KEITHLEY
A Tektronix Company

Model 7710 Multiplexer Module

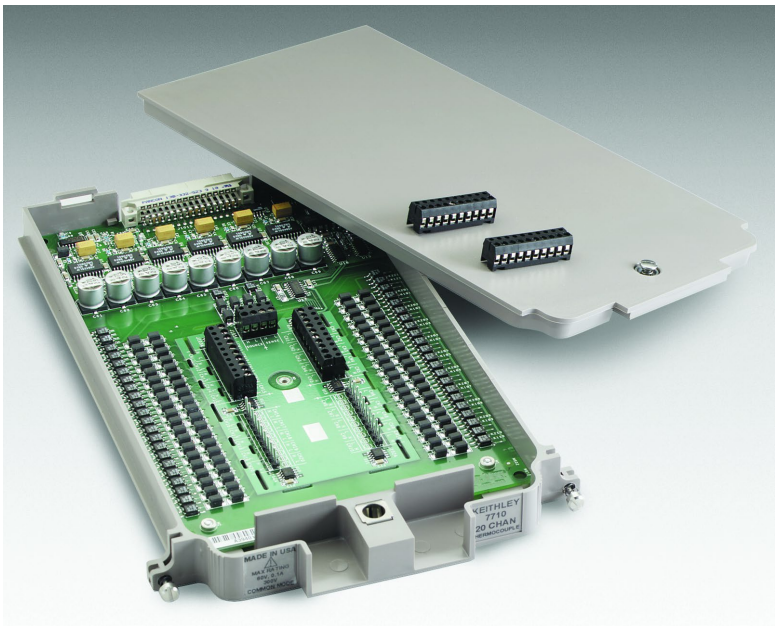
Instructions for use with the 2750

Keithley Instruments
28775 Aurora Road
Cleveland, Ohio 44139
1-800-833-9200
tek.com/keithley

Introduction

The 7710 20-channel Solid-state Differential Multiplexer with Automatic Cold Junction Compensation (CJC) module offers 20 channels of 2-pole or 10 channels of 4-pole relay input that can be configured as two independent banks of multiplexers. The relays are solid state, providing long life and low maintenance. It is ideal for long-term data logging applications and for demanding high-speed applications.

Figure 1: 7710 20-Channel Differential Multiplexer Module



Item shipped may vary from model pictured here.

The 7710 includes the following features:

- Fast-actuating, long-life solid-state relays
- DC and AC voltage measurement
- Two-wire or four-wire resistance measurements (automatically pairs relays for four-wire measurements)
- Temperature applications (RTD, thermistor, thermocouple)
- Built-in cold junction reference for thermocouple temperature
- Screw terminal connections

The Model 7710 will operate properly when installed in one of the following instruments:

- Model 2700 equipped with B05 (or later) firmware
- Model 2701 equipped with A01 (or later) firmware
- Model 2750 equipped with A04 (or later) firmware

NOTE

If you are using this switching module with the DAQ6510, see the *Model 7710 Multiplexer Card for use with the DAQ6510 User's Guide*, document number 0771451*xx*.

Connections

Screw terminals on the switching module are provided for connection to device under test (DUT) and external circuitry. The 7710 uses quick-disconnect terminal blocks. You can make connections to a terminal block when it is disconnected from the module. These terminal blocks are rated for 25 connects and disconnects.

WARNING

Connection and wiring procedures in this document are intended for use by qualified personnel only, as described by the types of product users in the Safety precautions (on page 19). Do not perform these procedures unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

The following information describes how to make connections to the switching module and define the channel designations. A connection log is provided that you can use to record your connections.

Wiring procedure

Use the following procedure to make connections to the 7710 module. Make all connections using the correct wire size (up to 20 AWG). For maximum system performance, all measurement cables should be less than three meters. Add supplementary insulation around the harness for voltages above 42 V_{PEAK}.

WARNING

All wiring must be rated for the maximum voltage in the system. For example, if 1000 V is applied to the front terminals of the instrument, the switching module wiring must be rated for 1000 V. Failure to recognize and observe normal safety precautions could result in personal injury or death.

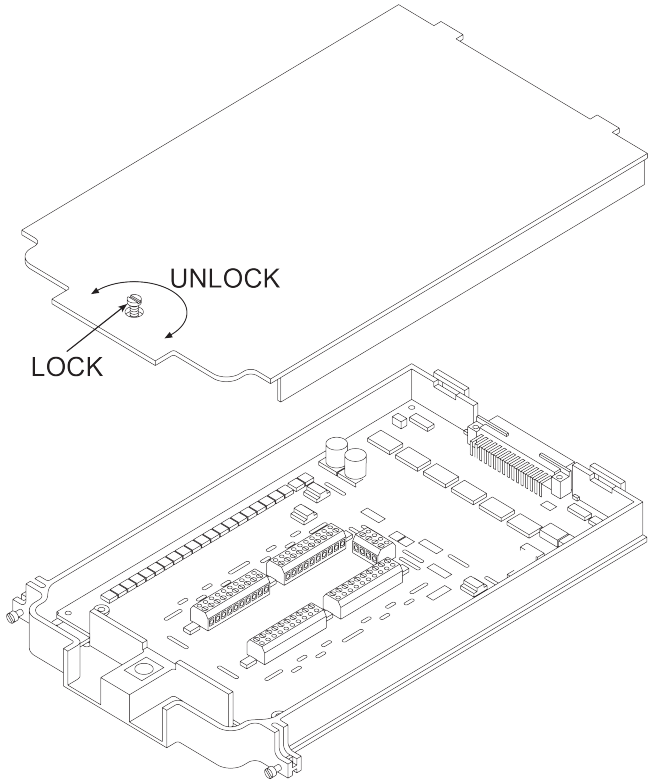
Equipment needed:

- Flat-blade screwdriver
- Needle-nose pliers
- Cable ties

To wire the 7710 module:

1. Make sure all power is discharged from the 7710 module.
2. Using a screwdriver, turn the access screw to unlock and open the cover, as shown in the following figure.

Figure 2: Screw terminal access

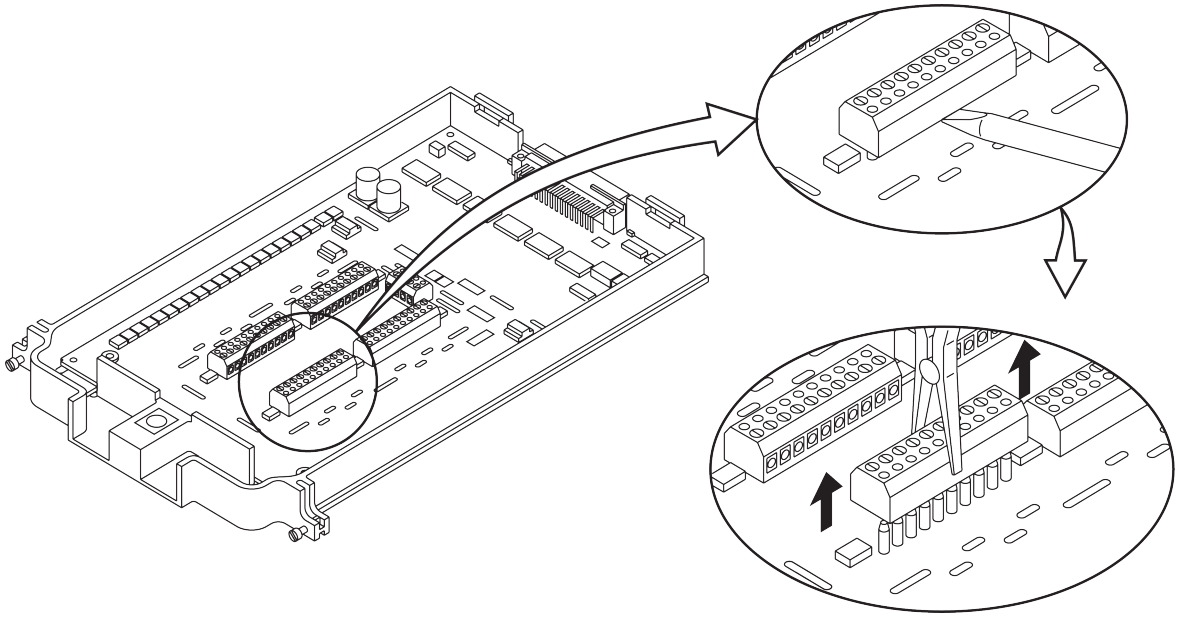


3. If needed, remove the appropriate quick-disconnect terminal block from the module.
   a. Place a flat-head screwdriver under the connector and gently push up to loosen it, as shown in the following figure.
   b. Use needle-nose pliers to pull the connector straight up.

CAUTION

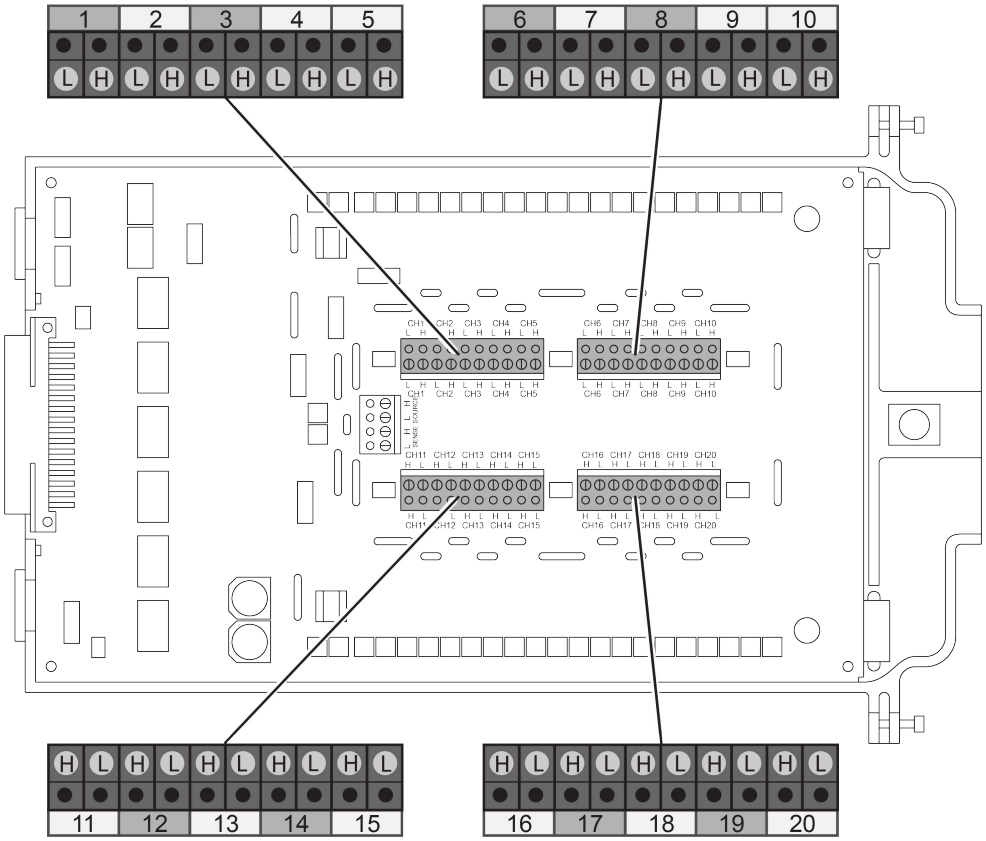
Do not rock the connector from side to side. Damage to the pins could result.

Figure 3: Proper procedure to remove terminal blocks



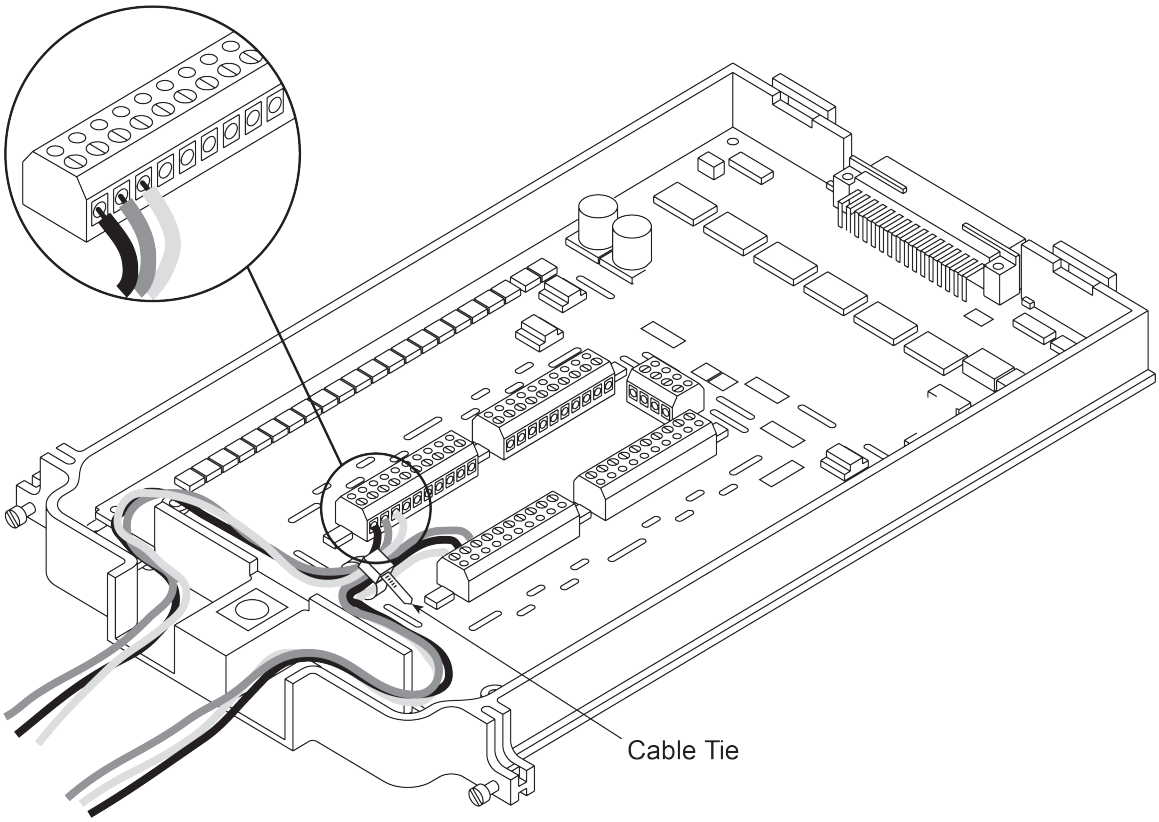
4. Using a small flat-blade screwdriver, loosen the terminal screws and install the wires as needed. The following figure shows the connections, including the connections to source and sense.

Figure 4: Screw terminal channel designations



5. Plug the terminal block into the module.
6. Route wire along the wire path and secure with cable ties as shown. The following figure shows connections to channels 1 and 2.

Figure 5: Wire dressing



7. Fill in a copy of the connection log. See Connection log (on page 8).
8. Close the screw terminal access cover.
9. Using a screwdriver, press in the access screw and turn to lock the cover.

Module configuration

The following figure shows a simplified schematic of the 7710 module. As shown, the 7710 has channels that are grouped into two banks of 10 channels (20 channels total). Backplane isolation is provided for each bank. Each bank includes separate cold junction reference points. The first bank contains channels 1 to 10, while the second bank contains channels 11 to 20. Each channel of the 20-channel multiplexer module is wired with separate inputs for HI/LO providing fully isolated inputs.

Connections to DMM functions are provided through the module backplane connector.

Channels 21, 22, and 23 are configured automatically by the instrument when using system channel operation.

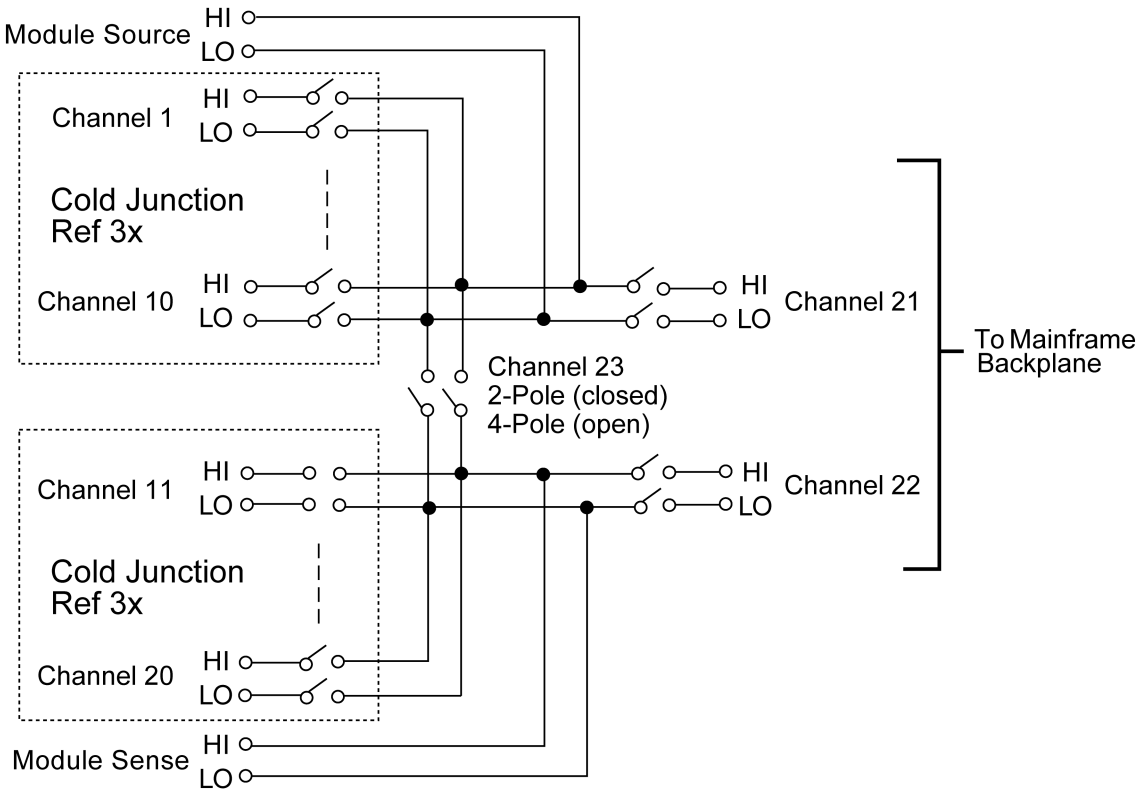
When using system channel operation for 4-wire measurements (including 4-wire ohms, RTD temperature, Ratio, and Channel Average), the channels are paired as follows:

CH1 and CH11	CH6 and CH16
CH2 and CH12	CH7 and CH17
CH3 and CH13	CH8 and CH18
CH4 and CH14	CH9 and CH19
CH5 and CH15	CH10 and CH20

NOTE

Channels 21 to 23 in this schematic refer to designations used for control and not actual available channels. For more information, refer to the instrument reference manual.

Figure 6: 7710 simplified schematic



Channels 21, 22, and 23 are configured automatically by the Model 2750 when using system channel operation. By using multiple channel operation, they can be manually configured.

For example, assume a 7710 module is installed in slot 1 of the mainframe and an external source is connected to Card Source input. To connect the source to channel 11 only, multiple channel operation must be used. For example:

```
ROUT:OPEN:ALL              'Open all channels.
ROUT:MULT:CLOS (@111,123)  'Close channels 11 and 23.
```

For this command sequence, the digital multimeter (DMM) of the 2750 is electrically isolated from the test circuit.

Refer to the *Model 2750 Reference Manual* for detail on multiple channel operation.

Typical connections

The following examples show typical wiring connections for the following types of measurements:

- Thermocouple
- Two-wire resistance and thermistor
- Four-wire resistance and RTD
- DC or AC voltage

Figure 7: Thermocouple connections

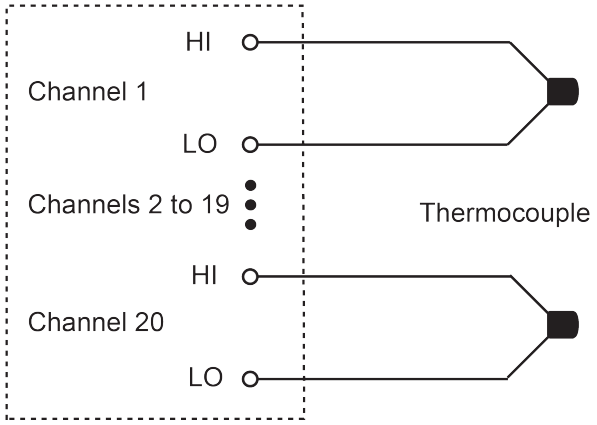


Figure 8: Two-wire resistance and thermistor connections

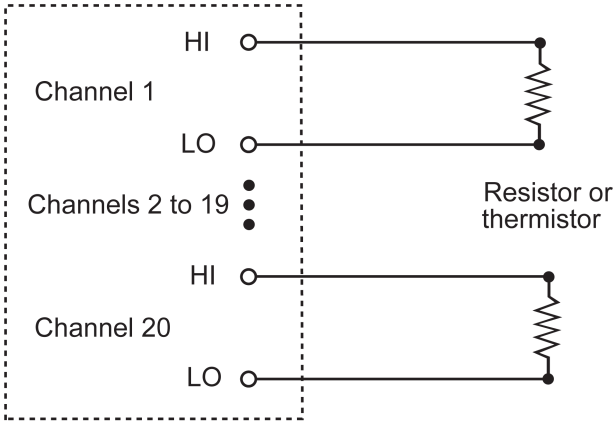


Figure 9: Four-wire resistance and RTD connections

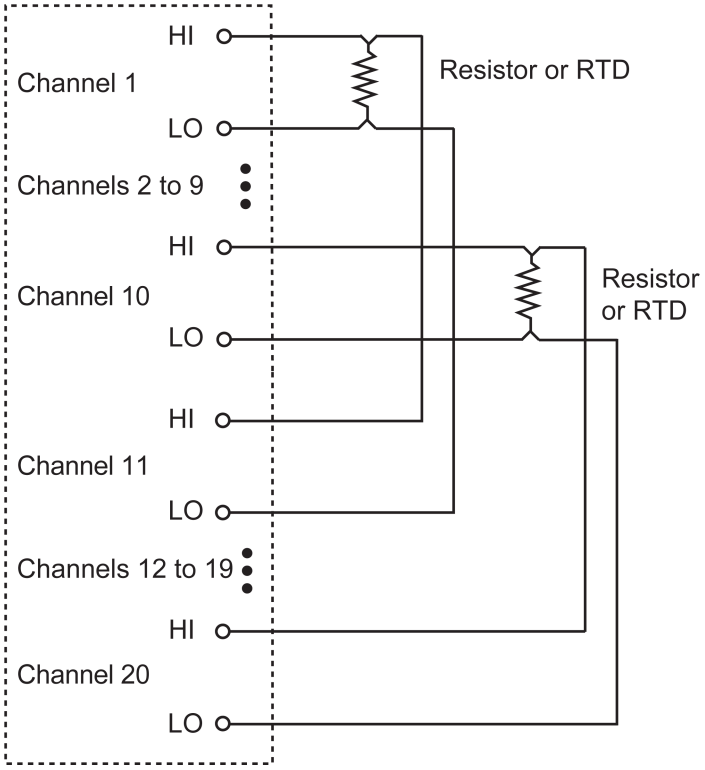
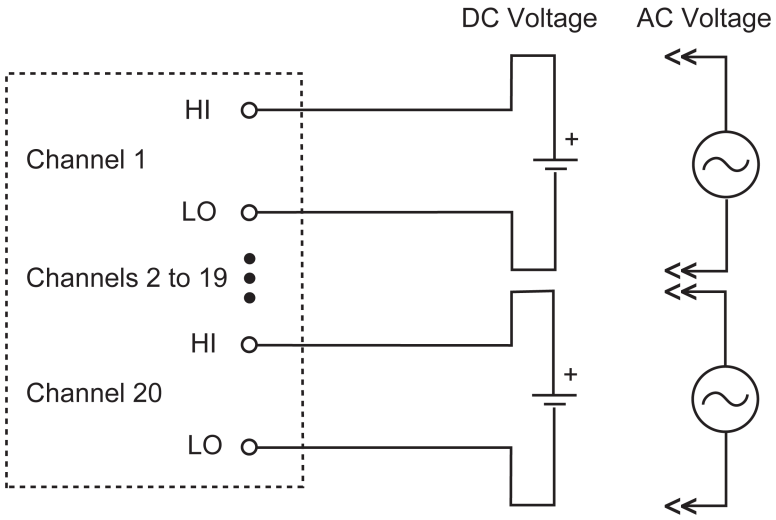


Figure 10: DC or AC voltage connections



Connection log

You can use the following table to record your connection information.

Connection log for the 7710

Channel		**Color**	**Description**
Card Source	H		
	L		
Card Sense	H		
	L		
CH1	H		
	L		
CH2	H		
	L		
CH3	H		
	L		
CH4	H		
	L		
CH5	H		
	L		
CH6	H		
	L		
CH7	H		
	L		
CH8	H		
	L		
CH9	H		
	L		
CH10	H		
	L		
CH11	H		
	L		
CH12	H		
	L		
CH13	H		
	L		
CH14	H		
	L		
CH15	H		
	L		
CH16	H		
	L		
CH17	H		
	L		
CH18	H		
	L		
CH19	H		
	L		
CH20	H		
	L		

Installation

⚠ WARNING

Before operating an instrument with a switching module, verify that the switching module is properly installed and the mounting screws are tightly fastened. If the mounting screws are not properly connected, an electrical shock hazard may be present.

NOTE

For inexperienced users, it is recommended that you do not connect a device under test (DUT) and external circuitry to the switching module. This allows you to exercise close and open operations without the dangers associated with live test circuits. You can also set up pseudocards to experiment with switching. Refer to “Pseudocards” in the *Model 2750 Reference Manual* for information on setting up pseudocards.

⚠ WARNING

To prevent electric shock that could result in injury or death, never handle a switching module that has power applied to it. Before installing or removing a switching module, make sure the instrument is turned off and disconnected from line power. If the switching module is connected to a DUT, make sure power is removed from all external circuitry.

⚠ WARNING

Slot covers must be installed on unused slots to prevent personal contact with high-voltage circuits. Failure to recognize and observe standard safety precautions could result in personal injury or death due to electric shock.

CAUTION

Before installing or removing a switching module, make sure the instrument power is turned off and disconnected from line power. Failure to comply may result in incorrect operation and loss of Model 7710 EPROM data.

Operation

CAUTION

To prevent overheating or damage to the 7710 switching module relays, never exceed the following maximum signal levels between any two inputs or chassis: Any channel to any channel (1 to 20): 60 V dc or 42 V_{RMS}, 100 mA switched, 6 W, 4.2 VA maximum.

WARNING

The system's maximum voltage, including other switch modules and front panel terminals, is limited to 60 V peak-to-peak AC or DC between any terminal and chassis, or any two terminals when the 7710 is installed. Exceeding these levels creates a shock hazard and could cause damage to the card. Refer to the specifications provided in the datasheet. Failure to recognize and observe normal safety precautions could result in personal injury or death.

WARNING

When a 7710 module is inserted into the 2750, it is connected to the front and rear inputs and the other modules in the system through the instrument backplane. To prevent damage the 7710 module and to prevent creation of a shock hazard, the entire test system and all of its inputs should be derated to 60 V DC (42 V_{RMS}). Failure to recognize and observe normal safety precautions could result in personal injury or death.

Refer to the instrument documentation for operating instructions.

The Model 7710 operates the same as the Model 7700 switching card with the following differences:

- The Model 7710 has no amps channel. The Model 7700 has two amps channels.
- The Model 7710 uses solid state optocoupled FET relays. Solid state relays provide longer relay life and are up to six times faster than the electromechanical types used in other switching modules.

Operating considerations

Low-ohms measurements

For resistances in the normal range (>100 Ω), the 2-wire method (Ω2) is typically used for ohms measurements. For low ohms (≤100 Ω), the signal path resistance in series with the DUT could be high enough to adversely affect the measurement. Therefore, the 4-wire method (Ω4) should be used for low-ohms measurements. The following discussion explains the limitations of the 2-wire method and the advantages of the 4-wire method.

Two-wire method

Resistance measurements in the normal range (>100 Ω) are generally made using the 2-wire method (Ω2 function). The test current is forced through the test leads and the resistance being measured (R_{DUT}). The meter then measures the voltage across the resistance value accordingly.

The main problem with the 2-wire method, as applied to low-resistance measurements is the test lead resistance (R_{LEAD}) and the channel resistance (R_{CH}). The sum of these resistances typically lies in the range of 1.5 to 2.5 Ω. Therefore, it is difficult to get accurate 2-wire ohms measurements below 100 Ω.

Due to this limitation, the 4-wire method should be used for resistance measurements ≤100 Ω.

Four-wire method

The 4-wire (Kelvin) connection method using the Ω4 function is generally preferred for low-ohms measurements. The 4-wire method cancels the effects of channel and test lead resistance.

With this configuration, the test current (I_{TEST}) is forced through the test resistance (R_{DUT}) through one set of test leads (R_{LEAD2} and R_{LEAD3}), while the voltage (V_M) across the device under test (DUT) is measured through a second set of leads (R_{LEAD1} and R_{LEAD4}) called the sense leads.

With this configuration, the resistance of the DUT is calculated as follows:

$R_{DUT} = V_M / I_{TEST}$

Where: I_{TEST} is the sourced test current and V_M is the measured voltage.

As shown in the figure in Maximum test lead resistance (on page 12), the measured voltage (V_M) is the difference between V_{SHI} and V_{SLO}. The equations below the figure show how test lead resistance and channel resistance are canceled out of the measurement process.

Maximum test lead resistance

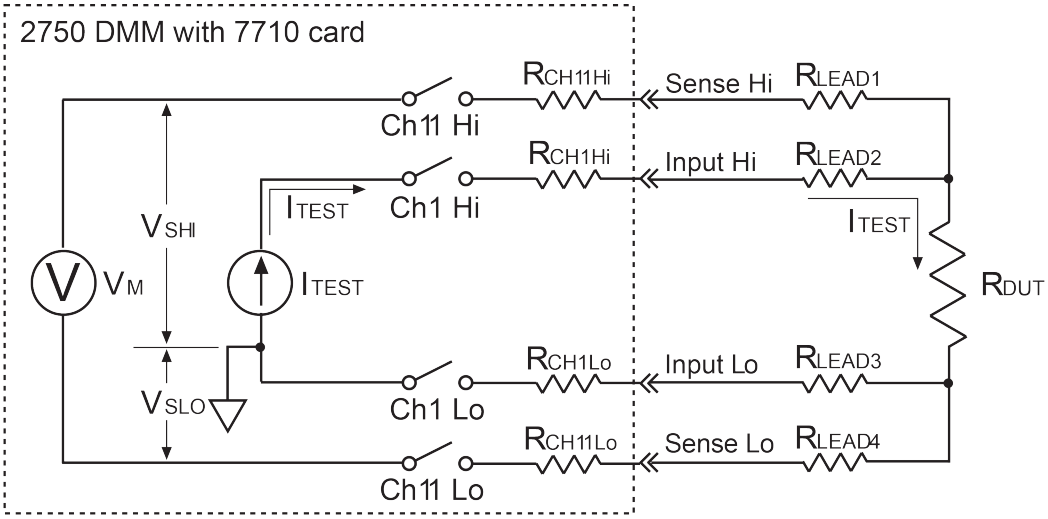
The following table lists the maximum test lead resistance (R_{LEAD}), plus the resistance of the DUT (R_{DUT}).

Maximum test lead resistance (Model 2750)

	Ω2		**Ω4**		**Ω4 dry circuit**	
Range	**R_{LEAD}**	**R_{DUT}**	**R_{LEAD}**	**R_{DUT}**	**R_{LEAD}**	**R_{DUT}**
1 Ω	Not applicable	Not applicable	0 Ω	1.2 Ω	Overflow	Overflow
10 Ω	0 Ω	2 Ω	0 Ω	7 Ω	3 Ω	12 Ω

Note that a larger test lead resistance can be tolerated with a smaller R_{DUT}. For example, R_{DUT} is 3 Ω on the 10 Ω range using the Ω4 function, the maximum test lead resistance (R_{LEAD}) can be 4 Ω.

Figure 11: Low-ohms measurements using the 4-wire method



Assumptions:

- Virtually no current flows in the high-impedance sense circuit because of the high impedance of the voltmeter (V_M). Therefore, the voltage drops across Channel 11 and test lead 1 and 4 are negligible and can be ignored.
- The voltage drops across Channel 1 Hi (R_{CH1Hi}) and test lead 2 (R_{LEAD2}) are not measured by the voltmeter (V_M).

$R_{DUT} = V_M/I_{TEST}$

Where:

- V_M is the voltage measured by the instrument.
- I_{TEST} is the constant current sourced by the instrument to the DUT.
- $V_M = V_{SHI} - V_{SLO}$
- $V_{SHI} = I_{TEST} \times (R_{DUT} + R_{LEAD3} + R_{CH1Lo})$
- $V_{SLO} = I_{TEST} \times (R_{LEAD3} + R_{CH1Lo})$
- $V_{SHI} - V_{SLO} = I_{TEST} \times [(R_{DUT} + R_{LEAD3} + R_{CH1Lo}) - (R_{LEAD3} + R_{CH1Lo})]$
- $= I_{TEST} \times R_{DUT}$
- $= V_M$

Voltage measurements

Path resistance can adversely affect low-ohms measurements (see Low-ohms measurements (on page 11) for more information). Series path resistance can cause loading problems for DC voltage measurements on the 100 V, 10 V, and 10 mV ranges when the 10 MΩ input divider is enabled.

High signal path resistance can also adversely affect AC voltage measurements on the 100 V range above 1 kHz.

Insertion loss

Insertion loss is AC signal power lost between the input and the output. In general, as frequency increases, insertion loss increases.

For the 7710 module, insertion loss is specified for a 50 Ω AC signal source routed through the module to a 50 Ω load. Signal power loss occurs as the signal is routed through the signal paths of the module to the load.

Insertion loss is expressed as dB magnitudes at specified frequencies. The specifications for insertion loss are provided in the data sheet.

As an example, assume the following specifications for insertion loss:

<1 dB @ 500 kHz 1 dB insertion loss is approximately 20% loss of signal power.

<3 dB @ 2 MHz 3 dB insertion loss is approximately 50% loss of signal power.

As signal frequency increases, power loss increases.

NOTE

The insertion loss values used in the above example may not be the actual insertion loss specifications of the 7710. The actual insertion loss specifications are provided in the datasheet.

Crosstalk

An AC signal can be induced into adjacent channel paths on the 7710 module. In general, crosstalk increases as frequency increases.

For the 7710 module, crosstalk is specified for an AC signal routed through the module to a 50 Ω load. Crosstalk is expressed as a dB magnitude at a specified frequency. The specification for crosstalk is provided in the datasheet.

As an example, assume the following specification for crosstalk:

<-40 dB @ 500 kHz -40 dB indicates that crosstalk into adjacent channels is 0.01% of the AC signal.

As signal frequency increases, crosstalk increases.

NOTE

The crosstalk values used in the above example may not be the actual crosstalk specification of the 7710. The actual crosstalk specification is provided in the datasheet.

Heat sink temperature measurements

Measuring the temperature of a heat sink is a typical test for a system that has temperature measurement capability. However, the 7710 module cannot be used if the heat sink is being floated at a dangerous voltage level (>60 V). An example of such a test is shown below.

In the following figure, the heat sink is floating at 120 V, which is the line voltage being input to a +5V regulator. The intention is to use channel 1 to measure the temperature of the heat sink, and use channel 2 to measure the +5 V output of the regulator. For optimum heat transfer, the thermocouple (TC) is placed in direct contact with the heat sink. This inadvertently connects the floating 120 V potential to the 7710 module. The result is 115 V between channel 1 and channel 2 HI, and 120 V between channel 1 and chassis. These levels exceed the 60 V limit of the module, creating a shock hazard and possibly causing damage to the module.

⚠ WARNING

The test in the following figure demonstrates how a dangerous voltage can unintentionally be applied to the 7710 module. In any test where floating voltages >60 V are present, you must be careful not to apply the floating voltage to the module. Failure to recognize and observe normal safety precautions could result in personal injury or death.

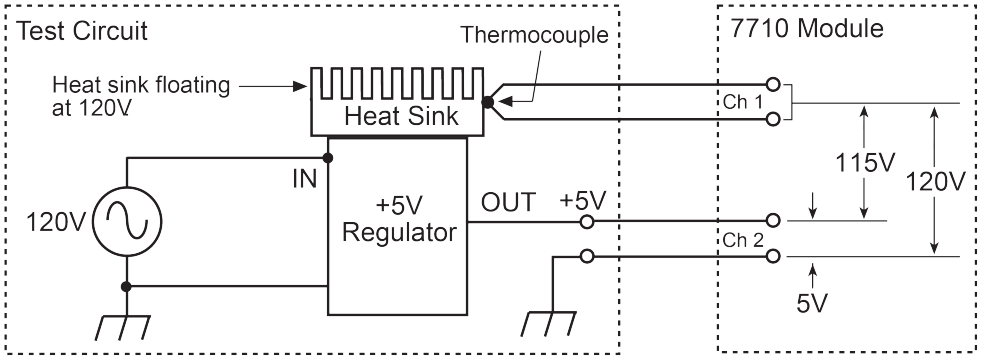
CAUTION

Do not use the 7710 module to perform this type of test. It exceeds the 60 V limit creating a shock hazard and could cause damage to the module. Excessive voltages:

The voltage differential between Ch 1 and Ch 2 HI is 115 V.

The voltage differential between Ch 1 and Ch 2 LO (chassis) is 120 V.

Figure 12: Example of an unsafe measurement practice



Ch 1 configured to measure TC temperature.
Ch 2 configured to measure 5 V regulator output.

Module handling precautions

The solid state relays used on the 7710 module are static sensitive devices. Therefore, they can be damaged by electrostatic discharge (ESD).

CAUTION

To prevent damage from ESD, only handle the module by the card edges. Do not touch the backplane connector terminals. When working with the quick-disconnect terminal blocks, do not touch any circuit board traces or other components. If working in a high-static environment, use a grounded wrist strap when wiring the module.

Touching a circuit board trace may contaminate it with body oils that can degrade the isolation resistance between circuit paths, adversely affecting measurements. It is good practice to handle a circuit board only by its edges.

Additional errors for 2750 switch systems

Refer to the *Model 2750 Specifications* for additional measurement errors and typical system scanning speeds. These measurement errors are to be added to the specifications of the Model 2750 used in the switch system.

See the “DC characteristics” section of the specifications for additional errors for high-ohms resistance measurements, voltage measurements, and temperature measurements.

Also see the specifications for the speed data when scanning.

Fast scanning

The 7710 module achieves fast scanning is achieved because of its high-speed solid-state FET relays.

To achieve the fastest scan possible, use the following Model 2750 mainframe settings for the scan:

```
VOLT:AVER:STAT OFF          ' Disables filtering.
VOLT:DIG 4                  ' Sets display resolution to 4.5 digits.
VOLT:NPLC 0.01              ' Sets reading rate.
SYST:AZER:STAT OFF          ' Disables auto-zero.
SYST:LSYN OFF               ' Disables line synchronization.
TRIG:DEL 0                  ' Sets trigger delay to 0 seconds.
FORM:DATA ASCII             ' Formats data as an ASCII string (N/A for 2701).
FORM:ELEM READ              ' Returns each reading with units only.
CALC3:OUTP OFF              ' Disables limit outputs.
CALC3:LIM1:STAT OFF         ' Disables limit 1 test.
DISP:ENAB OFF               ' Turns off display.
```

When finished with the scan, the display can be turned back on with the following command:

```
DISP:ENAB ON                ' Turns on display.
```

Calibration

The following procedures calibrate the temperature sensors on the 7710 plug-in modules.

WARNING

Do not attempt to perform this procedure unless you are qualified, as described by the types of product users in the Safety precautions. Do not perform these procedures unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

Calibration setup

To calibrate the module, you need the following equipment.

- Digital thermometer: 18 °C to 28 °C ±0.1 °C
- Keithley 7797 Calibration/Extender Board

Extender board connections

The extender board is installed in the 2750 for calibration. The module is connected to the extender board externally to prevent heating of the module during calibration.

To make extender board connections:

1. Remove power from the 2750.
2. Install the extender board into slot 1 of the instrument.
3. Plug the module into the P1000 connector on the rear of the 7797 Calibration/Extender Board.

Calibration

Before calibrating the temperature on the 7710, remove power the module for at least two hours to allow module circuitry to cool down. After turning on the power during the calibration procedure, complete the procedure as quickly as possible to minimize module heating that could affect calibration accuracy. Initially allow the 2750 to warm up for at least one hour with the 7797 calibration card installed. If calibrating multiple modules in a row, power off the 2750, quickly unplug the previously calibrated 7710, and plug in the next one. Wait three minutes before calibrating the 7710.

Calibration using the front panel

To calibrate the 7710 using the front panel:

1. Connect the Model 7710 to the Model 7797 Calibration/Extender Board. Refer to Extender board connections (on page 17) for instruction.
2. Select the rear inputs with the **INPUTS** switch. Allow three minutes for thermal equilibrium.
3. Accurately measure and record the cold temperature of the Model 7710 card surface at the center of the card with a digital thermometer.
4. Press in and hold the Model 2750 **OPEN** key while turning on the power.
5. Press **SHIFT** then **TEST**, and then display `TEST:CALIB` with the up or down range key. Press **ENTER**, select `RUN`, and then enter the appropriate calibration code (the default is 0027xx).
6. With `NEW CODE?` displayed, use the up or down range key to display `N`, and then press **ENTER**.
7. Using the up or down range key, select `CARD` at the `CAL:RUN` prompt, and then press **ENTER**.
8. Set the display value to the cold calibration temperature (°C) you measured in step 3, then press **ENTER** to complete Model 7710 calibration.

Calibration using remote commands

To calibrate the 7710 using remote commands:

1. Connect the Model 7710 to the Model 7797 Calibration/Extender Board. Refer to Extender board connections (on page 17) for instruction.
2. Select the rear inputs with the INPUTS switch. Allow three minutes for thermal equilibrium.
3. Accurately measure and record the cold temperature of the Model 7710 card surface at the center of the card with a digital thermometer.
4. Press in and hold the Model 2750 **OPEN** key while turning on the power.
5. Enable calibration by sending the `:CODE` command. For example, the default command is:
   ```
   CAL:PROT:CODE 'KI0027xx'
   ```
6. Initiate calibration by sending the following command:
   ```
   CAL:PROT:CARD1:INIT
   ```
7. Calibrate the Model 7710 with the following command:
   ```
   CAL:PROT:CARD1:STEP0 <temp>
   ```
   Where `<temp>` is the cold calibration temperature (˚C) measured in Step 3.
8. Send the following commands to save calibration and lock out calibration:
   ```
   CAL:PROT:CARD1:SAVE
   CAL:PROT:CARD1:LOCK
   ```

Factory service

To return your 2750 for repair or calibration, call 1-800-408-8165 or complete the form at tek.com/services/repair/rma-request. When you request service, you need the serial number and firmware or software version of the instrument.

To see the service status of your instrument or to create an on-demand price estimate, go to tek.com/service-quote.

Safety precautions

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

This product is intended for use by personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

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

The types of product users are:

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

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

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

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

Keithley products are designed for use with electrical signals that are measurement, control, and data I/O connections, with low transient overvoltages, and must not be directly connected to mains voltage or to voltage sources with high transient overvoltages. Measurement Category II (as referenced in IEC 60664) connections require protection for high transient overvoltages often associated with local AC mains connections. Certain Keithley measuring instruments may be connected to mains. These instruments will be marked as category II or higher.

Unless explicitly allowed in the specifications, operating manual, and instrument labels, do not connect any instrument to mains.

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 30 V RMS, 42.4 V peak, or 60 VDC 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 V, no conductive part of the circuit may be exposed.

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

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

For safety, instruments and accessories must be used in accordance with the operating instructions. If the instruments or accessories are used in a manner not specified in the operating instructions, the protection provided by the equipment may be impaired.

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

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

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

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

The **CAUTION** heading with the  symbol in the user documentation explains hazards that could result in moderate or minor injury or damage the instrument. Always read the associated information very carefully before performing the indicated procedure. Damage to the instrument 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. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. The detachable mains power cord provided with the instrument may only be replaced with a similarly rated power cord. 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 to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call a Keithley office for information.

Unless otherwise noted in product-specific literature, Keithley instruments are designed to operate indoors only, in the following environment: Altitude at or below 2,000 m (6,562 ft); temperature 0 °C to 50 °C (32 °F to 122 °F); and pollution degree 1 or 2.

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

Safety precaution revision as of June 2018.