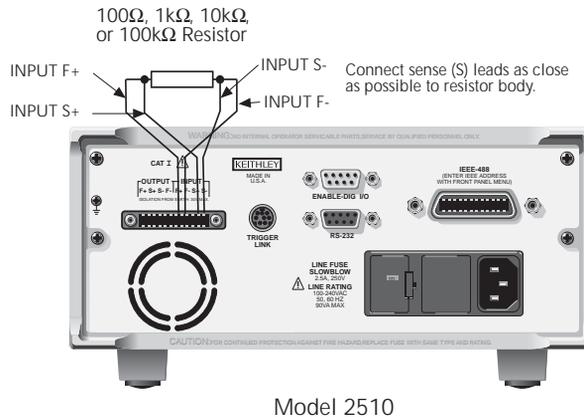
- Press ENTER. The Model 2510 will display the following:  
RES VALUE: 1.00000Ω  
Use β, ©, 1, f, ENTER or EXIT.
- Adjust the Model 2510 display to agree exactly with the characterized value of the 1Ω resistor, then press ENTER.
- Select I-PROTECTION, then press ENTER. The instrument will then display the following:  
CURRENT PROTECTION  
Connect 1Ω load to Peltier. ©  
β Then press ENTER.
- With the 1Ω resistor still connected to the OUTPUT terminals, press ENTER. The Model 2510 will automatically complete the current protection calibration process.
- Disconnect the 1Ω resistor from the OUTPUT terminals.

### Step 4: Temperature calibration

1. Connect the 100 $\Omega$  resistor to the Model 2510 INPUT terminals, as shown in Figure 2-3.
2. From the CAL EXECUTE menu, select TEMPERATURE, then press ENTER. The instrument will display the following message:

```
TEMPERATURE CAL
THERMISTOR RTD I-SS V-SS
```

**Figure 2-3**  
Thermistor and RTD  
calibration resistor  
connections



3. Select THERMISTOR, then press ENTER. The instrument will display the following:
 

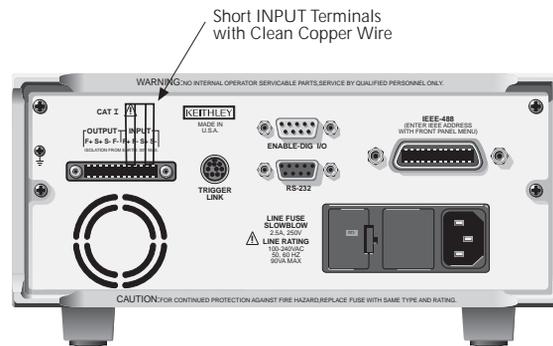
```
THERMISTOR CAL
100 $\Omega$  1k $\Omega$  10k $\Omega$  100k $\Omega$ 
```
4. Select 100 $\Omega$ , then press ENTER. The unit will display the following:
 

```
THERMISTOR CAL
Connect 100 $\Omega$  to temperature ©
 $\beta$  sensor and press ENTER.
```
5. Make sure the 100 $\Omega$  resistor is properly connected, then press ENTER. The Model 2510 will display the following:
 

```
RES VALUE: 0.100000k $\Omega$ 
Use  $\beta$ , ©, ^, f, ENTER or EXIT.
```
6. Use the EDIT keys to adjust the Model 2510 display to agree exactly with the characterized 100 $\Omega$  resistance value, then press ENTER. The unit will display the following:
 

```
THERMISTOR CAL
Connect a Short to temperature ©
 $\beta$  sensor and press ENTER.
```
7. Short all four INPUT terminals together using clean copper wire, as shown in Figure 2-4. Allow one minute for thermal equilibrium.

**Figure 2-4**  
Shorted input  
calibration connections



Model 2510

**NOTE** The characterized  $1\Omega$  resistor can be used in place of the shorted INPUT terminals, if desired. Enter the characterized value of the  $1\Omega$  resistor at the RES VALUE prompt.

8. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 00.00000 $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
9. Press ENTER to complete the shorted calibration step, then remove the shorting wires from the INPUT terminals.
10. From the THERMISTOR CAL menu, select  $1k\Omega$ , then press ENTER. The unit will display the following:  
THERMISTOR CAL  
Connect  $1k\Omega$  to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
11. Connect the  $1k\Omega$  resistor to the Model 2510 INPUT terminals (see Figure 2-3).
12. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 01.00000 $k\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
13. Use the EDIT keys to adjust the Model 2510 display to agree exactly with the characterized  $1k\Omega$  resistance value, then press ENTER. The unit will display the following:  
THERMISTOR CAL  
Connect a Short to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
14. Short all four INPUT terminals together using clean copper wire (see Figure 2-4). Allow one minute for thermal equilibrium.
15. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 00.00000 $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
16. Press ENTER to complete the shorted calibration step, then remove the shorting wires from the INPUT terminals.

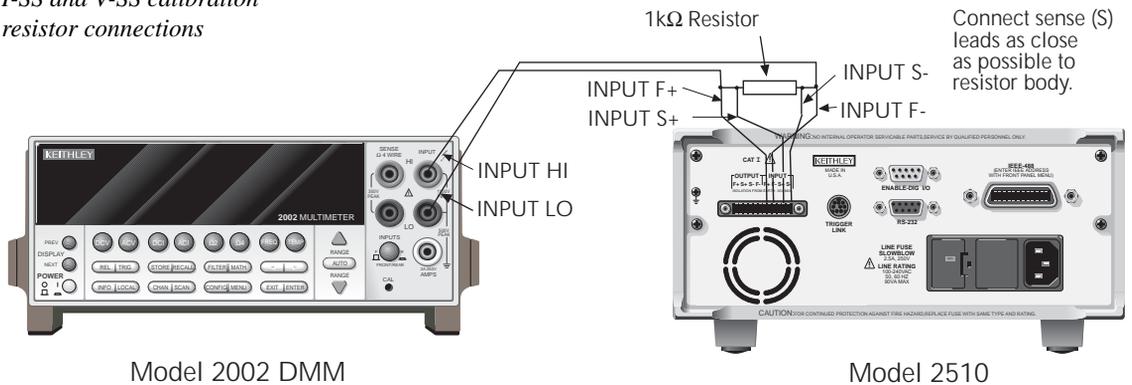
17. From the THERMISTOR CAL menu, select 10k $\Omega$ , then press ENTER. The unit will display the following:  
THERMISTOR CAL  
Connect 10k $\Omega$  to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
18. Connect the 10k $\Omega$  resistor to the Model 2510 INPUT terminals (Figure 2-3).
19. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 010.0000k $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
20. Use the EDIT keys to adjust the Model 2510 display to agree exactly with the characterized 10k $\Omega$  resistance value, then press ENTER. The unit will display the following:  
THERMISTOR CAL  
Connect a Short to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
21. Short all four INPUT terminals together using clean copper wire (see Figure 2-4). Allow one minute for thermal equilibrium.
22. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 00.00000 $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
23. Press ENTER to complete the shorted calibration step, then remove the shorting wires from the INPUT terminals.
24. From the THERMISTOR CAL menu, select 100k $\Omega$ , then press ENTER. The unit will display the following:  
THERMISTOR CAL  
Connect 100k $\Omega$  to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
25. Connect the 100k $\Omega$  resistor to the Model 2510 INPUT terminals (Figure 2-3).
26. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 0100.000k $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
27. Use the EDIT keys to adjust the Model 2510 display to agree exactly with the characterized 100k $\Omega$  resistance value, then press ENTER. The unit will display the following:  
THERMISTOR CAL  
Connect a Short to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
28. Short all four INPUT terminals together using clean copper wire (see Figure 2-4). Allow one minute for thermal equilibrium.
29. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 00.00000 $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.

30. Press ENTER to complete the shorted calibration step, then remove the shorting wires from the INPUT terminals.
31. Press EXIT to return to the TEMPERATURE CAL menu.
32. Select RTD, then press ENTER. The unit displays the following:  
RTD CAL  
Connect 100 $\Omega$  to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
33. Connect the 100 $\Omega$  resistor to the Model 2510 INPUT terminals (Figure 2-3).
34. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 0.100000k $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
35. Adjust the display to agree with the value of the 100 $\Omega$  resistor, then press ENTER. The unit will display the following:  
RTD CAL  
Connect a Short to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
36. Short all four INPUT terminals together using clean copper wire (see Figure 2-4). Allow one minute for thermal equilibrium.
37. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 00.00000 $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
38. Press ENTER to complete the shorted calibration step, then remove the shorting wires from the INPUT terminals.
39. Connect the 1k $\Omega$  resistor to the Model 2510 INPUT terminals (Figure 2-3).
40. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 01.00000k $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
41. Adjust the display to agree with the value of the 1k $\Omega$  resistor, then press ENTER. The unit will display the following:  
RTD CAL  
Connect a Short to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
42. Short all four INPUT terminals together using clean copper wire (see Figure 2-4). Allow one minute for thermal equilibrium.
43. Press ENTER. The Model 2510 will display the following:  
RES VALUE: 00.00000 $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.

44. Press ENTER to complete the shorted calibration step, then remove the shorting wires from the INPUT terminals.
45. From the TEMPERATURE CAL menu, select I-SS, then press ENTER. The unit displays the following:  
I-SS CAL  
Connect 1k $\Omega$  to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
46. Connect the DMM and 1k $\Omega$  resistor to the Model 2510 (Figure 2-5). Press ENTER. The Model 2510 will display the following:  
RES VALUE: 01.00000k $\Omega$   
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
47. Use the EDIT keys to adjust the Model 2510 display to agree exactly with the characterized 1k $\Omega$  resistance value, then press ENTER. The unit will prompt for the DMM voltage reading:  
DMM RDG: +0.833330 V  
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
48. Note the DMM reading, then adjust the Model 2510 display to agree with that value. Press ENTER.
49. From the TEMPERATURE CAL menu, select V-SS, then press ENTER. The unit displays the following:  
V-SS CAL  
Connect 1k $\Omega$  to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
50. Make sure the 1k $\Omega$  resistor and the DMM are still connected to the Model 2510 INPUT terminals (Figure 2-5).
51. Press ENTER. The Model 2510 will display the following:  
DMM RDG: +2.500000V  
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.
52. Note the DMM reading, use the EDIT keys to adjust the Model 2510 display to agree exactly with that value, then press ENTER. The unit will display the following:  
V-SS CAL  
Connect a Short to temperature  $\odot$   
 $\beta$  sensor and press ENTER.
53. Short all four INPUT terminals together using clean copper wire (see Figure 2-4). Allow one minute for thermal equilibrium.
54. Press ENTER. The Model 2510 will display the following:  
DMM RDG: +0.000000V  
Use  $\beta$ ,  $\odot$ ,  $\uparrow$ ,  $f$ , ENTER or EXIT.

55. Press ENTER to complete the shorted calibration step, then remove the shorting wires from the INPUT terminals.
56. Press EXIT to return to the CAL EXECUTE menu.

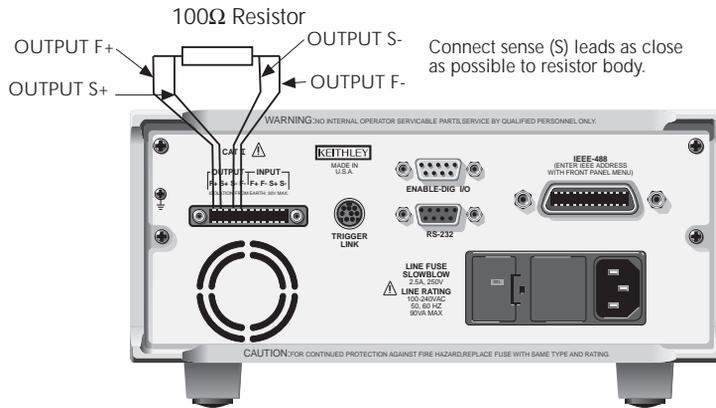
**Figure 2-5**  
I-SS and V-SS calibration  
resistor connections



## Step 5: AC ohms calibration

- From the CAL EXECUTE menu, select AC-OHMS, then press ENTER. The instrument will display the following message:  
AC-OHMS CAL  
Connect a 100Ω load to Peltier. ©  
β Then press ENTER.
- Connect the 100Ω resistor to the OUTPUT terminals (see Figure 2-6).
- Press ENTER. The instrument will display the following:  
RES VALUE: 0.100000kΩ  
Use β, ©, 1, f, ENTER or EXIT.
- Use the EDIT keys to adjust the Model 2510 display to agree exactly with the characterized 100Ω resistance value, then press ENTER.

**Figure 2-6**  
AC ohms calibration  
connections



Model 2510

## Step 6: Voltage source calibration

- From the CAL EXECUTE menu, select V-SOURCE, then press ENTER. The instrument will display the following message:  
V-SRC CAL  
Open Peltier leads then press ©  
β ENTER.
- Disconnect all resistors and test leads from the Model 2510 OUTPUT terminals.
- Press ENTER to complete voltage source calibration.
- Press EXIT to return to the CALIBRATION menu.

## Step 7: Enter calibration dates and save calibration

**NOTE** For temporary calibration without saving new calibration constants, proceed to Step 8: Lock out calibration.

1. From the CALIBRATION menu, select SAVE, then press ENTER. The unit will prompt you for the calibration date:  
CAL DATE: 02/15/2000  
Use  $\downarrow$ ,  $\uparrow$ ,  $\leftarrow$ ,  $\rightarrow$ , ENTER or EXIT.
2. Using the EDIT keys, change the displayed date to today's date, then press the ENTER key. Press ENTER again to confirm the date.
3. The unit will then prompt for the calibration due date:  
NEXT CAL: 02/15/2001  
Use  $\downarrow$ ,  $\uparrow$ ,  $\leftarrow$ ,  $\rightarrow$ , ENTER or EXIT.
4. Set the calibration due date to the desired value, then press ENTER. Press ENTER again to confirm the date.
5. Once the calibration dates are entered, calibration is complete, and the following message will be displayed:  
CALIBRATION COMPLETE  
Press ENTER to save; EXIT to abort
6. Press ENTER to save the calibration data (or press EXIT to abort without saving calibration data).

## Step 8: Lock out calibration

From the CAL EXECUTE menu, select LOCK, then press ENTER to lock out calibration. Press EXIT to return to normal display.

## Remote calibration

Use the following procedure to perform remote calibration by sending SCPI commands over the IEEE-488 bus or RS-232 port. The remote commands and appropriate parameters are separately summarized for each step.

### Remote calibration command summary

Table 2-5 summarizes remote calibration commands used in this section.

**NOTE** For a detailed description of all calibration commands and queries, refer to Appendix B.

**Table 2-5**  
Remote calibration command summary

| Command            | Description  |
|--------------------|--|
| :CALibration       | Calibration subsystem.                                 |
| :PROTeCted         | Calibration commands protected by code/password.       |
| :CODE '<password>' | Unlock calibration. (Default code/password: KI002510.) |
| :SENSe             |  |
| :VOLTage <NRf>     | Calibrate Peltier voltage measurement.                 |
| :CURRent <NRf>     | Calibrate current measurement.                         |
| :TEMPerature <NRf> | Calibrate temperature measurement.                     |
| :SOURce <NRf>      | Calibrate Peltier source/sense voltage.                |
| :AUTO              | Calibrate voltage source.                              |
| :IPDac             | Calibrate current protection DAC.                      |
| :RESistance        |  |
| [:AC] <NRf>        | Calibrate AC ohms.                                     |
| :DATE <y>,<m>,<d>  | Program calibration year, month, day.                  |
| :NDUE <y>,<m>,<d>  | Program calibration due year, month, day.              |
| :SAVE              | Save calibration data in EEPROM.                       |
| :LOCK              | Lock out calibration.                                  |

## Remote calibration procedure

### Step 1: Prepare the Model 2510 for calibration

1. With the power off, connect the Model 2510 to the controller IEEE-488 interface or RS-232 port using a shielded interface cable.
2. Turn on the Model 2510 and the test equipment, and allow them to warm up for at least one hour before performing calibration.
3. If you are using the IEEE-488 interface, make sure the primary address of the Model 2510 is the same as the address specified in the program you will be using to send commands. (Use the MENU key and the COMMUNICATION menu to access the IEEE-488 address.)
4. Send the following command to unlock calibration:  
:CAL:PROT:CODE 'KI002510'
5. Table 2-6 summarizes the various calibration steps and associated commands, which are covered in more detail throughout the procedure.

**Table 2-6**

*Remote calibration step summary*

| Calibrated function | Calibration command  | Test connections   |
|---------------------|--|--|
| Voltage             | :OUTP ON<br>:SOUR:VOLT 8.5<br>:CAL:PROT:SENS:VOLT <DMM_Reading><br>:CAL:PROT:SOUR <DMM_Reading><br>:SOUR:VOLT 0<br>:CAL:PROT:SENS:VOLT <DMM_Reading><br>:CAL:PROT:SOUR <DMM_Reading><br>:SOUR:VOLT -8.5<br>:CAL:PROT:SENS :VOLT <DMM_Reading><br>:CAL:PROT:SOUR <DMM_Reading><br>:OUTP OFF | DMM to OUTPUT (Figure 2-1)<br>DMM to OUTPUT (Figure 2-1)<br>DMM to OUTPUT (Figure 2-1)<br>DMM to OUTPUT (Figure 2-1)<br>DMM to OUTPUT (Figure 2-1) |
| Current             | :OUTP ON<br>:CAL:PROT:SENS:CURR <Resistance_Value>   | 1Ω to OUTPUT (Figure 2-2)  |
| Current protection  | :CAL:PROT:IPD<br>:OUTP OFF   | 1Ω to OUTPUT (Figure 2-2)  |

**Table 2-6 (cont.)**

Remote calibration step summary

| Calibrated function | Calibration command  | Test connections   |
|---------------------|--|--|
| Temperature         | :SYST:RSEN ON  |  |
| Thermistor sensor   | :SENS:TEMP:TRAN THER<br>:SENS:TEMP:THER:RANG 100<br>:CAL:PROT:TEMP <Resistance_Value><br>:CAL:PROT:TEMP 0<br>:SENS:TEMP:THER:RANG 1e3<br>:CAL:PROT:TEMP <Resistance_Value><br>:CAL:PROT:TEMP 0<br>:SENS:TEMP:THER:RANG 1e4<br>:CAL:PROT:TEMP <Resistance_Value><br>:CAL:PROT:TEMP 0<br>:SENS:TEMP:THER:RANG 1e5<br>:CAL:PROT:TEMP <Resistance_Value><br>:CAL:PROT:TEMP 0 | 100Ω to INPUT (Figure 2-3)<br>Short to INPUT (Figure 2-4)<br><br>1kΩ to INPUT (Figure 2-3)<br>Short to INPUT (Figure 2-4)<br><br>10kΩ to INPUT (Figure 2-3)<br>Short to INPUT (Figure 2-4)<br><br>100kΩ to INPUT (Figure 2-3)<br>Short to INPUT (Figure 2-4) |
| RTD sensor          | :SENS:TEMP:TRAN RTD<br>:SENS:TEMP:RTD:RANG 100<br>:CAL:PROT:TEMP <Resistance_Value><br>:CAL:PROT:TEMP 0<br>:SENS:TEMP:RTD:RANG 1000<br>:CAL:PROT:TEMP <Resistance_Value><br>:CAL:PROT:TEMP 0   | 100Ω to INPUT (Figure 2-3)<br>Short to INPUT (Figure 2-4)<br><br>1000¾ to INPUT (Figure 2-3)<br>Short to INPUT (Figure 2-4)  |
| Current sensor      | :SENS:TEMP:TRAN ISS<br>:CAL:PROT:TEMP <Resistance_Value><br>:CAL:PROT:TEMP <DMM_Reading>   | 1kΩ/DMM to INPUT (Figure 2-5)  |
| Voltage sensor      | :SENS:TEMP:TRAN VSS<br>:CAL:PROT:TEMP <DMM_Reading><br>:CAL:PROT:TEMP 0  | 1kΩ/DMM to INPUT (Figure 2-5)<br>Short to INPUT (Figure 2-4)   |
| AC ohms             | :CAL:PROT:RES <Resistance_Value>   | 100Ω to OUTPUT (Figure 2-6)  |
| Voltage source      | :OUTP ON<br>:CAL:PROT:SOUR:AUTO<br>:OUTP OFF   | None (open OUTPUT)   |

## Step 2: Voltage calibration

1. Connect the DMM to the Model 2510 OUTPUT terminals, as shown in Figure 2-1.
2. Select the DMM DC voltage function, and enable auto-range.
3. Send this command to turn on the output:  
:OUTP ON
4. Send the following command to output +8.5V:  
:SOUR:VOLT 8.5
5. Note and record the DMM reading, and then send that value as the parameter for the following commands:  
:CAL:PROT:SENS:VOLT <DMM\_Reading>  
:CAL:PROT:SOUR <DMM\_Reading>  
For example, if the DMM reading is 8.51V, the correct commands are:  
:CAL:PROT:SENS:VOLT 8.51  
:CAL:PROT:SOUR 8.51
6. Send the following command to output 0V:  
:SOUR:VOLT 0
7. Note and record the DMM reading, then send that value as the parameter for the following commands:  
:CAL:PROT:SENS:VOLT <DMM\_Reading>  
:CAL:PROT:SOUR <DMM\_Reading>
8. Send the following command to output -8.5V:  
:SOUR:VOLT -8.5
9. Note and record the DMM reading, then send that value as the parameter for the following commands:  
:CAL:PROT:SENS:VOLT <DMM\_Reading>  
:CAL:PROT:SOUR <DMM\_Reading>
10. Send this command to turn off the output:  
:OUTP OFF
11. Disconnect the DMM from the OUTPUT terminals.

## Step 3: Current and current protection calibration

1. Connect the 1 $\Omega$  resistor to the Model 2510 OUTPUT terminals, as shown in Figure 2-2.
2. Send this command to turn on the output:  
:OUTP ON
3. Send the following command with the characterized 1 $\Omega$  resistor value as the command parameter:  
:CAL:PROT:SENS:CURR <Resistance\_Value>  
For example, if the actual resistor value is 1.01 $\Omega$ , the correct command is:  
:CAL:PROT:SENS:CURR 1.01

4. With the  $1\Omega$  resistor still connected, send the following command to calibrate the current protection DAC:  
:CAL:PROT:IPD
5. Send this command to turn off the output:  
:OUTP OFF
6. Disconnect the  $1\Omega$  resistor from the OUTPUT terminals.

#### Step 4: Temperature calibration

1. Connect the  $100\Omega$  resistor to the Model 2510 INPUT terminals, as shown in Figure 2-3.
2. Send the following command to select the thermistor type temperature sensor:  
:SENS:TEMP:TRAN THER
3. Send the following command to enable 4-wire sensing:  
:SYST:RSEN ON
4. Send this command to select the  $100\Omega$  resistance range:  
:SENS:TEMP:THER:RANG 100
5. Send the following command with the characterized  $100\Omega$  resistance value as the parameter to calibrate the  $100\Omega$  range:  
:CAL:PROT:SENS:TEMP <Resistance\_Value>
6. Short the INPUT terminals with clean copper wire (Figure 2-4). Allow one minute for thermal equilibrium, then send this command:  
:CAL:PROT:SENS:TEMP 0
7. Connect the  $1k\Omega$  resistor to the Model 2510 INPUT terminals (Figure 2-3).
8. Send this command to select the  $1k\Omega$  resistance range:  
:SENS:TEMP:THER:RANG 1e3
9. Send the following command with the characterized  $1k\Omega$  resistance value as the parameter to calibrate the  $1k\Omega$  range:  
:CAL:PROT:SENS:TEMP <Resistance\_Value>
10. Short the INPUT terminals with clean copper wire (Figure 2-4). Allow one minute for thermal equilibrium, then send this command:  
:CAL:PROT:SENS:TEMP 0
11. Connect the  $10k\Omega$  resistor to the Model 2510 INPUT terminals (Figure 2-3).
12. Send this command to select the  $10k\Omega$  resistance range:  
:SENS:TEMP:THER:RANG 1e4
13. Send the following command with the characterized  $10k\Omega$  resistance value as the parameter to calibrate the  $10k\Omega$  range:  
:CAL:PROT:SENS:TEMP <Resistance\_Value>
14. Short the INPUT terminals with clean copper wire (Figure 2-4). Allow one minute for thermal equilibrium, then send this command:  
:CAL:PROT:SENS:TEMP 0
15. Connect the  $100k\Omega$  resistor to the Model 2510 INPUT terminals (Figure 2-3).

16. Send this command to select the 100k $\Omega$  resistance range:  
:SENS:TEMP:THER:RANG 1e5
17. Send the following command with the characterized 100k $\Omega$  resistance value as the parameter to calibrate the 100k $\Omega$  range:  
:CAL:PROT:SENS:TEMP <Resistance\_Value>
18. Short the INPUT terminals with clean copper wire (Figure 2-4). Allow one minute for thermal equilibrium, then send this command:  
:CAL:PROT:SENS:TEMP 0
19. Connect the 100 $\Omega$  resistor to the INPUT terminals (Figure 2-3).
20. Send the following command to select the RTD type temperature sensor:  
:SENS:TEMP:TRAN RTD
21. Send this command to select the 100 $\frac{3}{4}$  range:  
:SENS:TEMP:RTD 100
22. Send the following command with the characterized 100 $\Omega$  resistance value as the parameter to calibrate the RTD measurement function:  
:CAL:PROT:SENS:TEMP <Resistance\_Value>
23. Short the INPUT terminals with clean copper wire (Figure 2-4). Allow one minute for thermal equilibrium, then send this command:  
:CAL:PROT:SENS:TEMP 0
24. Connect the 1000 $\frac{3}{4}$  resistor to the INPUT terminals (Figure 2-5).
25. Send this command to select the 1000 $\frac{3}{4}$  range:  
:SENS:TEMP:RTD:RANG 1000
26. Send the following command with the characterized 1000 $\frac{3}{4}$  resistance value as the parameter to calibrate the RTD measurement function:  
:CAL:PROT:SENS:TEMP <Resistance\_Value>
27. Short the INPUT terminals with clean copper wire (Figure 2-4). Allow one minute for thermal equilibrium, then send this command:  
:CAL:PROT:SENS:TEMP 0
28. Connect the DMM and the 1k $\Omega$  resistor to the INPUT terminals (Figure 2-5).
29. Send the following command to select a solid-state, current-type temperature sensor:  
:SENS:TEMP:TRAN ISS
30. Send the following command with the characterized 1k $\Omega$  resistance value as the parameter:  
:CAL:PROT:SENS:TEMP <Resistance\_Value>
31. Note the DMM reading, then send that value as the parameter for the following command:  
:CAL:PROT:SENS:TEMP <DMM\_Reading>
32. Make sure the 1k $\Omega$  resistor and DMM are still connected to the Model 2510 INPUT terminals (Figure 2-5).
33. Send the following command to select a solid-state, voltage-type temperature sensor:  
:SENS:TEMP:TRAN VSS

34. Note the DMM reading, then send the following command with the DMM reading value as the parameter to calibrate the current type solid-state sensor:  
:CAL:PROT:SENS:TEMP <DMM\_Reading>
35. Short the INPUT terminals with clean copper wire (Figure 2-4). Allow one minute for thermal equilibrium, then send this command:  
:CAL:PROT:SENS:TEMP 0

### Step 5: AC ohms calibration

1. Connect the 100 $\Omega$  resistor to the OUTPUT terminals (see Figure 2-6). Note that the output will be turned off for the AC ohms calibration step.
2. Send the following command with the characterized 100 $\Omega$  resistance value as the command parameter to calibrate the AC ohms function:  
:CAL:PROT:RES <Resistance\_Value>

### Step 6: Voltage source calibration

1. Disconnect all resistors and test leads from the Model 2510 OUTPUT terminals.
2. Turn on the output by sending:  
:OUTP ON
3. Send this command to complete voltage source calibration:  
:CAL:PROT:SOUR:AUTO
4. Turn off the output by sending:  
:OUTP OFF

### Step 7: Program calibration dates

Use following commands to set the calibration date and calibration due date:

```
:CAL:PROT:DATE <yyyy>, <mm>, <dd>      (Calibration date)
:CAL:PROT:NDUE <yyyy>, <mm>, <dd>     (Next calibration due date)
```

Note that the year, month, and date must be separated by commas.

### Step 8: Save calibration constants

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

```
:CAL:PROT:SAVE
```

**NOTE** Calibration will be temporary unless you send the SAVE command.

### Step 9: Lock out calibration

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

```
:CAL:PROT:LOCK
```

**3**

# Routine Maintenance

---

# Introduction

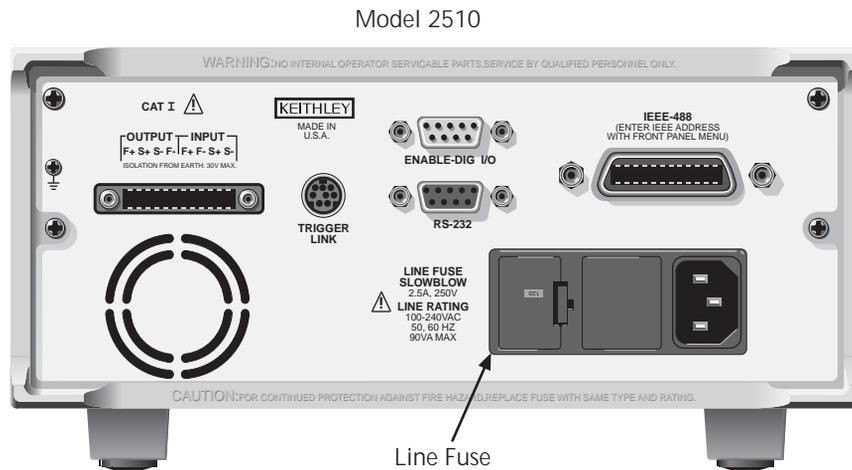
The information in this section deals with routine type maintenance that can be performed by the operator.

## Line fuse replacement

**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 accessible from the rear panel and is integral with the AC power module (see Figure 3-1).

**Figure 3-1**  
Rear panel



Perform the following steps to replace the line fuse:

1. Using a small flat-blade screwdriver, carefully release the locking tab that secures the fuse carrier to the power module.
2. Pull out the fuse carrier, and replace the fuse with the type specified in Table 3-1.

**CAUTION** To prevent instrument damage, use only the fuse type specified in Table 3-1.

3. Reinstall the fuse carrier, pushing it in firmly until it locks into place.

**NOTE** If the power line fuse continues to blow, a circuit malfunction exists and must be corrected. Refer to the troubleshooting information in Section 4 of this manual for additional information.

**Table 3-1**  
Power line fuse

| Line voltage | Rating                            | Keithley part no. |
|--------------|-----------------------------------|-------------------|
| 100-240V     | 250V, 2.5A, Slow<br>Blow 5 × 20mm | FU-106-2.5        |



# 4

## Troubleshooting

---

## Introduction

This section of the manual will assist you in troubleshooting and repairing the Model 2510. Included are self-tests, test procedures, troubleshooting tables, and circuit descriptions. Note that disassembly instructions are located in Section 5, and component layout drawings are at the end of Section 6.

## Safety considerations

**WARNING** The information in this section is intended for qualified service personnel only. 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 2510, 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 2510 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 2510. 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 2510 must be recalibrated. See Section 2 for details on calibrating the unit.

## Power-on self-test

During the power-on sequence, the Model 2510 will perform a checksum test on its EPROM and test its RAM. If one of these tests fails, the instrument will lock up.

## Front panel tests

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

### KEYS test

The KEYS test lets you check the functionality of each front panel key. Perform the following steps to run the KEYS test.

1. Display the MAIN MENU by pressing the MENU key.
2. Using the EDIT keys, select TEST, and press ENTER to display the SELF-TEST MENU.
3. Select DISPLAY-TESTS, and press ENTER to display the following menu:  
FRONT PANEL TESTS  
KEYS DISPLAY-PATTERNS CHAR-SET
4. Select KEYS, and press ENTER to start the test. When a key is pressed, the label name for that key will be displayed to indicate that it is functioning properly. When the key is released, the message “No keys pressed” is displayed.
5. Pressing EXIT tests the EXIT key. However, the second consecutive press of EXIT aborts the test and returns the instrument to the SELF-TEST MENU. Continue pressing EXIT to back out of the menu structure.

## DISPLAY PATTERNS test

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

1. Display the MAIN MENU by pressing the MENU key.
2. Select TEST, and press ENTER to display the SELF-TEST MENU.
3. Select DISPLAY-TESTS, and press ENTER to display the following menu:  
FRONT PANEL TESTS  
KEYS DISPLAY-PATTERNS CHAR-SET
4. Select DISPLAY-PATTERNS, and press ENTER to start the display test. There are five parts to the display test. Each time a front panel key (except EXIT) is pressed, the next part of the test sequence is selected. The five parts of the test sequence are as follows:
  - Checkerboard pattern (alternate pixels on) and all annunciators.
  - Checkerboard pattern and the annunciators that are on during normal operation.
  - Horizontal lines (pixels) of the first digit are sequenced.
  - Vertical lines (pixels) of the first digit are sequenced.
  - Each digit (and adjacent annunciator) is sequenced. All the pixels of the selected digit are on.
5. When finished, abort the display test by pressing EXIT. The instrument returns to the FRONT PANEL TESTS MENU. Continue pressing EXIT to back out of the menu structure.

## CHAR SET test

The character set test lets you display all characters. Perform the following steps to run the character set test:

1. Display the MAIN MENU by pressing the MENU key.
2. Select TEST, and press ENTER to display the SELF-TEST MENU.
3. Select DISPLAY-TESTS, and press ENTER to display the following menu:  
FRONT PANEL TESTS  
KEYS DISPLAY-PATTERNS CHAR-SET
4. Select CHAR-SET, and press ENTER to start the character set test. Press any key except EXIT to cycle through all displayable characters.
5. When finished, abort the character set test by pressing EXIT. The instrument returns to the FRONT PANEL TESTS MENU. Continue pressing EXIT to back out of the menu structure.

# Principles of operation

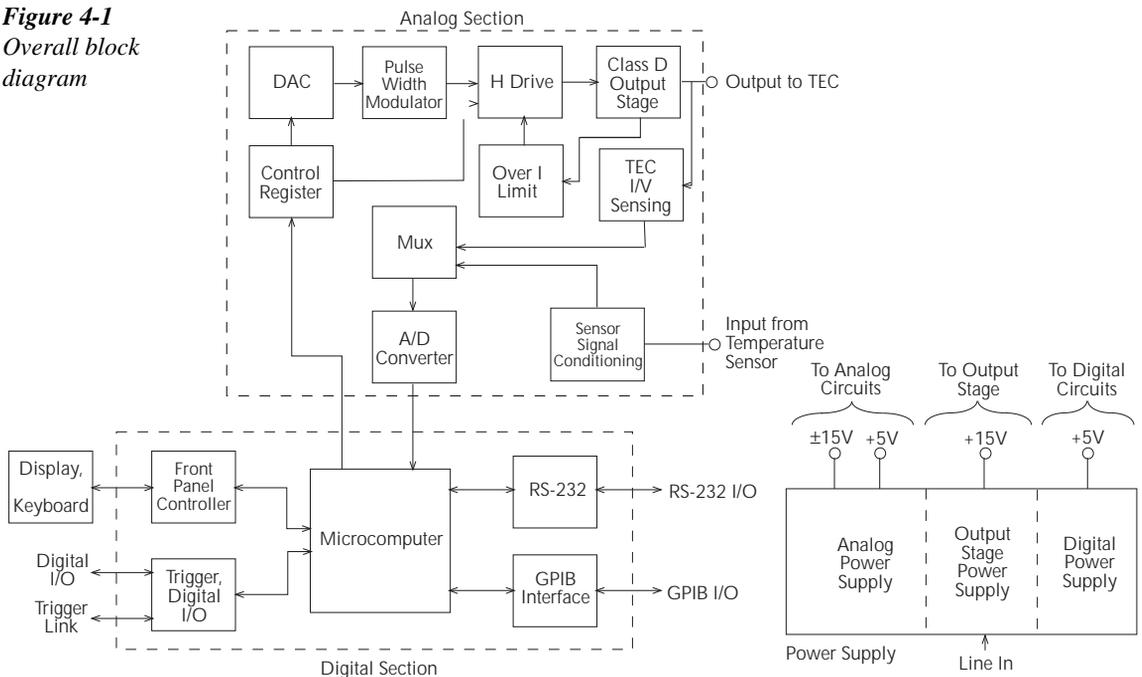
The following information is provided to support the troubleshooting tests and procedures covered in this section of the manual.

## Overall block diagram

Figure 4-1 shows an overall block diagram of the Model 2510. Circuitry may be divided into three general areas:

- **Analog circuits** — includes source circuits such as the pulse-width modulator, H-drive, and class D output stages, as well as measurement circuits such as the sensor signal conditioning and A/D converter circuits.
- **Digital circuits** — includes the microcomputer that controls the analog section, front panel, and GPIB and RS-232 ports, as well as associated interfacing circuits.
- **Power supplies** — converts the AC line voltage into DC voltages that supply the power for the digital and analog circuits, and the class D power amplifier.

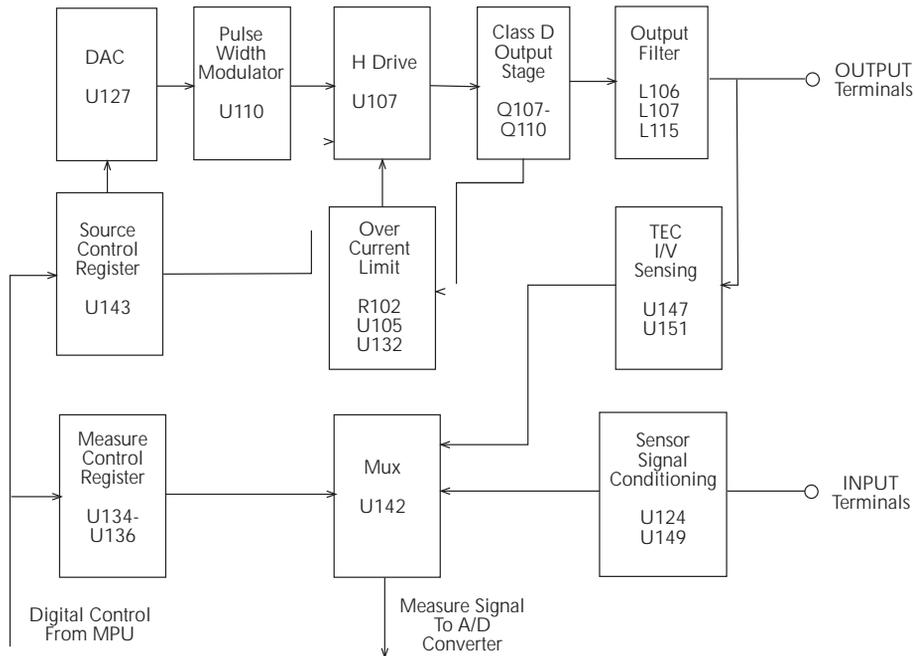
**Figure 4-1**  
Overall block diagram



## Analog circuits

Figure 4-2 shows a block diagram of the analog circuits. These circuits are discussed in more detail in the following paragraphs.

**Figure 4-2**  
Block diagram of  
analog circuits



## Source circuits

The Model 2510 source is a digitally controlled, class D power amplifier with the output stage in an H-bridge configuration. U127 is a 16-bit DAC that controls the pulse-width modulator U110. The H-drive IC, U107, switches the four output FETs, Q107 - Q110. Output filtering is provided by L106, L107, L115, and associated components. Control information for the DAC and H-drive circuit is fed through serial-to-parallel converter U143.

The source amplitude voltage is controlled by varying the duty cycle of the pulse-width modulator and, ultimately, the output stage with the digital control information fed to the DAC and the serial-to-parallel converter. For example, with a duty cycle of 50%, the output is 2.5V.

The hardware current limit circuit consists of R102, U105, U132, and associated components. The output stage current that flows through R102 develops a voltage that is amplified by U105 and compared with a programmed current limit in 10-bit DAC U132. If the current value exceeds the pre-programmed limit, the H-drive IC is disabled, turning off the output stage.

## Class D Amplifier

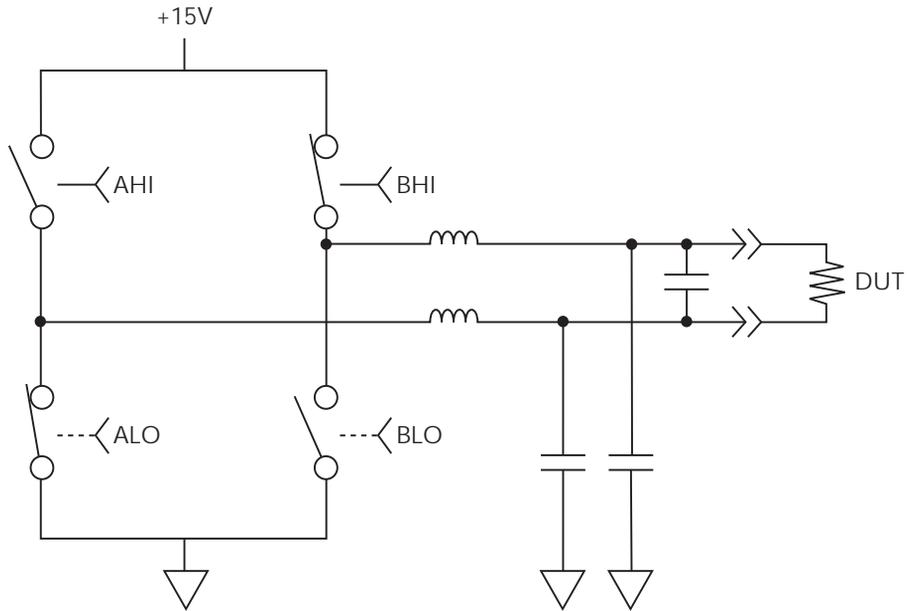
Figure 4-3 shows a simplified schematic of the class D amplifier output stage. The H\_DAC converts control information from the processor into an analog signal that controls the pulse-width modulator (PWM) through the H-bridge control. The IP\_DAC converts current limit control information from the processor and forms the BRIDGE OFF signal that turns off the output stage in an over-current condition.



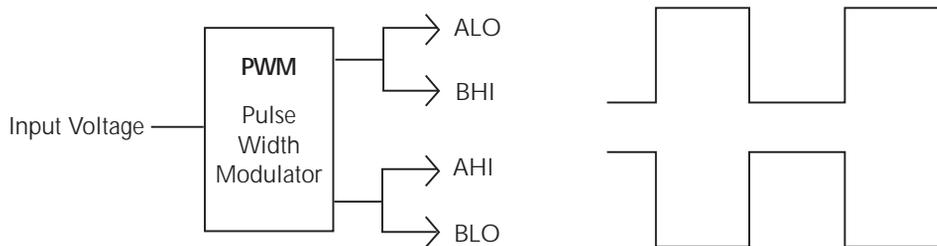
## H-bridge

Figure 4-4 shows a simplified schematic of the H-bridge output stage switching as well as the pulse-width modulator waveforms. The four output stage transistors function as simple switches with the switching phases and duty cycles controlled by the pulse-width modulator as shown.

**Figure 4-4**  
Simplified schematic of  
H-bridge output stage



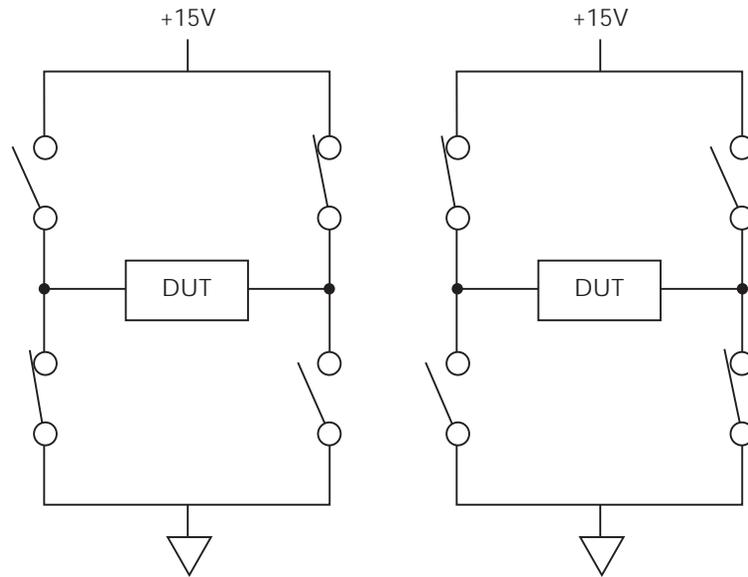
**A. H-Bridge Switching**



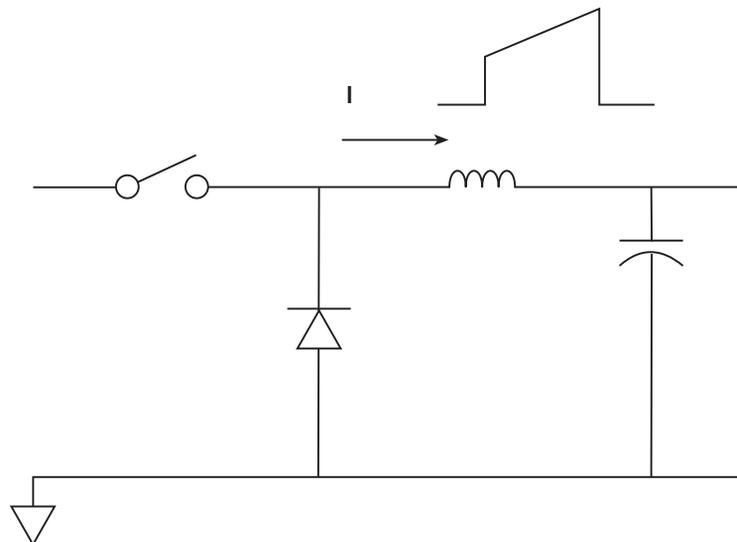
**B. Pulse-Width Modulator Waveforms**

Figure 4-5 shows alternate switching phases of the H-bridge output stage as well as a simplified schematic of the step-down “buck” regulator. Note that the bridge switches between alternate configurations as shown, with the duration and duty cycles controlled by the pulse-width modulator. The step-down “buck” regulator smooths the H-bridge switching waveform into a constant DC level.

**Figure 4-5**  
*H-bridge switching and  
step-down regulator*



**A. H-Bridge**



**B. Step-Down "Buck" Regulator**

## Measurement circuits

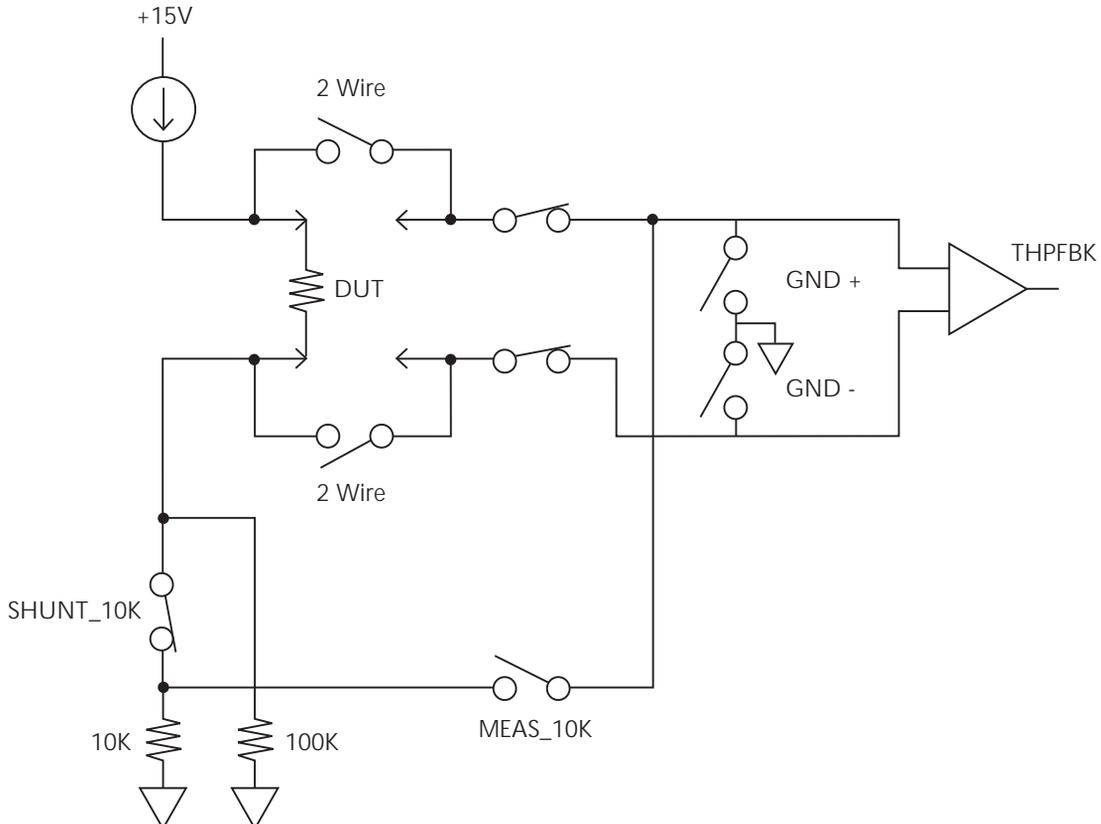
Signal conditioning for the external temperature sensor is provided by U124, U149, and associated components. Voltage and current feedback signals from the TEC output terminals are developed by U147 and U151.

The conditioned temperature sensor, voltage, and current, feedback signals are fed to the multiplexer IC, U142, that switches among the signals during the various phases of the measurement cycle. The output of the mux is fed to the A/D converter for conversion to digital data. Additional signals switched by the mux during the measurement cycle include a reference voltage, reference temperature, internal circuit board temperature signal, and an internal +15V measurement.

## Sensor conditioning

Figure 4-6 shows a simplified schematic of the sensor conditioning circuits. In this example, measurement using a  $10\text{k}\Omega$  thermistor is assumed. Sensor conditioning for other thermistor ranges and sensor types is similar.

**Figure 4-6**  
Sensor conditioning  
for  $10\text{k}\Omega$  thermistor



A constant current is forced through the DUT (thermistor) as well as a reference resistor (in this example,  $10\text{k}\Omega$  for the  $10\text{k}\Omega$  range). As various phases of the measurement cycle, the voltages across the DUT and  $10\text{k}\Omega$  reference resistor are measured, and the actual DUT resistance is computed from the ratio of the two voltages. Since the resistance of the  $10\text{k}\Omega$  reference resistance is accurately known (as determined during instrument calibration), the DUT resistance and a given temperature can be accurately determined, and internal software converts the resistance into an equivalent temperature reading.

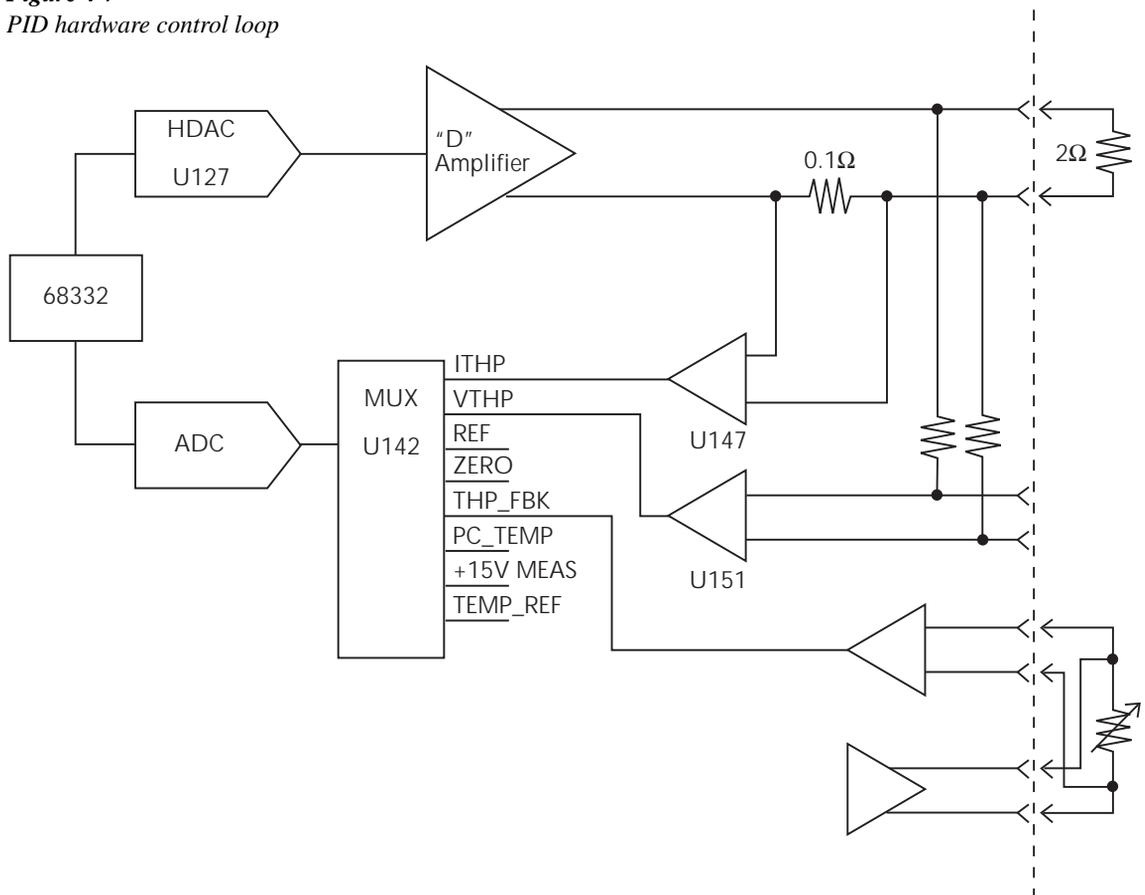
### A/D converter

The Model 2510 unit uses a multi-slope charge balance A/D converter with a single-slope run-down. The converter is controlled by a gate array. Commands are issued by the MPU to the gate array, and the gate array IC sends A/D reading data back to the MPU for calibration and processing.

### PID hardware loop control

Figure 4-7 shows an overall diagram of the hardware aspects of the PID control loop.

**Figure 4-7**  
PID hardware control loop

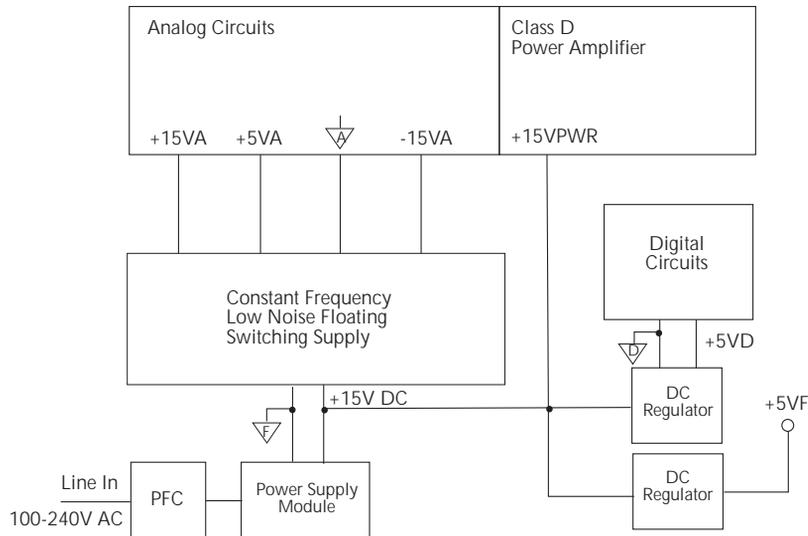


As previously discussed, source control information from the 68332 processor is fed to the HDAC where it is converted into an analog signal to control the class D amplifier output.

## Power supply

Figure 4-8 shows a block diagram of the Model 2510 power supply system.

**Figure 4-8**  
Power supply  
block diagram



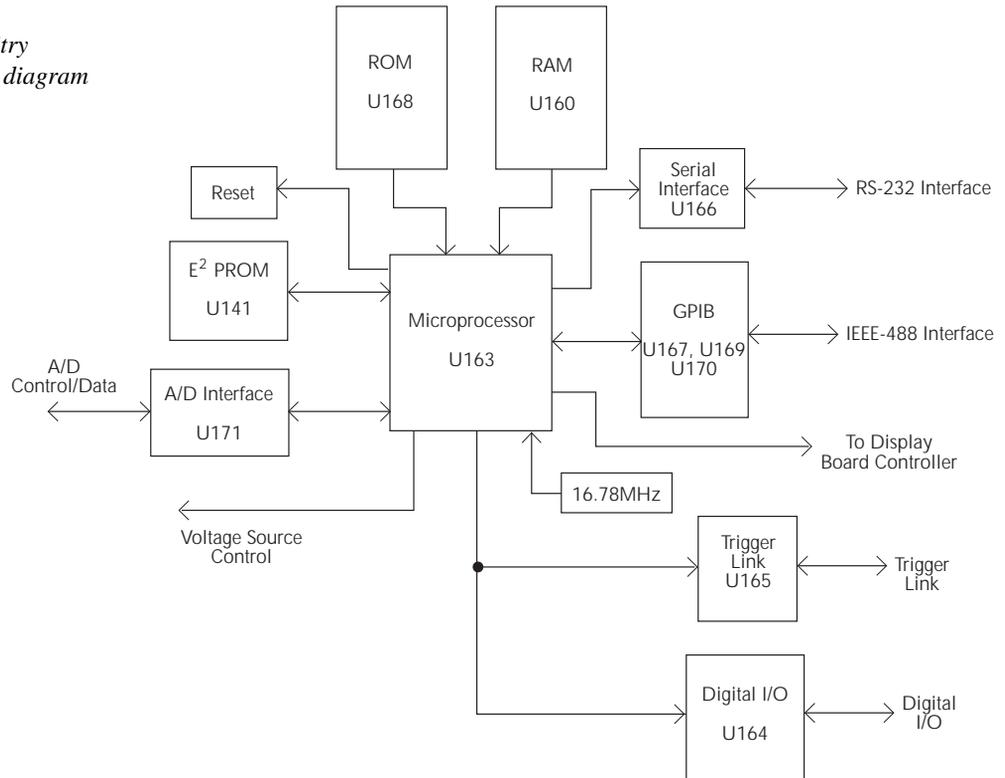
The integrated switching power supply module provides all power for the instrument while providing universal inputs and power factor correction for the 120/240V line. The +15VPWR voltage from the module powers the output stage directly, and this supply voltage is further regulated to develop a +5VF (floating) supply voltage and the +5VD (digital) voltage that powers the digital circuits.

A constant-frequency switching supply also runs off the +15V power module supply and generates the supply voltages for the analog circuits: +5VA and  $\pm 15VA$ .

## Digital circuitry

Refer to Figure 4-9 for the following discussion on digital circuitry.

**Figure 4-9**  
Digital circuitry  
overall block diagram

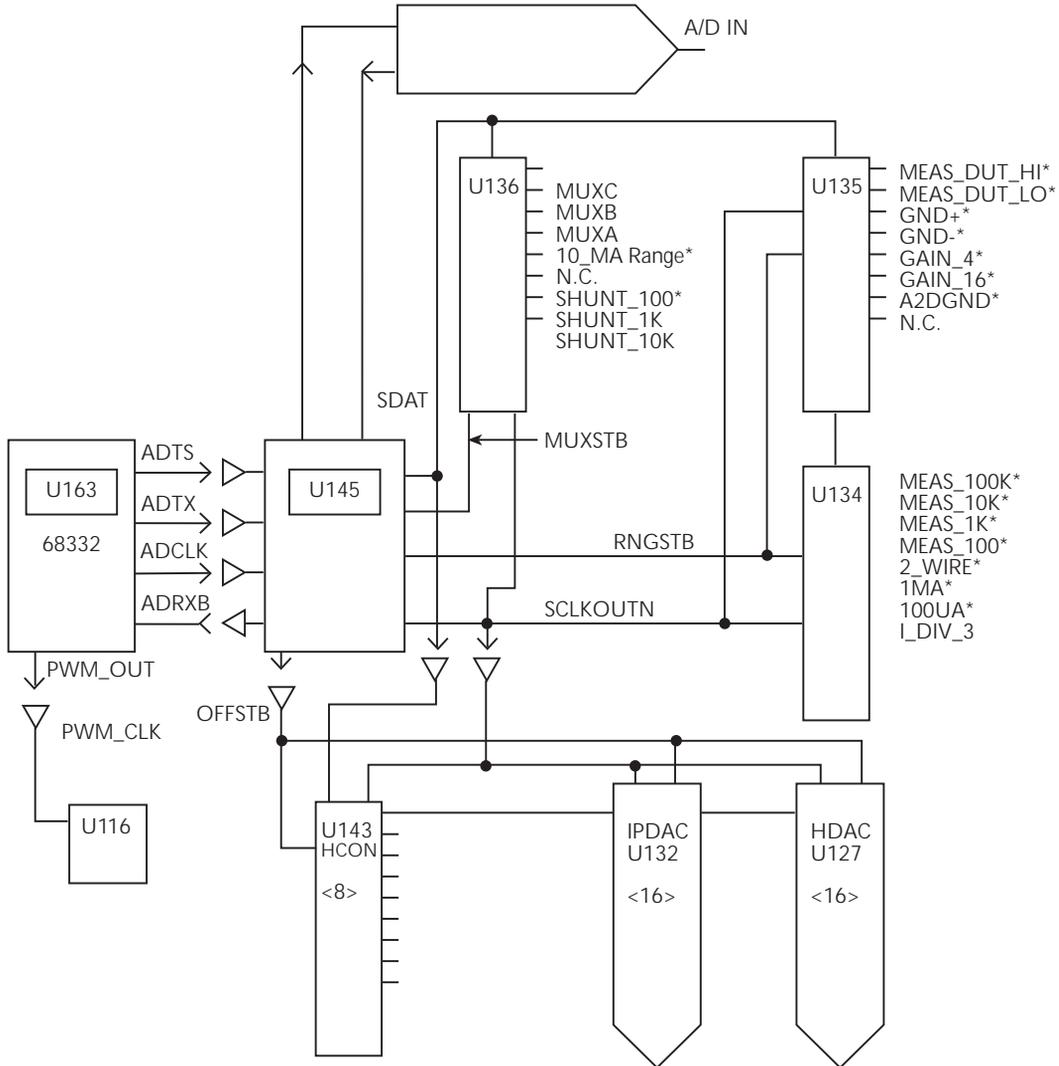


The core digital circuitry uses a Motorola 68332 microcontroller (U163) running at 16.78MHz. The memory configuration includes a flash EEPROM (U168) and a RAM (U160). Flash ROM support allows internal firmware upgrades using either the serial or GPIB port for downloading new firmware. All calibration constants and the saved setups are stored in a separate serial EEPROM (U141).

External communication is provided via GPIB and serial interfaces. A 9914 GPIB IEEE-488 standard interface IC (U167) is used for the GPIB, and a U166 provides the voltage conversion for the RS-232 port. U164 provides interfacing for the Digital I/O port.

Figure 4-10 shows a diagram for digital control that includes serial-to-parallel converters U134 to U136 and associated control signal nomenclatures.

**Figure 4-10**  
Digital control circuits



## Display board circuits

U902 is the display microcontroller that controls the VFD (vacuum fluorescent display) and interprets key data. The microcontroller has four peripheral I/O ports that are used for the various control and read functions.

Display data is serially transmitted to the microcontroller from the digital board via the TXB line to the microcontroller PD0 terminal. In a similar manner, key data is serially sent back to the mother board through the RXB line via PD1. The 4MHz clock for the microcontroller is generated on the digital board.

DS901 is the VFD (vacuum fluorescent display) module, which can display up to 49 characters. Each character is organized as a  $5 \times 7$  matrix of dots or pixels and includes a long underbar segment to act as a cursor.

The display uses a common multiplexing scheme with each character refreshed in sequence. U903 and U904 are the grid drivers, and U901 and U905 are the dot drivers. Note that dot driver and grid driver data is serially transmitted from the microcontroller (PD3 and PC1).

## Troubleshooting

Troubleshooting information for the various circuits is summarized below. Refer to the component layout drawings at the end of Section 6 for component locations.

### Display board checks

If the front panel display tests indicate that there is a problem on the display board, use Table 4-1. See "Principles of operation" for display circuit theory.

**Table 4-1**  
*Display board checks*

| Step | Item/component   | Required condition                                 | Remarks                               |
|------|------------------|--|---------------------------------------|
| 1    | Front panel test | Verify that all segments operate.                  | Use front panel display test.         |
| 2    | J1033            | +5V, $\pm 5\%$                                     | Digital +5V supply.                   |
| 3    | U902, pin 1      | Goes low briefly on power up, and then goes high.  | Microcontroller RESET.                |
| 4    | U902, pin 43     | 4MHz square wave.                                  | Controller 4MHz clock.                |
| 5    | U902, pin32      | Pulse train every 1 ms.                            | Control from main processor.          |
| 6    | U902, pin 33     | Brief pulse train when front panel key is pressed. | Key down data sent to main processor. |

## Power supply checks

Power supply problems can be checked out using Table 4-2. See “Principles of operation” for circuit theory on the power supply.

**Table 4-2**  
*Power supply checks*

| Step | Item/component | Required condition                      | Remarks                              |
|------|----------------|---|--------------------------------------|
| 1    | Line fuse      | Check continuity.                       | Remove to check.                     |
| 2    | Line power     | Plugged into live receptacle, power on. | Check for correct power-up sequence. |
| 3    | J1003, pin 3   | +15V, $\pm 10\%$ (+15VPWR)              | Referenced to TP121.                 |
| 4    | TP102          | +5V, $\pm 5\%$ (+5VF)                   | Referenced to TP121.                 |
| 5    | TP112          | +5V, $\pm 5\%$ (+5VD)                   | Referenced to U163, pin 19.          |
| 6    | TP101          | +15V, $\pm 5\%$ (+15VA)                 | Referenced to TP122.                 |
| 7    | TP105          | -15V, $\pm 5\%$ (-15VA)                 | Referenced to TP122.                 |
| 8    | TP106          | +5V, $\pm 5\%$ (+5VA)                   | Referenced to U104, pin 2.           |
| 9    | TP107          | +5V, $\pm 5\%$ (+5VRF)                  | Referenced to U104, pin 2.           |

## Digital circuitry checks

Digital circuit problems can be checked out using Table 4-3. See “Principles of operation” for a digital circuit description.

**Table 4-3**  
*Digital circuitry checks*

| Step | Item/component  | Required condition               | Remarks                                   |
|------|-----------------|----------------------------------|---|
| 1    | Power-on test   | RAM OK, ROM OK.                  | Verify that RAM and ROM are functional.   |
| 2    | U163 pin 19     | Digital common. common.          | All signals referenced to digital common. |
| 3    | U163 pin 7      | +5V                              | Digital logic supply.                     |
| 4    | U163 pin 68     | Low on power-up, then goes high. | MPU RESET line.                           |
| 5    | U163, A0-A19    | Check for stuck bits.            | MPU address bus.                          |
| 6    | U163, D0-D15    | Check for stuck bits.            | MPU data bus.                             |
| 7    | U163 pin 66     | 16.78MHz.                        | MPU clock.                                |
| 8    | U166 pin 7      | Pulse train during RS-232 I/O.   | RS-232 TX line.                           |
| 9    | U166 pin 8      | Pulse train during RS-232 I/O.   | RS-232 RX line.                           |
| 10   | U167 pins 34-42 | Pulse train during IEEE-488 I/O. | IEEE-488 data bus.                        |
| 11   | U167 pins 26-31 | Pulses during IEEE-488 I/O.      | IEEE-488 command lines.                   |
| 12   | U167 pin 24     | Low with remote enabled.         | IEEE-488 REN line.                        |
| 13   | U167 pin 25     | Low during interface clear.      | IEEE-488 IFC line.                        |
| 14   | U163 pin 43     | Pulse train.                     | D_ADDDATA                                 |
| 15   | U163 pin 44     | Pulse train.                     | D_DATA                                    |
| 16   | U163 pin 45     | Pulse train.                     | D_CLK                                     |
| 17   | U163 pin 47     | Pulse train                      | D_STB                                     |

## Analog circuitry checks

Table 4-4 summarizes analog circuitry checks.

**NOTE** All measurements are with the V function selected, +5V output voltage, 5A current limit, and 1 $\Omega$  and 100 $\Omega$  resistors connected to the OUTPUT and INPUT terminals respectively. Turn OUTPUT ON while measuring.

**Table 4-4**  
Analog circuitry checks

| Step | Item/component <sup>1</sup> | Required condition | Remarks                     |
|------|-----------------------------|--------------------|-----------------------------|
| 1    | TP103 <sup>1</sup>          | +10.4V             | H drive signal              |
| 2    | TP104 <sup>1</sup>          | +4V                | H drive signal              |
| 3    | TP108 <sup>2</sup>          | +6.3V              | A/D reference signal        |
| 4    | TP109 <sup>2</sup>          | -12.5V             | -14V nominal supply         |
| 5    | TP110 <sup>2</sup>          | +12.5V             | +14V nominal supply         |
| 6    | TP114 <sup>2</sup>          | 0V                 | Sensor feedback signal      |
| 7    | TP118 <sup>2</sup>          | Pulse train        | Mux output to A/D converter |
| 8    | TP119 <sup>2</sup>          | 0.5V               | OUTPUT current sense signal |
| 9    | TP120 <sup>2</sup>          | 5V                 | OUTPUT voltage sense signal |

1. Measured with respect to F common (TP121).
2. Measured with respect to A2 common (TP122).

## Internal fuse replacement

**WARNING** Disconnect the line cord and all cables and test leads from the instrument before replacing internal fuses.

**CAUTION** Do not install a fuse with a higher current rating than specified, or instrument damage may occur.

## Power supply module fuse replacement

An internal fuse protects the power supply module from over-current conditions. Replace this fuse as follows:

1. Turn off the power, and disconnect the line cord and all other test leads and cables from the instrument.
2. Remove the case cover and mother board, as covered in Section 5.
3. Locate the fuse on the power supply module circuit board. The module is mounted on the chassis bottom.
4. Replace the fuse with one with the same current and voltage rating marked on the power supply module circuit board.

## Digital I/O +5V supply fuse replacement

An internal fuse protects the +5V supply line on the ENABLE-DIG I/O connector from over-current conditions. Replace this fuse as follows:

1. Turn off the power, and disconnect the line cord and all other test leads and cables from the instrument.
2. Remove the case cover, as covered in Section 5.
3. Locate fuse F101 on the mother board. This fuse is located near the ENABLE-DIG I/O/RS-232 connector assembly (J1007) at the back of the board. See the 2510-100 component layout drawing at the end of Section 6 for location.
4. Carefully unsolder the blown fuse.
5. Replace the fuse with one with the following rating: 0.6A, Keithley part number FU-103, then solder it in place.
6. After soldering, clean the mother board as covered in Section 5, “Handling and cleaning precautions.”

## No comm link error

A “No Comm Link” error indicates that the front panel processor has stopped communicating with the main processor, which is located on the mother board. This error indicates that the main processor ROM (U168) may require reseating in its socket. The ROM may be reseated as follows:

1. Turn off the power, and disconnect the line cord and all other test leads and cables from the instrument.
2. Remove the case cover as outlined in Section 5.
3. Locate the firmware ROM, U168, located on the digital board. This ROM is the only IC installed in a socket. (Refer to the 2510-100 component layout drawing at the end of Section 6 for exact location.)
4. Carefully push down on the ROM IC to make sure it is properly seated in its socket.

**CAUTION**     **Be careful not to push down excessively, or you might crack the mother board.**

5. Connect the line cord, and turn on the power. If the problem persists, additional troubleshooting will be required.

# 5 Disassembly

---

## Introduction

This section explains how to handle, clean, and disassemble the Model 2510. 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. Mother board areas covered by the 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 you must solder 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 2510. 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 work station. 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 solder 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 assembly drawings located at the end of this section to assist you as you disassemble and reassemble the Model 2510. Refer to these drawings for information about the Keithley part numbers of most mechanical parts in the unit. Assembly drawings include:

- Front panel assembly — 2510-040
- Chassis/power module assembly — 2510-050
- Front panel/chassis assembly — 2510-051
- Chassis assembly — 2510-052
- Final inspection — 2510-080

## 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 reinstalling 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 screws that secure the rear bezel to the chassis, then pull the bezel away from the case.
4. **Remove bottom screws** — Remove the four screws that secure the case to the chassis. They are located on the bottom of the case.
5. **Remove chassis** — 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.

## Mother board removal

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

1. Remove the IEEE-488, ENABLE-DIG I/O, and RS-232 fasteners.  
The IEEE-488, ENABLE-DIG I/O, and RS-232 connectors each have two hex-head screws that secure the connectors to the rear panel. Remove these screws.
2. Remove mother board mounting screws.  
Remove the two mounting screws that secure the mother board to the chassis.
3. Unplug cables:
  - Unplug the display board ribbon cable from J1014.
  - Unplug the cables going to the power supply from J1003.
  - Unplug the cable going to the OUTPUT indicator from J102.
  - Unplug the fan cable from J1015.

4. Remove mother board.

Slide the mother board forward until the slots line up with the guide pins, then remove the board.

During reassembly, replace the mother board, and start the IEEE-488, ENABLE-DIG I/O, and RS-232 connector screws and the board mounting screws. Tighten all the fasteners once they are all in place and the board is correctly aligned. Be sure to plug in all cables.

## Front panel disassembly

Use the following procedure to remove the display board and/or the pushbutton switch pad.

1. Remove the power switch rod. Carefully disconnect the power switch rod from the power switch mounted on the rear panel power module. Slide the rod toward the rear until it clears the access hole in the front panel, then remove the rod.
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. Unplug the display board ribbon cables.
4. Using a thin-bladed screw driver, 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.
5. Remove the switch pad by pulling it from the front panel.

## Removing power components

The following procedures to remove the power supply and/or power module require that the case cover and mother board be removed, as previously explained.

### Power supply module removal

Perform the following steps to remove the power supply module:

1. Remove the wires that connect the power supply module to the rear panel power module.
2. Remove any cable clamps or cable ties that secure the power supply module wires.
3. Remove the screws that secure the power supply to the chassis bottom, then remove the module.

## Power module removal

Perform the following steps to remove the rear panel power module:

1. Disconnect the power module's ground wire. This green and yellow wire connects to a threaded stud on the chassis with a kep nut.
2. Squeeze the latches on either side of the power module while pushing the module from the access hole.

## Fan removal

1. Remove the two nuts that secure the fan to the rear of the chassis.
2. 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.

**WARNING** To ensure continued protection against electrical shock, verify that power line ground (green and yellow wire attached to the power module) is connected to the chassis.

Also make sure the four bottom case screws are properly installed to secure and ground the case cover to the chassis.

# 6

## Replaceable Parts

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## Introduction

This section contains replacement parts information and component layout drawings for the Model 2510.

## Parts lists

The electrical parts lists for the Model 2510 are shown in the tables at the end of this section. For part numbers to the various mechanical parts and assemblies, use the Miscellaneous parts list and 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 2510)
- 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 1-800-552-1115 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 the original packing carton.
- Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label.

## Component layouts

The component layouts for the circuit boards are provided on the following pages. Drawings include:

- Mother board — 2510-100
- Display board — 2400-110

**Table 6-1***Mother board parts list*

| <b>Circuit designation</b>               | <b>Description</b>                 | <b>Keithley part no.</b> |
|--|------------------------------------|--------------------------|
| C101,C102,C204,C205,C206,C207            | CAP, 680U, 20%, 50V ALUM ELEC      | C-578-680                |
| C103,C106                                | CAP, 2.2U, 10%, 50V TANTALUM       | C-563-2.2                |
| C104,105,118,121,122,125,126,127,157,158 | CAP, .1UF, 20%, 50V CERAMIC        | C-418-.1                 |
| C107,109,112,114,135,136,143,152,155,161 | CAP, .1UF, 10%, 25V, CERAMIC       | C-495-.1                 |
| C110,C113                                | CAP, .033U, 10%, 50V CERAMIC       | C-491-.033               |
| C111,C128,C188,C189,C192,C194,C290       | CAP, 1UF, 20%, 35V, TANTALUM       | C-494-1                  |
| C115,C175                                | CAP, 2200P, 1%, 50V CERAMIC        | C-532-2200P              |
| C116,C174                                | CAP, 220PF, 10%, 100V, CERAMIC     | C-451-220P               |
| C119,C172,C185                           | CAP, 100PF, 5%, 100V CERAMIC       | C-465-100P               |
| C120                                     | CAP, 470P, 10%, 100V, CERAMIC      | C-451-470P               |
| C123,131,132,133,134,137,138,141,142,146 | CAP, 22UF, 20%, 25V, TANTALUM      | C-440-22                 |
| C130                                     | CAP, 100UF, 20%, 10V, ALUM ELEC    | C-483-100                |
| C139,C140,C144,C145                      | CAP, 47U, 20%, 50V, ALUM           | C-579-47                 |
| C151,156,178,187,199,210,236,150         | CAP, 22UF, 20%, 25V, TANTALUM      | C-440-22                 |
| C162,163,167,170,171,181,182,196,198,200 | CAP, .1UF, 10%, 25V, CERAMIC       | C-495-.1                 |
| C164,C184                                | CAP, 2200P, 10%, 100V CERAMIC      | C-430-2200P              |
| C165,166,186,193,220,225,226,229,230,231 | CAP, .01UF, 10%, 50V CERAMIC       | C-491-.01                |
| C168,169,183,195,197,250,268             | CAP, 47P, 5%, 100V, CERAMIC        | C-465-47P                |
| C173,251,266,117,147,297-305             | CAP, 1000PF,10%, 50V, MONO CERAMIC | C-452-1000P              |
| C176,177,180,208,209,214,215,216,253,271 | CAP, .1UF, 20%, 50V CERAMIC        | C-418-.1                 |
| C179,C247,C260,C265,C275,C292            | CAP, 100P, 10%, 100V CERAMIC       | C-451-100P               |
| C201,202,203,211,212,213,219,221,222     | CAP, .1UF, 10%, 25V, CERAMIC       | C-495-.1                 |
| C223                                     | CAP, 47PF, 10%, 100V, CERAMIC      | C-451-47P                |
| C224,C228                                | CAP, 15P, 1%, 100V CERAMIC         | C-512-15P                |
| C227,233,234,237,238,239,240,241,243     | CAP, .1UF, 10%, 25V, CERAMIC       | C-495-.1                 |
| C232,C235,C242,C245,C282                 | CAP, .01UF, 10%, 50V CERAMIC       | C-491-.01                |
| C246,248,249,252,254,255,256,261,267,269 | CAP, .1UF, 10%, 25V, CERAMIC       | C-495-.1                 |
| C270,C295,C218,C296                      | CAP, .1UF, 20%, 50V CERAMIC        | C-418-.1                 |
| C272,C273                                | CAP, 1UF, 20%, 100V, CERAMIC       | C-487-1                  |
| C277,278,280,281,283-289,291,293,294     | CAP, .1UF, 10%, 25V, CERAMIC       | C-495-.1                 |
| C279                                     | CAP, .1UF, 20%,100V, CERAMIC       | C-436-.1                 |
| CR101,CR113                              | DIODE, MBRS140T3                   | RF-110                   |

**Table 6-1 (cont.)**  
 Mother board parts list

| <b>Circuit designation</b>              | <b>Description</b>                  | <b>Keithley part no.</b> |
|---|-------------------------------------|--------------------------|
| CR102                                   | ULTRA FAST BRIDGE RECTIFIER, EDF1BM | RF-123                   |
| CR103,CR104,CR105,CR106                 | ULTRAFAST POWER RECTIFIER           | RF-107                   |
| CR107,CR108,CR130                       | DIODE, SWITCHING, MMBD914           | RF-83                    |
| CR109,CR110,CR111,CR112,CR133           | DIODE, SWITCHING, MMSD914T19        | RF-112                   |
| CR114                                   | DIODE, DUAL HSM-2822T31             | RF-95                    |
| CR115,CR116,CR122-CR129,CR131,CR132     | DIODE, DUAL SWITCHING, BAV99L       | RF-82                    |
| CR117,CR118,CR119,CR120,CR121           | DIODE, DUAL COMMON ANODE BAW56LT2   | RF-98                    |
| F101                                    | POLYSWITCH, SMD030-2                | FU-103                   |
| HS101,HS105-HS110                       | HEAT SINK                           | HS-55                    |
| J1001                                   | CONNECTOR, MODULES                  | CS-834                   |
| J1003                                   | CONNECTOR, HEADER                   | CS-784-4                 |
| J1006                                   | CONN, MICRODIN W/GND FINGERS        | CS-792                   |
| J1007                                   | CONN, D-SUB DUAL STACK M-F          | CS-1072-1                |
| J1008                                   | CONN, RIGHT ANGLE, 24 PIN           | CS-501                   |
| J101                                    | CONN,BERG                           | CS-339                   |
| J1014                                   | CONN, HEADER STRAIGHT SOLDER PIN    | CS-368-16                |
| J102,J1015                              | LATCHING HEADER,FRICTON, SGL ROW    | CS-724-3                 |
| K101                                    | N.C RELAY, 1 FORMB, AQV214          | RL-176                   |
| K102                                    | MINI POWER RELAY, DK1A-5V           | RL-249                   |
| L101,L105                               | CHOKE, 22UH                         | CH-66-22                 |
| L102,L103,L104                          | FERRITE BEAD                        | CH-91                    |
| L106,L107,L116                          | HIGH CURRENT TOROID                 | CH-103-1                 |
| L108,L109,L110,L111,L112,L113,L114,L118 | FERRITE CHIP 600 OHM BLM32A07       | CH-62                    |
| L115                                    | EMI SUPPRESSION INDUCTOR            | CH-84                    |
| L117,L120                               | CHOKE, EMI                          | CH-57                    |
| L119,L121,L122,L123,L124                | FERRITE CHIP 600 OHM BLM32A07       | CH-62                    |
| L125                                    | CHOKE, 100MHZ                       | CH-50                    |
| PS101                                   | POWER SUPPLY DC-DC CONVERTER        | PS-76-1A                 |
| Q101,Q102,Q104,Q119                     | TRANS, NPN, MMBT3904                | TG-238                   |
| Q103                                    | TRANS, PNP, MMBT3906L               | TG-244                   |
| Q105,Q106                               | TRANS, N CHANNEL MOSFET, BUZ11      | TG-211                   |
| Q107,Q108,Q109,Q110                     | HEXFET POWER MOSFET, IRFZ44N        | TG-354                   |

**Table 6-1 (cont.)**

Mother board parts list

| <b>Circuit designation</b>               | <b>Description</b>                 | <b>Keithley part no.</b> |
|--|------------------------------------|--------------------------|
| Q111,Q116,Q117                           | TRANS, P-CHAN, MOSFET, TP0610T     | TG-259                   |
| Q112,Q113,Q114,Q115,Q120,Q121,Q122,Q123  | TRANS, N-MOSFET, VN0605T           | TG-243                   |
| Q124,Q125,Q126,Q127                      | TRANS, N-MOSFET, VN0605T           | TG-243                   |
| R101,R103,R104,R105,R188                 | RES, 10, 5%, 125MW METAL FILM      | R-375-10                 |
| R102                                     | RES, .02, 1.5W, 1%                 | R-468-.02                |
| R107,R198,R200                           | RES, 20K, 1%, 100MW, THICK FILM    | R-418-20K                |
| R112,R113                                | RES, 200K, 1%, 125MW, METAL FILM   | R-391-200K               |
| R114,115,106,123,208,135,136,130,157,143 | RES, 1K, 1%, 100MW, THICK FILM     | R-418-1K                 |
| R116,R117,R150,R161,R162,R199,R209,R221  | RES, 475, 1%, 100MW, THICK FILM    | R-418-475                |
| R119,R118,R141                           | RES, 30.1K, 1%, 100MW, THICK FILM  | R-418-30.1K              |
| R120,R142                                | RES, 24.3, 1%, 100MW, THICK FILM   | R-418-24.3               |
| R121                                     | RES, 3.01K, 1%, 100MW, THICK FILM  | R-418-3.01K              |
| R122                                     | RES, 1.74K, 1%, 100MW, THICK FILM  | R-418-1.74K              |
| R124,R126,R307                           | RES, .0499, 1%, 100MW, THICK FILM  | R-418-.0499              |
| R125,127,131,165,151,152,168,169,171     | RES, 10K, 1%, 100MW, THICK FILM    | R-418-10K                |
| R132,R311                                | RES, 7.5K, 1%, 100MW, THICK FILM   | R-418-7.5K               |
| R133                                     | RES, 51, 5%, 125MW, METAL FILM     | R-375-51                 |
| R134,R137,R201,R306                      | RES, 200, 1%, 100MW, THICK FILM    | R-418-200                |
| R138,R139,R316                           | RES, 5.11K, 1%, 100MW, THICK FILM  | R-418-5.11K              |
| R146,147,167,177,178,202,216,217,218,219 | RES, 1K, 1%, 100MW, THICK FILM     | R-418-1K                 |
| R148,R149,R255,R256,R257,R279,R284,R140  | RES, 2.21K, 1%, 100MW, THICK FILM  | R-418-2.21K              |
| R153                                     | RES, 49.9K, 1%, 100MW, THICK FILM  | R-418-49.9K              |
| R154                                     | RES, 1.28M, .1%, 1/8W, METAL FILM  | R-176-1.28M              |
| R159                                     | RES, 4.99K, 1%, 125mW, METAL FILM  | R-391-4.99K              |
| R160                                     | RES, 100K, 1%, 100MW, THICK FILM   | R-418-100K               |
| R163                                     | RES, 2.49K, 1%, 125MW, METAL FILM  | R-391-2.49K              |
| R164                                     | RES, 20K, .1%, 1/10W, METAL FILM   | R-263-20K                |
| R170                                     | RES, 2.49K, .1%, .125MW, THIN FILM | R-456-2.49K              |
| R172                                     | RES, 10K, .1%, .125W, THIN FILM    | R-456-10K                |
| R173                                     | RES, 249K, .1%, .125W, THIN FILM   | R-456-249K               |
| R174                                     | RES, 27.7K, .1%, .125W, THIN FILM  | R-456-27.7K              |
| R175                                     | RES, 10K, .1%, 1/10W, METAL FILM   | R-263-10K                |

**Table 6-1 (cont.)**  
**Mother board parts list**

| <b>Circuit designation</b>               | <b>Description</b>                 | <b>Keithley part no.</b> |
|--|------------------------------------|--------------------------|
| R176                                     | RES, 1K, .1%, 1/10W, METAL FILM    | R-263-1K                 |
| R179                                     | RES, 100K, .1%, 1/10W, METAL FILM  | R-263-100K               |
| R180                                     | RES, 34K, 1%, 100MW, THICK FILM    | R-418-34K                |
| R181,R248,R254,R270                      | RES, 4.75K, 1%, 100MW, THICK FILM  | R-418-4.75K              |
| R182                                     | RES, 82.5, 1%, 100MW, THICK FILM   | R-418-82.5               |
| R183,R293,R295,R297,R299,R301,R303       | RES, 5.11K, 1%, 100MW, THICK FILM  | R-418-5.11K              |
| R184                                     | RES, 470,5%, 125MW, METAL FILM     | R-375-470                |
| R185,189,239,294,296,298,300,302,304     | RES, 100, 1%, 100MW, THICK FILM    | R-418-100                |
| R186                                     | RES, 6.65K, .1%, 1/10W, METAL FILM | R-263-6.65K              |
| R187                                     | RES NET                            | TF-245                   |
| R190,R191,R192,R193,R194,R195,R196,R197  | RES, 5.11K, 1%, 100MW, THICK FILM  | R-418-5.11K              |
| R203                                     | RES, .1, 1%, 3W                    | R-475-.1                 |
| R210,R305,R313,R314,R315,R320            | RES, 10K, 1%, 100MW, THICK FILM    | R-418-10K                |
| R211,R215,R252                           | RES, 10M, 1%, 125MW, THICK FILM    | R-418-10M                |
| R212                                     | RES, 18K, .1%, 1/10W, METAL FILM   | R-263-18K                |
| R213,235,236,241-247,249-251,253,263-266 | RES, 10K, 1%, 100MW, THICK FILM    | R-418-10K                |
| R214                                     | RES, 3.2K, .1%, 1/10W, METAL FILM  | R-263-3.2K               |
| R220,222,230,231,258-262,267,272,280,281 | RES, 1K, 1%, 100MW, THICK FILM     | R-418-1K                 |
| R223,R224,R225,R226,R227,R228,R229,R232  | RES, 475, 1%, 100MW, THICK FILM    | R-418-475                |
| R233,R234,R237                           | RES, 475, 1%, 100MW, THICK FILM    | R-418-475                |
| R238                                     | RES, 15k, 1%, 100MW, THICK FILM    | R-418-15K                |
| R240                                     | RES, 332K, 1%, 100MW, THICK FILM   | R-418-332K               |
| R268,R269,R271,R274-277,282,283,285-290  | RES, 10K, 1%, 100MW, THICK FILM    | R-418-10K                |
| R273                                     | RES, 100, 5%, 250MW, METAL FILM    | R-376-100                |
| R278                                     | RES, 100, .1%, 1/10W, METAL FILM   | R-263-100                |
| R291,292,312,R158                        | RES, 1K, 1%, 100MW, THICK FILM     | R-418-1K                 |
| R308                                     | RES, .1%, 1/10W, METAL FILM        | R-263-229                |
| R309                                     | RES, 56.2, .1%, 1/10W, METAL FILM  | R-263-56.2               |
| RV101                                    | TRANSIENT VOLTAGE SUPPRESSOR       | VR-25                    |
| SO-168                                   | SOCKET PLCC-032-T-A                | SO-143-32                |
| T101                                     | TRANSFORMER                        | TR-315A                  |
| TP103,TP104,TP111-TP113,TP118-TP120      | SURFACE MOUNT PCB TEST POINT       | CS-1026                  |

**Table 6-1 (cont.)**

Mother board parts list

| <b>Circuit designation</b> | <b>Description</b>                           | <b>Keithley part no.</b> |
|----------------------------|--|--------------------------|
| TP121,TP122                | SURFACE MOUNT PCB TEST POINT                 | CS-1026                  |
| U101                       | IC, +5V VOLTAGE REGULATOR, LM2940CT          | IC-576                   |
| U102                       | IC, VOLTAGE REGULATOR                        | IC-1133                  |
| U103                       | IC, -15V VOLTAGE REGULATOR                   | IC-1135                  |
| U104                       | IC, VOLTAGE REGULATOR                        | IC-1132                  |
| U105,U119                  | IC, DUAL FET OPAMP                           | IC-1128                  |
| U107                       | IC, 80V 2.5A FULL BRIDGE FET DRIVER          | IC-1139                  |
| U108,U109,U123             | IC, 2 - INPUT AND GATE                       | IC-1140                  |
| U110                       | IC, HIGH SPEED PWM CONTROLLER                | IC-1119                  |
| U113                       | IC, SUPPLY VOLT SUPERVISOR,TL7705A           | IC-860                   |
| U114                       | IC, AJD SHUNT REGULATOR, TL431CLP            | IC-677                   |
| U115,U150                  | IC, SINGLE TRANSISTOR OPTO COUPLER           | IC-1182                  |
| U116                       | IC, HIGH SPEED PWN CONTROLLER                | IC-1120                  |
| U118                       | IC, VOLT COMPARATOR LM393D                   | IC-775                   |
| U120,U124                  | IC, OPA177GS                                 | IC-960                   |
| U121                       | IC, PRECISION BIFET OPAMP                    | IC-1194                  |
| U122                       | IC, DUAL BIPOLAR OP-AMP, LT1124CS8           | IC-955                   |
| U125,U172                  | IC, VOLTAGE REFERENCE                        | IC-1065                  |
| U126,U130,U131,U152,U153   | IC, CMOS ANAL SWITCH, DG444DY                | IC-866                   |
| U127                       | IC, +5V 16 BIT DAC, MAX542ACSD               | IC-1176                  |
| U128                       | IC, VOLT. COMPARATOR, LM311M                 | IC-776                   |
| U129                       | IC, OP-AMP, NE5534D                          | IC-802                   |
| U132                       | IC, +5V 10 BIT DAC, MAX515CSA                | IC-1331                  |
| U133                       | IC, NCHAN LAT DMOS QUADFET, SD5400CY         | IC-893                   |
| U134,U135,U136,U143        | IC, 8 STAGE SHIFT C074HC409AM                | IC-1026                  |
| U138                       | IC, QUAD D FLIP FLOP W/CLK, RESET<br>74HC175 | IC-923                   |
| U139,U140                  | IC, QUAD 2 IN NOR, 74HCT02                   | IC-809                   |
| U141                       | IC, SERIAL EPROM 24LC16B                     | LSI-153                  |
| U142                       | IC, 8-CHAN ANA MULTIPLEXER, DG408DY          | IC-844                   |
| U145                       | PROGRAM                                      | 2000-802A02              |
| U146                       | IC, DUAL D-TYPE F/F, 74HC74                  | IC-773                   |

**Table 6-1 (cont.)**  
*Mother board parts list*

| <b>Circuit designation</b> | <b>Description</b>                     | <b>Keithley part no.</b> |
|----------------------------|--|--------------------------|
| U147,U151                  | IC, DIFFERENTIAL AMP, INA117P          | IC-889                   |
| U148                       | IC, OP-AMP, LOW NOISE LT1007CS8        | IC-949                   |
| U149                       | IC, OPAMP                              | IC-1357                  |
| U155,U158,U154             | IC, HCPL0631, PACK                     | IC-1153                  |
| U156,U157                  | IC, HIGH SPEED OPTO COUPLER            | IC-1225                  |
| U159,U165                  | IC, POS NAND GATES/INVERT, 74HCT14     | IC-656                   |
| U160                       | IC, 64KX16 BIT CMOS STATIC RAM         | LSI-215-1                |
| U161                       | IC, 2 INPUT EXCLUSIVE OR GATE, NC7SZ86 | IC-1180                  |
| U163                       | IC, MICROCONTROLLER MC68332-FC         | LSI-161                  |
| U164                       | IC, PROTECTED QUAD POWER DRIVERS       | IC-1212                  |
| U166                       | IC, +5V RS-232 TRANSCEIVER, MAX202     | IC-952                   |
| U167                       | IC, GPIB ADAPTER, 9914A                | LSI-123                  |
| U168                       | PROGRAMMED ROM                         | 2510-800*                |
| U169                       | IC, OCTAL INTER BUS TRANS,75161        | IC-647                   |
| U170                       | IC, OCTAL INTERFACE BUS, 75160         | IC-646                   |
| U171,U137                  | IC, 2-INPUT OR GATE                    | IC-1206                  |
| U173                       | IC, CURRENT SOURCE, LM334H             | IC-421                   |
| U174                       | IC, CENTIGRADE TEMP SENSOR, LM35DZ     | IC-933                   |
| VR103,VR104                | DIODE, ZENER, 6.2V MMSZ6V2             | DZ-97                    |
| VR105                      | DIODE                                  | DZ-127                   |
| VR106                      | DIODE, ZENER 30V BZX84C30              | DZ-106-30                |
| W101,W102                  | JUMPER, .300                           | J-7-1                    |
| Y101                       | OSCILLATOR HIGH SPEED CMOS 12MHZ       | CR-37                    |
| Y102                       | CRYSTAL, FSM327                        | CR-41                    |

\*Order current firmware revision, for example 2510-800A01.

**Table 6-2**  
Display board parts list

| <b>Circuit designation</b> | <b>Description</b>                 | <b>Keithley part no.</b> |
|----------------------------|------------------------------------|--------------------------|
| C901                       | CAP, 22UF, 20%, 6.3 TANTALUM       | C-417-22                 |
| C902,C904,C907,C908,C910   | CAP, .1UF, 20%,100V, CERAMIC       | C-436-.1                 |
| C903,C905,C906,C909,C911   | CAP, .1UF, 20%, 50V, CERAMIC       | C-418-.1                 |
| C912                       | CAP, 2.2UF, 20%,100V, ALUM ELEC    | C-503-2.2                |
| C913,C914                  | CAP, 100UF, 20%, 16V, TANTALUM     | C-504-100                |
| C915,C916                  | CAP, 33PF, 10%, 100V, CERAMIC      | C-451-33P                |
| CR901,CR902,CR903,CR904    | DIODE, SWITCHING, 250MA,BAV103     | RF-89                    |
| CR905,CR906                | DIODE, SWITCHING, MMBD914          | RF-83                    |
| DS901                      | VACUUM FLUORESCENT DISPLAY         | DD-51C                   |
| J1032                      | CONN, BERG                         | CS-339                   |
| J1033                      | CONN, HEADER STRAIGHT SOLDER PIN   | CS-368-16                |
| Q901,Q902                  | TRANS, NPN GEN PURPOSE BC868       | TG-293                   |
| R901                       | RES NET, 15K, 2%, 1.875W           | TF-219-15K               |
| R902                       | RES, 13K, 5%,125MW, METAL FILM     | R-375-13K                |
| R903,R904                  | RES, 4.7K, 5%, 250MW, METAL FILM   | R-376-4.7K               |
| R905                       | RES, 1M, 5%, 125MW, METAL FILM     | R-375-1M                 |
| R906                       | RES, 1K, 5%, 250MW, METAL FILM     | R-376-1K                 |
| R907                       | RES, 240, 5%, 250MW, METAL FILM    | R-376-240                |
| R908                       | RES, 10M, 5%, 125MW, METAL FILM    | R-375-10M                |
| T901                       | TRANSFORMER, TDK, ER14.5 SERIES    | TR-300                   |
| U901,U904,U905             | IC, LATCHED DRIVERS, UCN-5812EPF-1 | IC-732                   |
| U902                       | PROGRAMMED ROM                     | 7001-800*                |
| U903                       | IC, 32-BIT, SERIAL UCN5818EPF-1    | IC-830                   |
| VR901                      | DIODE, ZENER, 8.2V, MMBZ5237       | DZ-92                    |
| Y901                       | CRYSTAL, 4MHZ                      | CR-36-4M                 |

\*Order current revision level, for example 7001-800A02.

**Table 6-3**  
Miscellaneous parts list

| Qty. | Description                   | Keithley part no. |
|------|-------------------------------|-------------------|
| 1    | BEZEL, REAR                   | 428-303D          |
| 1    | CHASSIS                       | 2510-301A         |
| 1    | CONDUCTIVE RUBBER SWITCH      | 2510-315A         |
| 1    | COVER                         | 2510-307A         |
| 1    | DISPLAY LENS                  | 2510-311B         |
| 1    | FAN                           | FN-39-1           |
| 2    | FOOT                          | 428-319A          |
| 2    | FOOT, EXTRUDED                | FE-22A            |
| 2    | FOOT,RUBBER                   | FE-6              |
| 1    | FUSE HOLDER                   | FH-39             |
| 1    | FUSE, EXP. 2.5/5X20MM         | FU-106-2.5        |
| 1    | HANDLE                        | 428-329F          |
| 1    | LENS, LED                     | 6517-309B         |
| 1    | LINE CORD                     | CO-7              |
| 1    | LINE MODULE                   | PM-1-1B           |
| 1    | MATING INPUT/OUTPUT CONNECTOR | CS-846            |
| 1    | MEMBRANE SWITCH, FRONT PANEL  | 6430-313A         |
| 1    | MODIFIED FRONT PANEL          | 2510-308A         |
| 1    | MOUNTING EAR, LEFT            | 428-338B          |
| 1    | MOUNTING EAR, RIGHT           | 428-328E          |
| 1    | OVERLAY FRONT PANEL           | 2510-309A         |
| 2    | PC BOARD STOP                 | 2001-371A         |
| 1    | POWER ROD                     | 2001-320A         |
| 1    | POWER SUPPLY                  | PS-77-1A          |
| 1    | REAR PANEL                    | 2510-303A         |

# A Specifications

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# 2510 TEC SourceMeter

The Model 2510 Thermoelectric Cooler Controller is designed to:

- control the power to the TEC to maintain a constant temperature, current, voltage, or thermistor resistance
- measure the resistance of the TEC
- software PID loop

## CONTROL SYSTEM SPECIFICATIONS

**SET:** Constant Peltier Temperature  
Constant Peltier Voltage  
Constant Peltier Current  
Constant Thermistor Resistance

### CONTROL METHOD:

Programmable software PID loop.  
Proportional, Integral, and Derivative gains independently programmable.

**SETPOINT SHORT TERM STABILITY:**  $\pm 0.005^\circ\text{C}$  rms.<sup>2,3</sup>

**SETPOINT LONG TERM STABILITY:**  $\pm 0.01^\circ\text{C}$ .<sup>2,4</sup>

**SETPOINT RANGE:**  $-50^\circ\text{C}$  to  $225^\circ\text{C}$ .

**OVER TEMPERATURE LIMIT:**  $250^\circ\text{C}$  max.

**UNDER TEMPERATURE LIMIT:**  $-50^\circ\text{C}$  max.

**SETPOINT RESOLUTION:**  $0.001^\circ\text{C}$ , 1mV, 100 $\mu\text{A}$ , 0.01% of nominal ( $25^\circ\text{C}$ ) thermistor resistance.

**HARDWARE CURRENT LIMIT:** 1.0A to 5.25A  $\pm 5\%$ .

**SOFTWARE VOLTAGE LIMIT:**  $\pm 0.5$  to 10.5V  $\pm 5\%$ .

## TEC OUTPUT SPECIFICATIONS

**OUTPUT RANGE:**  $\pm 10$  VDC at up to  $\pm 5$  ADC.

**OUTPUT RIPPLE:**  $< 5$  mV rms.<sup>5</sup>

**AC RESISTANCE EXCITATION:**  $\pm(9.6\text{mA} + 190\mu\text{A})$ .<sup>10,11</sup>

## TEC MEASUREMENT SPECIFICATIONS

**FUNCTION** 1 Year,  $23^\circ\text{C} \pm 5^\circ\text{C}$

| FUNCTION                                       | 1 Year, $23^\circ\text{C} \pm 5^\circ\text{C}$ |
|--|--|
| <b>Operating Resistance</b> <sup>1,6,7,8</sup> | $\pm(2.0\%$ of rdg + 0.1 $\Omega$ )            |
| <b>Operating Voltage</b> <sup>1,6</sup>        | $\pm(0.1\%$ of rdg + 4mV)                      |
| <b>Operating Current</b> <sup>6</sup>          | $\pm(0.4\%$ of rdg + 8mA)                      |
| <b>AC Resistance</b> <sup>1,13</sup>           | $\pm(0.10\%$ of rdg + 0.02 $\Omega$ )          |

### OPEN SHORTED THERMOELECTRIC DETECTION

**LOAD IMPEDANCE:** Stable into 1 $\mu\text{F}$  typical.

**COMMON MODE VOLTAGE:** 30VDC maximum.

**COMMON MODE ISOLATION:**  $> 10^9\Omega$ ,  $< 1500\text{pF}$

**MAX. SENSE LEAD RESISTANCE:** 1 $\Omega$  for rated accuracy.

**MAX. FORCE LEAD RESISTANCE:** 0.1 $\Omega$ .

## THERMAL FEEDBACK ELEMENT SPECIFICATIONS (1 Year, $23^\circ\text{C} \pm 5^\circ\text{C}$ )

| Sensor Type  | RTD                                 |                                     | Thermistor                          |                                     |                                     |                                     | Solid State                         |                                     |
|--|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
|  | 100 $\Omega$                        | 1 k $\Omega$                        | 100 $\Omega$                        | 1 k $\Omega$                        | 10 k $\Omega$                       | 100 k $\Omega$                      | Current Output ( $I_{SS}$ )         | Voltage Output ( $V_{SS}$ )         |
| <b>Excitation</b> <sup>9</sup>                           | 2.50 mA                             | 833 $\mu\text{A}$                   | 2.5 mA                              | 833 $\mu\text{A}$                   | 100 $\mu\text{A}$                   | 33 $\mu\text{A}$                    | 2.5 mA                              | +13.5 V                             |
| <b>Compliance</b>  |                                     |                                     |                                     |                                     |                                     | 833 $\mu\text{A}$ max               | 15.75 V max                         |                                     |
| <b>Nominal Resistance Range</b>                          | 0–250 $\Omega$                      | 0–2.50 k $\Omega$                   | 0–1 k $\Omega$                      | 0–10 k $\Omega$                     | 0–80 k $\Omega$                     | 0–200 k $\Omega$                    |                                     |                                     |
| <b>Excitation Accuracy</b>                               | -2.9%                               | -2.9%                               | $\pm 2.9\%$                         | $\pm 2.9\%$                         | $\pm 2.9\%$                         | $\pm 2.9\%$                         | $\pm 12\%$                          | $\pm 2.9\%$                         |
| <b>Nominal Sensor Temperature Range</b>                  | $-50^\circ$ to $+250^\circ\text{C}$ | $-40^\circ$ to $+100^\circ\text{C}$ | $-40^\circ$ to $+100^\circ\text{C}$ |
| <b>Sensor Coefficients</b>                               | $\alpha, \beta, \delta$             | $\alpha, \beta, \delta$             | A, B, C                             | A, B, C                             | A, B, C                             | A, B, C                             | Slope & offset                      | Slope & offset                      |
| <b>Measurement Accuracy</b><br>( $\pm$ (% rdg + offset)) | 0.04 + 0.07 $\Omega$                | 0.04 + 0.4 $\Omega$                 | 0.04 + 0.07 $\Omega$ <sup>1</sup>   | 0.04 + 0.4 $\Omega$ <sup>1</sup>    | 0.02 + 3 $\Omega$ <sup>1</sup>      | 0.04 + 21 $\Omega$                  | 0.03 + 100 nA                       | 0.03 + 500 $\mu\text{V}$            |

### THERMISTOR MEASUREMENT ACCURACY<sup>14</sup>

| Nominal Thermistor Resistance | Accuracy vs. Temperature |                        |                        |                       |
|-------------------------------|--------------------------|------------------------|------------------------|-----------------------|
|                               | 0 $^\circ\text{C}$       | 25 $^\circ\text{C}$    | 50 $^\circ\text{C}$    | 100 $^\circ\text{C}$  |
| 100 $\Omega$                  | 0.021 $^\circ\text{C}$   | 0.035 $^\circ\text{C}$ | 0.070 $^\circ\text{C}$ | 0.27 $^\circ\text{C}$ |
| 1 k $\Omega$                  | 0.015 $^\circ\text{C}$   | 0.023 $^\circ\text{C}$ | 0.045 $^\circ\text{C}$ | 0.18 $^\circ\text{C}$ |
| 10 k $\Omega$                 | 0.006 $^\circ\text{C}$   | 0.012 $^\circ\text{C}$ | 0.026 $^\circ\text{C}$ | 0.15 $^\circ\text{C}$ |
| 100 k $\Omega$                | 0.009 $^\circ\text{C}$   | 0.014 $^\circ\text{C}$ | 0.026 $^\circ\text{C}$ | 0.13 $^\circ\text{C}$ |

### OPEN/SHORTED ELEMENT DETECTION

#### SOFTWARE LINEARIZATION FOR THERMISTOR AND RTD

**COMMON MODE VOLTAGE:** 30VDC.

**COMMON MODE ISOLATION:**  $> 10^9\Omega$ ,  $< 1000\text{pF}$

**MAX. VOLTAGE DROP IN INPUT FORCE LEADS:** 1 volt.

**MAX. SENSE LEAD RESISTANCE:** 100 $\Omega$  for rated accuracy.

**SENSE INPUT IMPEDANCE:**  $> 1 \cdot 10^9\Omega$ .

## GENERAL

### NOISE REJECTION:

| SPEED  | NPLC | CMRR <sup>12</sup> |
|--------|------|--------------------|
| Normal | 1.00 | 90 dB              |

**SOURCE OUTPUT MODES:** Fixed DC level.

**PROGRAMMABILITY:** IEEE-488 (SCPI-1995.0), RS-232, 3 user-definable power-up states plus factory default and \*RST.

**POWER SUPPLY:** Nominal 100 to 240VAC rms, 50–60Hz, 90VA.

**WARRANTY:** 1 year.

**EMC:** Conforms to European Union Directive 89/336/EEC, EN 61326-1.

**SAFETY:** Conforms to European Union Directive 73/23/EEC, EN 61010-1.

**VIBRATION:** MIL-PRF-28800F Class 3 Random Vibration.

**WARM-UP:** 1 hour to rated accuracies.

**DIMENSIONS, WEIGHT:** 89mm high  $\times$  213 mm wide  $\times$  370mm deep (3 $\frac{1}{2}$  in  $\times$  8 $\frac{1}{2}$  in  $\times$  14 $\frac{1}{2}$  in).  
**Bench configuration (with handle & feet):** 104mm high  $\times$  238mm wide  $\times$  370mm deep (4 $\frac{1}{8}$  in  $\times$  9 $\frac{1}{2}$  in  $\times$  14 $\frac{1}{2}$  in). **Net Weight:** 3.8kg (8.38 lbs).

**ENVIRONMENT:** **Operating:** 0 $^\circ$ –50 $^\circ\text{C}$ , 70% R.H. up to 35 $^\circ\text{C}$ . Derate 3% R.H./ $^\circ\text{C}$ , 35 $^\circ$ –50 $^\circ\text{C}$ .  
**Storage:**  $-25^\circ$  to 65 $^\circ\text{C}$

## NOTES

- 1 With remote voltage sense.
- 2 With 10k $\Omega$  thermistor as sensor.
- 3 Short term stability is defined as 24 hours with Peltier and Model 2510 at  $25^\circ\text{C} \pm 0.5^\circ\text{C}$ .
- 4 Long term stability is defined as 30 days with Peltier and Model 2510 at  $25^\circ\text{C} \pm 0.5^\circ\text{C}$ .
- 5 10Hz to 10MHz measured at 5A output into a 2 $\Omega$  load.
- 6 Common mode voltage = 0V (meter connect enabled, connects Peltier low output to thermistor measure circuit ground).  $\pm(0.1\%$  of rdg + 0.1 $\Omega$ ) with meter connect disabled.
- 7 Resistance range 0 $\Omega$  to 20 $\Omega$  for rated accuracy.
- 8 Current through Peltier  $> 0.2\text{A}$ .
- 9 Default values shown, selectable values of 3 $\mu\text{A}$ , 10 $\mu\text{A}$ , 33 $\mu\text{A}$ , 100 $\mu\text{A}$ , 833 $\mu\text{A}$ , 2.5mA. Note that temperature control performance will degrade at lower currents.
- 10 AC Ohms is a dual pulsed measurement using current reversals available over bus only.
- 11 @  $23^\circ\text{C} \pm 5^\circ\text{C}$ .
- 12 For 1k $\Omega$  unbalance in LO lead. Minimum amplifier specification.
- 13 Resistance range 0 $\Omega$  to 100 $\Omega$  for rated accuracy.
- 14 Accuracy figures represent the uncertainty that the Model 2510 may add to the temperature measurement, not including thermistor uncertainty. These accuracy figures are for thermistors with typical A, B, C constants.

## Accuracy calculations

The information below discusses how to calculate accuracy for both TEC measurement and thermal feedback element specifications.

Accuracy specifications are stated as follows:

$$\text{Accuracy} = \pm(\% \text{ of reading} + \text{offset})$$

As an example of how to calculate the actual limits, assume an output voltage of 5V. You can compute the limits from one-year operating voltage accuracy specifications as follows:

$$\begin{aligned}\text{Accuracy} &= \pm(\% \text{ of reading} + \text{offset}) \\ &= \pm[(0.1\% \times 5\text{V}) + 4\text{mV}] \\ &= \pm(5\text{mV} + 4\text{mV}) \\ &= \pm 9\text{mV}\end{aligned}$$

Thus, the actual operating voltage range is:  $5\text{V} \pm 9\text{mV}$ , or from 4.991 to 5.009V.



# **B** Calibration Reference

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## Introduction

This appendix contains detailed information on the various Model 2510 remote calibration commands, calibration error messages, and methods to detect the end of each calibration step.

Section 2 of this manual covers detailed calibration procedures.

## Command summary

Table B-1 summarizes Model 2510 calibration commands. These commands are covered in detail in the following paragraphs.

**Table B-1**  
*Calibration commands*

| Command                | Description   |
|------------------------|---|
| :CALibration           | Calibration subsystem.                                      |
| :PROTected             | Calibration commands protected by code/password.            |
| :CODE '<password>'     | Unlock calibration. (Default code/password: KI002510.)      |
| :CODE?                 | Query calibration code/password.                            |
| :SENSe                 |   |
| :VOLTage <NRf>         | Calibrate Peltier voltage measurement.                      |
| :DATA?                 | Query Peltier voltage calibration constants.                |
| :CURRent <NRf>         | Calibrate current measurement.                              |
| :DATA?                 | Query current calibration constants.                        |
| :TEMPerature <NRf>     | Calibrate temperature measurement.                          |
| :DATA?                 | Query temperature calibration constants.                    |
| :SOURce <NRf>          | Calibrate Peltier source/sense voltage.                     |
| :DATA?                 | Query Peltier source/sense calibration constants.           |
| :AUTO                  | Calibrate voltage source.                                   |
| :IPDac                 | Calibrate current protection DAC.                           |
| :DATA?                 | Query current protection DAC calibration constants.         |
| :RESistance            |   |
| [:AC] <NRf>            | Calibrate AC ohms.  |
| :DATA?                 | Query AC ohms calibration constants                         |
| :DATE <yyyy>,<mm>,<dd> | Program calibration year, month, day.                       |
| :DATE?                 | Query calibration date.                                     |
| :NDUE <yyyy>,<mm>,<dd> | Program calibration due year, month, day.                   |
| :NDUE?                 | Query calibration due date.                                 |
| :SAVE                  | Save calibration data in EEPROM.                            |
| :LOCK                  | Lock out calibration.                                       |
| :LOCK?                 | Query if calibration is locked. (1 = locked; 0 = unlocked). |
| :COUNT?                | Query number of times Model 2510 has been calibrated.       |

## Miscellaneous commands

Miscellaneous commands are those commands that perform such functions as unlocking calibration, saving calibration constants, locking out calibration, and programming date parameters.

### **:CODE**

(:CALibration:PROTECTED:CODE)

**Purpose** To unlock calibration so that you can perform the calibration procedures.

**Format** :cal:prot:code '<password>'

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

**Description** The :CODE command sends the password/code and enables calibration when performing these procedures via remote. The correct password must be sent to the unit before sending any other calibration command. The default remote password is KI002510.

- NOTE**
- *The :CODE command should be sent only once before performing calibration. Do not send :CODE before each calibration step.*
  - *To change the code, first send the present code, then send the new code.*
  - *The password parameter must be enclosed in single quotes.*
  - *If you change the first two characters of the password to something other than "KI", you will not be able to unlock calibration from the front panel.*

**Example** :CAL:PROT:CODE 'KI002510' Send default code of KI002510.

### **:COUNT?**

(:CALibration:PROTECTED:COUNT?)

**Purpose** To request the number of times the Model 2510 has been calibrated.

**Format** :cal:prot:count?

**Response** Number of times calibrated.

**Description** The :COUNT? query may be used to determine the total number of times the Model 2510 has been calibrated.

**Example** :CAL:PROT:COUNT? Request calibration count.

**:LOCK**

(:CALibration:PROTeCted:LOCK)

**Purpose** To lock out calibration.**Format** :cal:prot:lock**Query** :cal:prot:lock?**Response**  
0 Calibration unlocked  
1 Calibration locked**Description** The :LOCK command allows you to lock out calibration after completing the procedure. Thus, :LOCK performs the opposite of sending the password with the :CODE command. The :LOCK? query returns calibration lock status.**NOTE** To unlock calibration, send the :CODE command with the appropriate password.**Example** :CAL:PROT:LOCK Lock out calibration**:SAVE**

(:CALibration:PROTeCted:SAVE)

**Purpose** To save calibration constants in EEROM after the calibration procedure.**Format** :cal:prot:save**Description** The :SAVE command stores internally calculated calibration constants derived during comprehensive in EEROM. EEROM is non-volatile memory, and 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. Calibration data will not be saved if calibration was not unlocked by sending the :CODE command or if invalid calibration data exists.**Example** :CAL:PROT:SAVE Save calibration constants

**:DATE**

(:CALibration:PROTeCted:DATE)

**Purpose** To program the calibration date.**Format** :cal:prot:date <year>, <month>, <day>**Parameters** <year> = 2000 to 2099  
<month> = 1 to 12  
<day> = 1 to 31**Query** :cal:prot:date?**Response** <year>, <month>, <day>**Description** The :DATE command allows you to store the calibration date in instrument EEROM for future reference. You can read back the date from the instrument by using the :DATE? query, or by using the front panel CAL menu.*NOTE* The year, month, and day parameters must be delimited by commas.**Example** :CAL:PROT:DATE 2000,11,20 Send cal date (11/20/2000).**:NDUE**

(:CALibration:PROTeCted:NDUE)

**Purpose** To send the next calibration due date to the instrument.**Format** :cal:prot:ndue <year>, <month>, <day>**Parameters** <year> = 2000 to 2099  
<month> = 1 to 12  
<day> = 1 to 31**Query** :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 by using the :NDUE? query, or by using the front panel CAL menu.*NOTE* The next due date parameters must be delimited by commas.**Example** :CAL:PROT:NDUE 2001,11,20 Send due date (11/20/2001).

# SENSe commands

## :VOLTage

(:CALibration:PROTeCted:SENSe:VOLTage)

(:CALibration:PROTeCted:SENSe:VOLTage:DATA?)

**Purpose** To calibrate the Peltier voltage measurement.

**Format** :cal:prot:sens:volt <DMM\_Reading>

**Parameters** <DMM\_Reading> = 3.5 to 12.5[V] = cal at + F.S.  
 -2.5 to 2.5[V] = zero cal  
 -3.5 to -12.5[V] = cal at - F.S.

**Query** :cal:prot:sens:volt:data?

**Description** The :CAL:PROT:SENS:VOLT command calibrates the Model 2510 Peltier voltage measurement. During the calibration process, this command is sent three times; once each with parameters of approximately +F.S, 0, and -F.S. The actual parameters are voltage readings taken with a precision DMM. The :CAL:PROT:SENS:VOLT:DATA? query allows you to request the Peltier voltage calibration parameters.

**Example** :CAL:PROT:SENS:VOLT 8.51 Calibrate positive voltage.

## :CURRent

(:CALibration:PROTeCted:SENSe:CURRent)

(:CALibration:PROTeCted:SENSe:CURRent:DATA?)

**Purpose** To calibrate the current measurement.

**Format** :cal:prot:sens:curr <Resistor\_Value>

**Parameters** <Resistor\_Value> = 0.5 to 1.5[Ω]

**Query** :cal:prot:sens:curr:data?

**Description** The :CAL:PROT:SENS:CURR command calibrates the Model 2510 current measurement. During the calibration process, a 1Ω (nominal) resistor must be connected to the OUTPUT terminals, and the source is automatically set to +4.5V, 0V, and -4.5V. The command parameter is the characterized value of the 1Ω resistor.

The :CAL:PROT:SENS:CURR:DATA? query allows you request the current calibration parameters.

**Example** :CAL:PROT:SENS:CURR 1.01 Calibrate current.

**:TEMPerature**

(:CALibration:PROTeCted:SENSe:TEMPerature)

(:CALibration:PROTeCted:SENSe:TEMPerature:DATA?)

**Purpose** To calibrate the temperature sensor measurements.**Format** :cal:prot:sens:temp <Value>

**Parameters** <Resistor\_Value> = 100k $\Omega$  thermistor: 0 to 125e3[ $\Omega$ ]  
 10k $\Omega$  thermistor: 0 to 12.5e3[ $\Omega$ ]  
 1k $\Omega$  thermistor: 0 to 1.25e3[ $\Omega$ ]  
 100 $\Omega$  thermistor: 0 to 125[ $\Omega$ ]  
 100 $\Omega$  RTD: 0 to 125[ $\Omega$ ]  
 1000 $\frac{3}{4}$  RTD: 0 to 1250 [ $\frac{3}{4}$ ]  
 VSS: 0V to 5[V]  
 ISS: 350 to 1.25e3[ $\Omega$ ] then 0.01 to 1.5[V]

**Query** :cal:prot:sens:temp:data?

**Description** The :CAL:PROT:SENS:TEMP command calibrates the Model 2510 temperature sensor measurements. During the calibration process, a 100 $\Omega$ , 1k $\Omega$ , 10k $\Omega$ , or 100k $\Omega$  (nominal) resistor or a short must be connected to the INPUT terminals, and the characterized value, a zero value, or a voltage reading is sent as the command parameter, depending on the calibration step (see Section 2 for details). The appropriate sensor and range must first be selected with the following commands:

- Enable 4-wire sensing: :SYST:RSEN ON
- Thermistor sensor: :SENS:TEMP:TRAN THER
- Thermistor range: :SENS:TEMP:THER:RANG <Range>
- RTD sensor: :SENS:TEMP:TRAN RTD
- RTD range: :SENS:TEMP:RTD:RANG <Range>
- ISS sensor: :SENS:TEMP:TRAN ISS
- VSS sensor: :SENS:TEMP:TRAN VSS

The :CAL:PROT:SENS:TEMP:DATA? query allows you request the temperature sensor calibration parameters.

**Example** :CAL:PROT:SENS:TEMP 100.5 Calibrate temperature sensor.

# SOURce commands

## :SOURCE

(:CALibration:PROTected:SOURce)  
(:CALibration:PROTected:SOURce:DATA?)

**Purpose** To calibrate the Peltier source/sense voltage.

**Format** :cal:prot:sour <DMM\_Reading>

**Parameters** <DMM\_Reading> = 3.5 to 12.5[V] = cal at + F.S.  
-2.5 to 2.5[V] = zero cal  
-3.5 to -12.5[V] = cal at - F.S.

**Query** :cal:prot:sour:data?

**Description** The :CAL:PROT:SOUR command calibrates the Model 2510 Peltier source/sense voltage. During the calibration process, this command is sent three times; once each with parameters of approximately +F.S (full scale), 0, and -F.S. The actual parameters are voltage readings taken with a precision DMM.

The :CAL:PROT:SOUR:DATA? query allows you request the voltage calibration parameters.

**Example** :CAL:PROT:SOUR 8.51 Calibrate with positive voltage.

## :AUTO

(:CALibration:PROTected:SOURce:AUTO)

**Purpose** To calibrate the voltage source.

**Format** :cal:prot:sour:auto

**Description** The :CAL:PROT:SOUR:AUTO command calibrates the Model 2510 voltage source. Disconnect all test leads or equipment from the OUTPUT terminals before sending this command.

**Example** :CAL:PROT:SOUR:AUTO Calibrate voltage source.

## DAC commands

### :IPDac

(:CALibration:PROTected:IPDac)  
(:CALibration:PROTected:IPDac:DATA?)

|                    |   |                                   |
|--------------------|---|-----------------------------------|
| <b>Purpose</b>     | To calibrate the current protection DAC.  |                                   |
| <b>Format</b>      | :cal:prot:ipd   |                                   |
| <b>Query</b>       | :cal:prot:ipd:data?   |                                   |
| <b>Description</b> | The :CAL:PROT:IPD command calibrates the current protection DAC. A resistor of less than 1.5Ω must be connected to the OUTPUT terminals before this command is sent.<br>The :CAL:PROT:IPD:DATA? query allows you request the current protection DAC calibration parameters. |                                   |
| <b>Example</b>     | :CAL:PROT:IPD   | Calibrate current protection DAC. |

## RESistance commands

### :RESistance

(:CALibration:PROTected:RESistance[:AC])  
(:CALibration:PROTected:RESistance[:AC]:DATA?)

|                    |   |                                       |
|--------------------|---|---------------------------------------|
| <b>Purpose</b>     | To calibrate the AC ohms circuit.   |                                       |
| <b>Format</b>      | :cal:prot:res <Resistance_Value>  |                                       |
| <b>Parameters</b>  | <Resistance_Value> = 10 to 1e3 [Ω] (100 default)  |                                       |
| <b>Query</b>       | :cal:prot:res:data?   |                                       |
| <b>Description</b> | The :CAL:PROT:RES command calibrates the Model 2510 AC ohms circuit. A 10Ω to 1kΩ (100Ω preferred) resistor must be connected to the OUTPUT terminals, and the characterized value of that resistor is used as the :CAL:PROT:RES command parameter. The output is off.<br>The :CAL:PROT:RES:DATA? query requests the AC ohms calibration constants. |                                       |
| <b>Example</b>     | :CAL:PROT:RES 99.5  | Calibrate with 100Ω nominal resistor. |

## Detecting calibration errors

If an error occurs during any calibration step, the Model 2510 will generate an appropriate error message. Several methods to detect calibration errors are discussed below.

### Reading the error queue

As with other Model 2510 errors, any calibration errors will be reported in the error queue. (You can read the error queue by using the `:SYST:ERR?` query.)

### Error summary

Table B-2 summarizes calibration errors. If errors occur, and `:CAL:PROT:SAVE` is sent, calibration constants without errors will be saved while those with errors will not.

### 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 appropriate error query to read the error and at the same time clear the EAV bit in the status byte.

### Generating an SRQ on error

To program the instrument to generate an IEEE-488 bus SRQ (Service Request) when an error occurs, send the following command: `*SRE 4`. This command will enable SRQ when the EAV bit is set. You can then read the status byte and error queue as outlined above to check for errors and to determine the exact nature of the error.

**Table B-2**  
Calibration errors

| <b>Error number</b> | <b>Error message</b>               |
|---------------------|------------------------------------|
| +500                | “Date of calibration not set”      |
| +501                | “Next date of calibration not set” |
| +502                | “Calibration data invalid”         |
| +509                | “Not permitted with cal locked”    |
| +510                | “Not permitted with cal un-locked” |
| +520                | “Source + gain data invalid”       |
| +521                | “Source + offset data invalid”     |
| +522                | “Source - gain data invalid”       |
| +523                | “Source - offset data invalid”     |
| +524                | “Source DAC Overflow”              |
| +525                | “Source DAC Underflow”             |
| +530                | “I Protection gain data invalid”   |
| +531                | “I Protection offset data invalid” |
| +532                | “I Protection DAC Overflow”        |
| +533                | “I Protection DAC Underflow”       |
| +540                | “V Meas + gain data invalid”       |
| +541                | “V Meas + offset data invalid”     |
| +542                | “V Meas - gain data invalid”       |
| +543                | “V Meas - offset data invalid”     |
| +550                | “I Meas + gain data invalid”       |
| +551                | “I Meas + offset data invalid”     |
| +552                | “I Meas - gain data invalid”       |
| +553                | “I Meas - offset data invalid”     |
| +560                | “100 Ohm Thermistor data invalid”  |
| +561                | “1kOhm Thermistor data invalid”    |
| +562                | “10kOhm Thermistor data invalid”   |
| +563                | “100kOhm Thermistor data invalid”  |
| +564                | “RTD data invalid”                 |
| +565                | “VSS data invalid”                 |
| +566                | “ISS data invalid”                 |
| +570                | “AC Ohms data invalid”             |

## Detecting calibration step completion

When sending remote calibration commands, you must wait until the instrument completes the current operation before sending another command. You can use either `*OPC?` or `*OPC` to help determine when each calibration step is completed.

### Using the `*OPC?` query

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

1. Repeatedly test the MAV (Message Available) bit (bit 4) in the status byte and wait until it is set. (You can request the status byte by using the `*STB?` query.)
2. When MAV is set, a message is available in the output queue, and you can read the output queue and test for an ASCII 1.
3. After reading the output queue, repeatedly test MAV again until it clears. At this point, the calibration step is completed.

### Using the `*OPC` command

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

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

```
:CAL:PROT:SENS:VOLT 8;*OPC
```

Note that you must include the semicolon (;) to separate the two commands, and that the `*OPC` command must appear on the same line as the calibration command.

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

## Generating an SRQ on calibration complete

An IEEE-488 bus SRQ (service request) can be used to detect operation complete instead of repeatedly polling the Model 2510. To use this method, send both \*ESE 1 and \*SRE 32 to the instrument, then include the \*OPC command at the end of each calibration command line, as covered above. Clear the SRQ by querying the ESR (using the \*ESR? query) to clear OPC status, then request the status byte with the \*STB? query.

Refer to your controller's documentation for information on detecting and servicing SRQs.



C

# Calibration Program

---

## Introduction

This appendix includes a calibration program written in BASIC to help you to calibrate the Model 2510. Refer to Section 2 for more details on calibration procedures, equipment, and connections. Appendix B covers calibration commands in detail.

## Computer hardware requirements

The following computer hardware is required to run the calibration programs:

- IBM PC compatible computer.
- Keithley KPC-488.2, KPS-488.2, or KPC-488.2AT, or CEC PC-488 IEEE-488 interface for the computer.
- Two shielded IEEE-488 connecting cables (Keithley Model 7007).

## Software requirements

In order to use the calibration programs, you will need the following computer software:

- Microsoft QBasic (supplied with MS-DOS 5.0 or later) or Quick Basic.
- MS-DOS version 5.0 or later or Windows 95/98/Me.
- HP-style Universal Language Driver, CECHP.EXE (supplied with Keithley and CEC interface cards listed above).

## Calibration equipment

The following calibration equipment is required:

- Keithley Model 2002 DMM.
- 1 $\Omega$ , 100 $\Omega$ , 1k $\Omega$ , 10k $\Omega$ , and 100k $\Omega$  resistors.
- Clean copper wire.

See Section 2 for detailed equipment specifications.

---

## General program instructions

1. With the power off, connect the Model 2510 and the digital multimeter to the IEEE-488 interface of the computer. Be sure to use shielded IEEE-488 cables for bus connections.
2. Turn on the computer, the Model 2510, and the digital multimeter. Allow the Model 2510 and the multimeter to warm up for at least one hour before performing calibration.
3. Make sure the Model 2510 is set for a primary address of 15. (Use the front panel MENU/COMMUNICATIONS/GPIB selection to check or change the address.)
4. Make sure the digital multimeter primary address is set to 16.
5. Make sure that the computer bus driver software (CECHP.EXE) is properly initialized.
6. Enter the QBasic editor, and type in the program below.

**NOTE** *Be sure to change the resistor parameters (R\$, R\$(1) - R\$(4)) to the characterized values of the 1 $\Omega$ , 100 $\Omega$ , 1k $\Omega$ , 10k $\Omega$ , and 100k $\Omega$  resistors. (See Section 2 for details.)*

7. Check thoroughly for errors, then save it using a convenient filename.
8. Run the program, and follow the prompts on the screen to perform calibration. For test connections, refer to the following figures in Section 2:
  - Voltage calibration DMM connections: Figure 2-1.
  - Current and current protection calibration 1 $\Omega$  resistor connections: Figure 2-2.
  - Thermistor and RTD calibration 100 $\Omega$  to 100k $\Omega$  resistor connections: Figure 2-3.
  - Shorted INPUT connections: Figure 2-4.
  - I-SS and V-SS calibration resistor/DMM connections: Figure 2-5.
  - AC ohms calibration 100 $\Omega$  resistor connections: Figure 2-6.

**Program C-1 Model 2510 calibration program**

```

` Model 2510 calibration program for use with Keithley 2002 DMM.
` 2510 primary address = 15. 2002 primary address = 16.
OPEN "IEEE" FOR OUTPUT AS #1           ` Open IEEE-488 output path.
OPEN "IEEE" FOR INPUT AS #2           ` Open IEEE-488 input path.
PRINT #1, "INTERM CRLF"               ` Set input terminator.
PRINT #1, "OUTTERM LF"                ` Set output terminator.
PRINT #1, "REMOTE 15 16"              ` Put 2510, 2002 in remote.
PRINT #1, "OUTPUT 15;*RST"            ` Initialize 2510.
PRINT #1, "OUTPUT 15;*CLS"            ` Clear 2510 status.
PRINT #1, "OUTPUT 15;*ESE 1;*SRE 32"  ` Enable OPC and SRQ.
PRINT #1, "OUTPUT 16;:SYST:PRES"      ` Initialize 2002.
PRINT #1, "OUTPUT 16;:FORM:ELEM READ" ` 2002 reading data only.
`
` Replace nominal resistor values below with characterized values.
R$ = "1"                               ` 1 ohm value.
R$(1) = "100"                          ` 100 ohm value.
R$(2) = "1e3"                          ` 1k ohm value
R$(3) = "1e4"                          ` 10k ohm value.
R$(4) = "1e5"                          ` 100k ohm value.
`
CLS
PRINT "Model 2510 Calibration Program"
GOSUB KeyCheck
PRINT #1, "OUTPUT 15;:CAL:PROT:CODE `KI002510`"
J = 1
FOR I = 1 TO 46
READ Cmd$
SELECT CASE I
CASE 1
PRINT "Connect DMM INPUT to 2510 OUTPUT terminals."
GOSUB KeyCheck
CASE 3, 4, 6, 7, 9, 10, 39, 41
GOSUB ReadDMM
Cmd$ = Cmd$ + Reading$
CASE 12
PRINT "Connect 1 ohm resistor to OUTPUT terminals."
GOSUB KeyCheck
CASE 13
Cmd$ = Cmd$ + R$
CASE 19, 22, 25, 28, 32, 35
IF I = 32 THEN J = 1
PRINT "Connect "; R$(J); " ohm resistor to INPUT terminals."
GOSUB KeyCheck
Cmd$ = Cmd$ + R$(J)
J = J + 1

```



```

\
ErrCheck:                                ` Error check routine.
PRINT #1, "OUTPUT 15;:SYST:ERR?"        ` Query error queue.
PRINT #1, "ENTER 15"
INPUT #2, E, Err$
IF E <> 0 THEN PRINT Err$: GOTO ErrCheck' Display error.
RETURN
\
ReadDMM:                                  ` Get reading from DMM.
SLEEP 3
PRINT #1, "OUTPUT 16;:READ?"
PRINT #1, "ENTER 16"
INPUT #2, Reading$
RETURN
\
EndProg:                                  ` Close files, end program.
BEEP: PRINT "Calibration aborted."
PRINT #1, "OUTPUT 15;:CAL:PROT:LOCK"
PRINT #1, "OUTPUT 15;*RST"
PRINT #1, "LOCAL 15 16"
CLOSE
END
\
CmdList:                                  ` Calibration command list.
DATA ":OUTP ON",":SOUR:VOLT 8.5","CAL:PROT:SENS:VOLT ","CAL:PROT:SOUR "
DATA ":SOUR:VOLT 0","CAL:PROT:SENS:VOLT ","CAL:PROT:SOUR "
DATA ":SOUR:VOLT -8.5","CAL:PROT:SENS:VOLT ","CAL:PROT:SOUR ",":OUTP OFF"
DATA ":OUTP ON", "CAL:PROT:SENS:CURR ","CAL:PROT:IPD",":OUTP OFF"
DATA ":SYST:RSEN ON","SENS:TEMP:TRAN THER"
DATA ":SENS:TEMP:THER:RANG 100","CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP 0"
DATA ":SENS:TEMP:THER:RANG 1E3","CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP 0"
DATA ":SENS:TEMP:THER:RANG 1E4","CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP 0"
DATA ":SENS:TEMP:THER:RANG 1E5","CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP 0"
DATA ":SENS:TEMP:TRAN RTD","SENS:TEMP:RTD:RANG 100"
DATA ":CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP 0"
DATA ":SENS:TEMP:RTD:RANG 1E3","CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP 0"
DATA ":SENS:TEMP:TRAN ISS","CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP "
DATA ":SENS:TEMP:TRAN VSS","CAL:PROT:SENS:TEMP ","CAL:PROT:SENS:TEMP 0"
DATA ":CAL:PROT:RES ",":OUTP ON"
DATA ":CAL:PROT:SOUR:AUTO",":OUTP OFF"

```

---

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