

# Model 2001-TCSCAN Scanner Card for use with the DMM6500

## User's Manual

2001-TCSCAN-900-01 Rev. A / April 2018



2001-TCSCAN-900-01A

# Model 2001-TCSCAN

## Scanner Card

## User's Manual

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Cleveland, Ohio, U.S.A.

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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 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.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

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

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

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


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.

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


Chassis connections must only be used as shield connections for measuring circuits, NOT as protective earth (safety 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 protective earth (safety ground) using the wire recommended in the user documentation.

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

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


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

The  symbol indicates a connection terminal to the equipment frame.

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

The **WARNING** heading in the user documentation explains 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 2017.

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## General information

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## Introduction

The 2001-TCSCAN scanner card is designed for use in a digital multimeter (DMM) to make accurate, multi-channel thermocouple measurements. The 2001-TCSCAN can also be used for multiple nine-channel, mixed-signal switching applications. The 500 nV - 125 V signal voltage range allows for both low and high signal levels.

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### NOTE

If you are using this scanner card with the 2700, 2701, or 2750, please see the Model 2001 scanner card Instruction Manual.

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## Features

The 2001-TCSCAN is a scanner card designed to be installed in the DMM6500 6½ Digit Graphical Sampling Multimeter. Features of the card include:

- Built-in reference junction (channel 1)
- Low contact potential and offset current
- Input connectors are in contact with an isothermal block to minimize temperature differences
- Nine channels of 2-pole relay input
- Four channel pairs configurable for 4-pole operation
- The capability to multiplex one of nine 2-pole or one of four 4-pole channels into the DMM

## Unpacking and inspection

### Inspecting for damage

The 2001-TCSCAN is packaged in a resealable, anti-static bag to protect from damage due to static discharge and contamination that could degrade its performance. Before removing the card from the bag, observe the following handling precautions.

## Handling precautions

- Always grasp the card by the side edges and covers. Do not touch the board surfaces or components.
- When the card is not installed in a multimeter, keep the card in the anti-static bag and store it in the original packing carton.
- After removing the card from its anti-static bag, inspect it for any obvious signs of physical damage. Report any such damage to the shipping agent immediately.

## Factory service

To return the scanner card to Keithley Instruments for repair:

- Call the Repair Department at 1-800-833-9200 or send an email to [RMAREQUEST@tektronix.com](mailto:RMAREQUEST@tektronix.com) for a Return Material Authorization (RMA) number.
- Carefully pack the instrument in the original packing carton.
- Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label.



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# Card connectors and installation

### In this section:

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## Introduction

This section includes information on making connections to the 2001-TCSCAN Thermocouple General Purpose Scanner Card and installing the scanner card in a DMM6500.

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### **WARNING**

**The information in this topic is intended only for qualified service personnel. Some of the procedures may expose you to hazardous voltages that could result in personal injury or death. Do not attempt to perform these procedures unless you are qualified to do so.**

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## Installation handling precautions

To maintain high-impedance isolation between channels, avoid contamination from foreign materials as body oils when handling the scanner card. Contamination can substantially lower leakage resistances, degrading card performance. To avoid possible contamination, always hold the scanner card by the side edges or covers. Do not touch board surfaces, components, or areas adjacent to electrical contacts.

Dirt build-up over a period of time is another possible source of contamination. To avoid this problem, operate the multimeter and scanner card in a clean environment.

## Board cleaning

The circuit board should be thoroughly cleaned with pure water after soldering to remove all contaminants. After cleaning with water, swab the area with pure methanol and allow the board to dry for several hours in a 50 °C environment before use.

## Connections

This section provides the information necessary to connect your thermocouples or other external test circuitry to the scanner card.

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### CAUTION

Failure to observe the following precautions may result in degraded card performance.

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## Connection precautions

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### WARNING

Connection and wiring procedures in this document are intended for use by qualified personnel only. 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.

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### WARNING

Do not attempt to perform this procedure unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

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### WARNING

Do not exceed the maximum specifications for the 2001-TCSCAN Thermocouple General Purpose Scanner Card. Refer to the specifications provided in the data sheet. Failure to recognize and observe normal safety precautions could result in personal injury or death.

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### WARNING

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, scanner cards are Installation Category I and must not be connected to mains.

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### WARNING

To prevent electric shock that could result in serious injury or death, make sure the DMM power is turned off and power is removed from all external circuitry before making or breaking connections to the scanner card.

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## Card configurations

The following figure shows a simplified schematic of the 2001-TCSCAN. The scanner card has nine input channels and two output channels. Channel 1 is the reference junction for thermocouple temperature measurements.

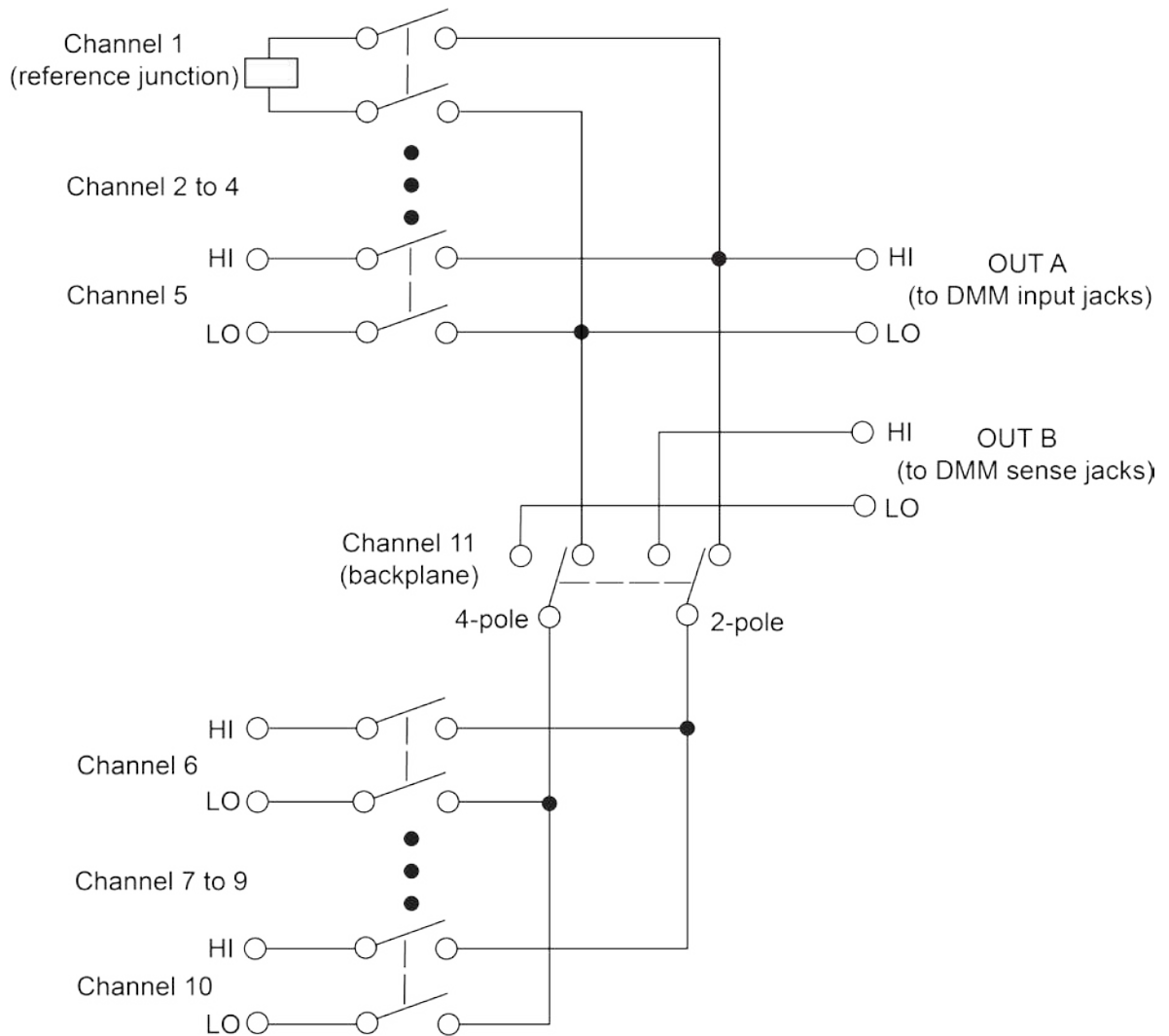
Four-pole paired channels are as follows:

- Channels 2 and 7
- Channels 3 and 8
- Channels 4 and 9
- Channels 5 and 10

### CAUTION

**Do not attempt to pair channels 1 and 6. If a signal is applied to channel 6 when channels 1 and 6 are paired, you may cause damage to the reference junction.**

Figure 1: Simplified schematic



## Card connectors

The following figure shows the input and output connectors for the 2001-TCSCAN. Card connections include:

- CH 2 to 10 (channels 2 to 10): HI and LO input terminals are provided for each of the nine channels on the card.

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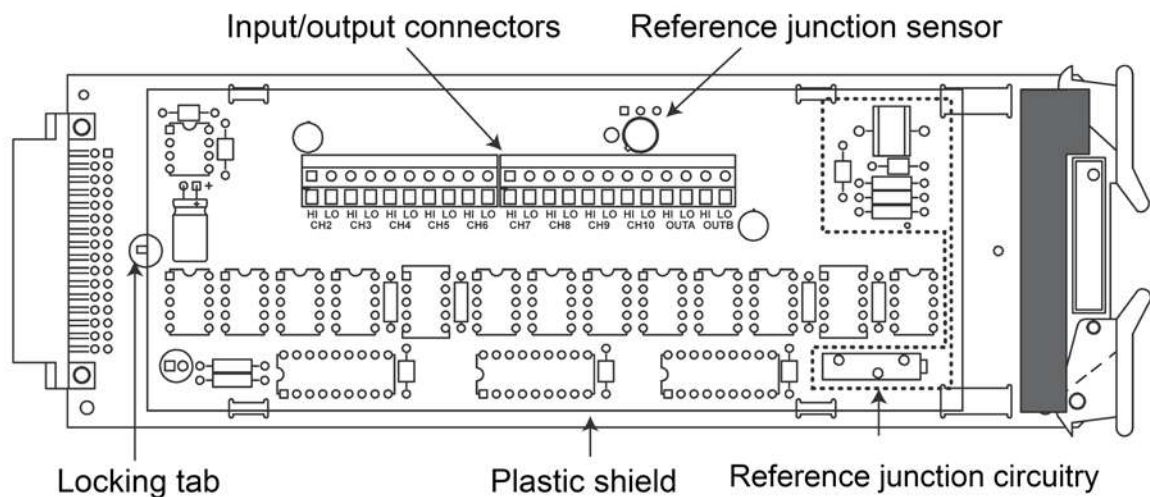
### NOTE

Channels 5 and 10 have current-limiting resistors installed. Path resistance for these two channels is approximately 240  $\Omega$ .

- OUT A: HI and LO output connections for all nine channels in the 2-pole mode or channels 2 to 5 in 4-pole mode.
- OUT B: HI and LO output connections for channels 7 to 10 in 4-pole mode.

To access the connections, open the plastic shield by pressing on the locking tab. Swing the shield away from the circuit board.

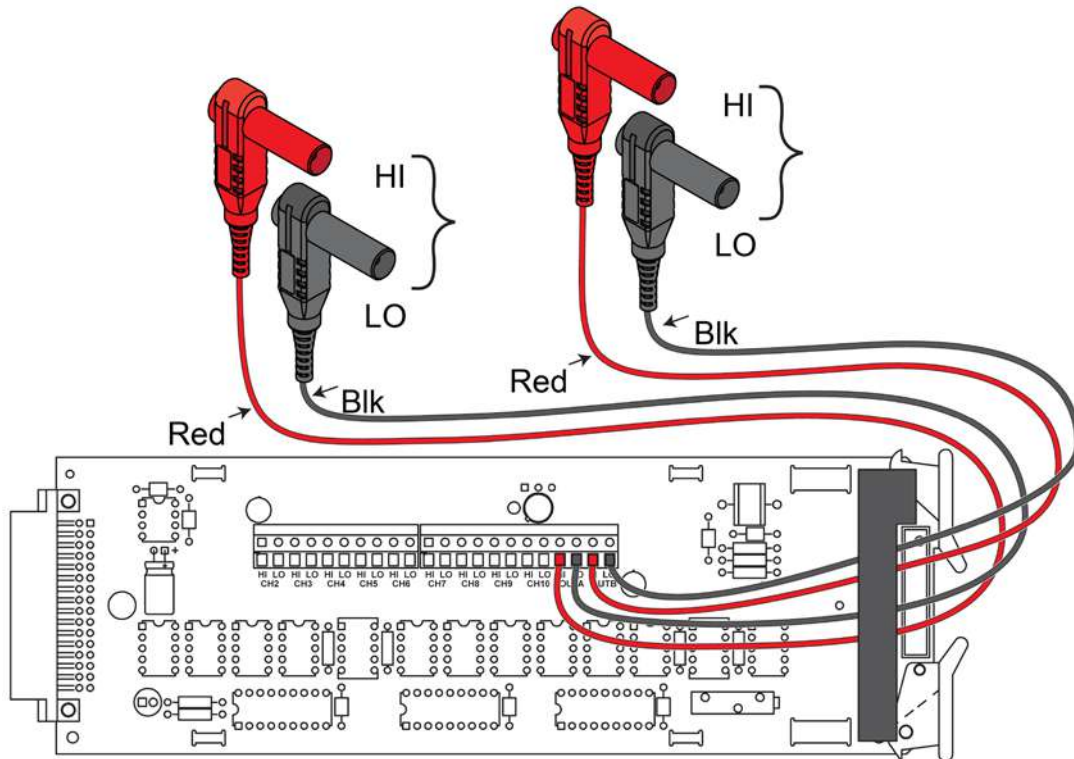
**Figure 2: Card connectors**



## Output connections

Use the supplied test leads for scanner output connections. Connect the red leads to the output (OUT A and OUT B) HI terminals, and connect the black leads to the output LO terminals. See the following figure for details. Dress the output test leads through the cable clamp, as described in Dressing leads. After all wires are connected and secure, close the plastic shield, and secure it with the locking tab.

Figure 3: Output connections



Note: OUT B connections are not required for 2-pole operation. The plastic shield is not shown.

## Wiring procedures

### **⚠ WARNING**

Before connecting or disconnecting wires, all power must be off and stored energy in external circuitry discharged.

### **CAUTION**

Mechanical shock may open or close latching relays on the scanner card. Before enabling any external sources, open all relays by inserting the 2001-TCSCAN into the multimeter and turning on the power.

*To wire the circuitry to the screw terminals on the scanner card:*

1. To access the connectors, open the plastic shield.
2. Strip approximately 7.93 mm (5/16 in.) of insulation from the end of each wire.
3. Twist the strands of the wire together.

### **NOTE**

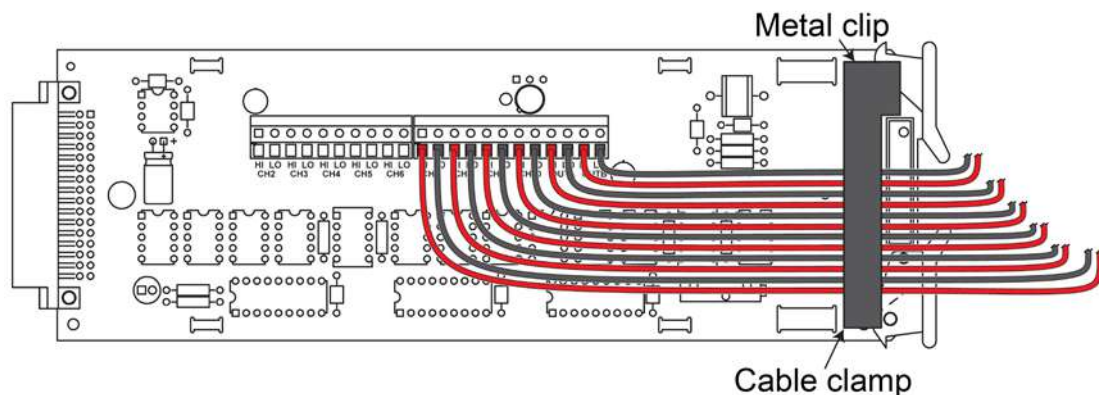
#22 AWG stranded wire is recommended for scanner card connections.

4. Loosen the screw terminal.
5. Insert the wire into the access hole.
6. While holding the wire in place, tighten the connector screw securely.
7. Repeat the above steps until all wires are connected.
8. Dress input wires through the cable clamp.

## Dressing leads

After the wires are connected to the terminal blocks, they should be dressed through the cable clamp as shown in the figure below. Unlatch the clip that holds the cable clamp together, then route all wires flat against the lower half of the clamp. Clamp the wires down, then secure the clamp with the unlatched metal clip.

**Figure 4: Routing wires through a cable clamp**



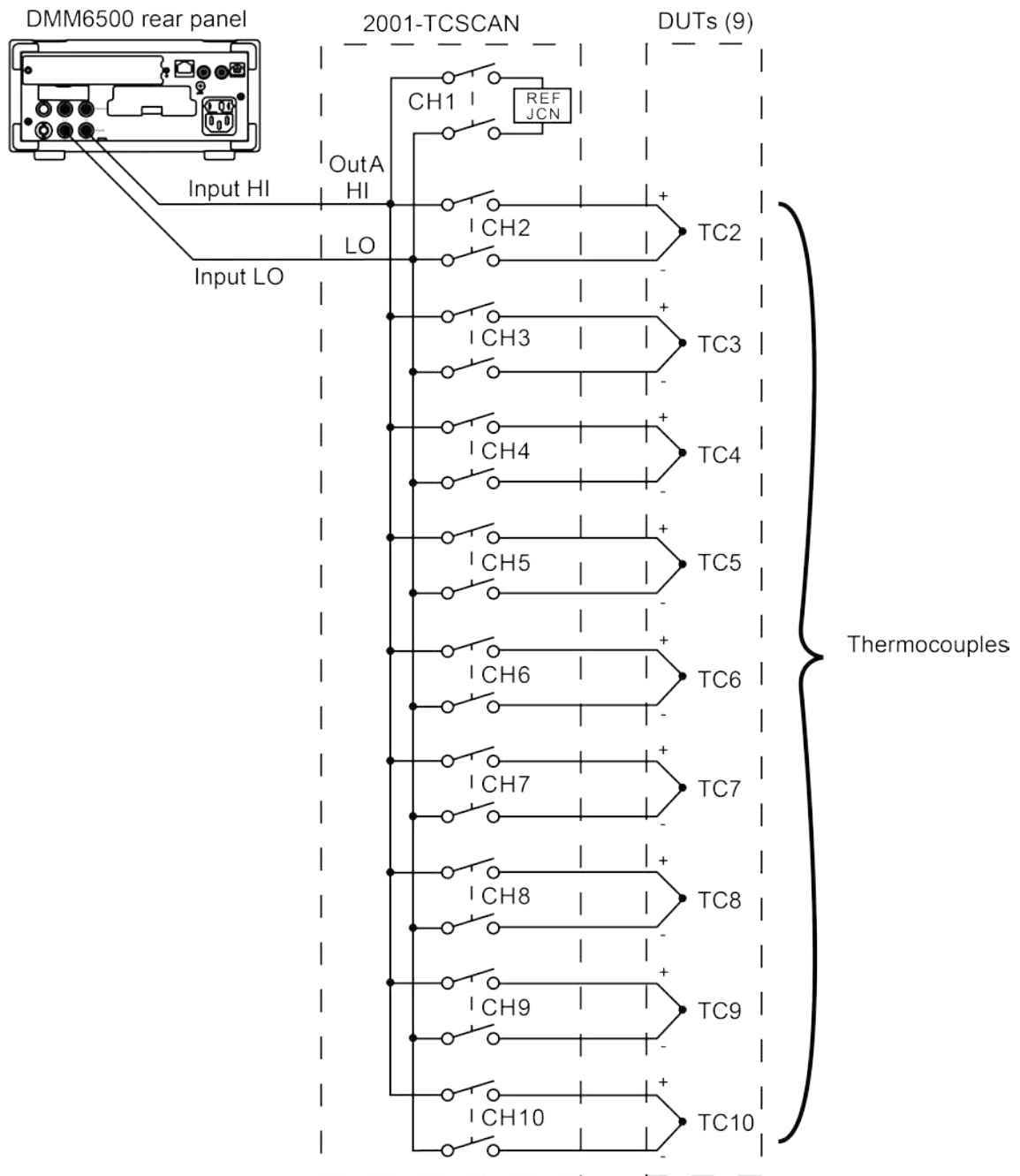
## Typical connecting schemes

This section discusses typical connections for the scanner card.

### Thermocouple connections

The figure below shows typical thermocouple connections. Note that thermocouples are connected to channels 2-10, and the output connections are taken from the OUT A terminals.

**Figure 5: Typical connections for thermocouple scanning**



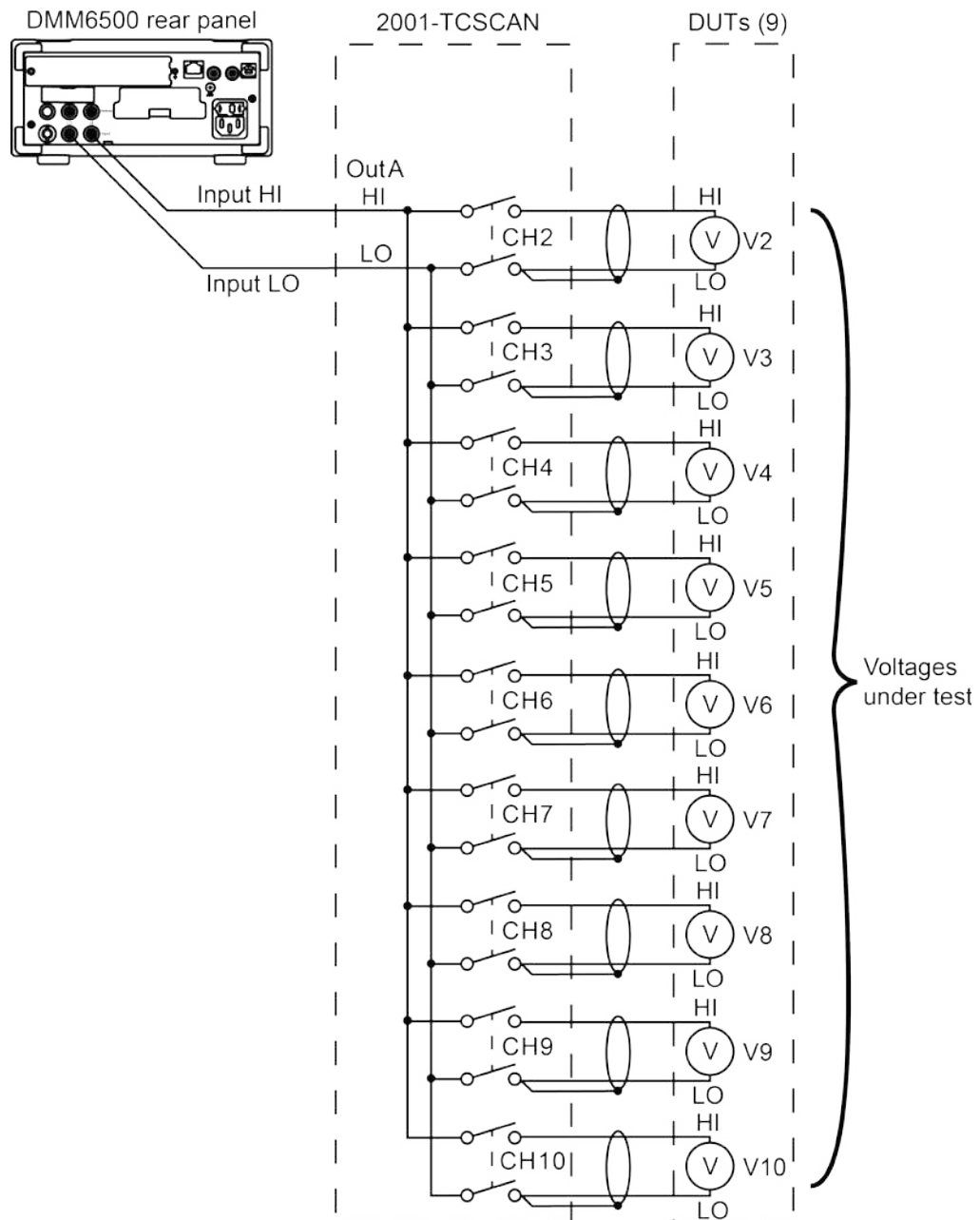
## Voltage connections

The following figure shows typical connections for voltage measurements. Note that up to nine voltage sources can be switched with this configuration. This basic configuration can be for the following measurement types:

- DCV
- ACV
- Frequency

Channels 2-10 can be used with this configuration.

**Figure 6: Connections for voltage scanning**





## Resistance connections

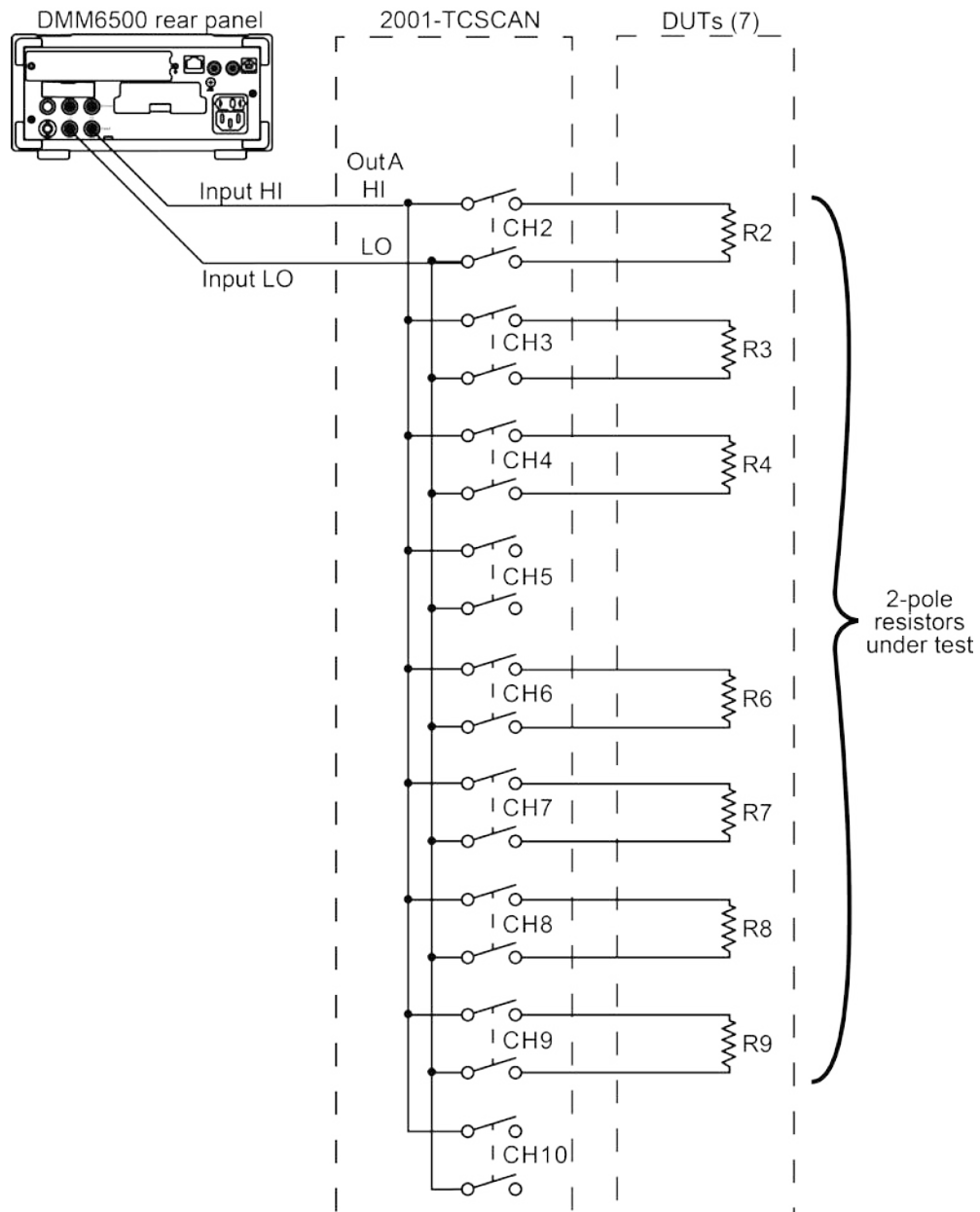
### Two-pole resistance connections

The following figure shows typical 2-pole resistor test connections. The 2-pole resistance configuration can be used to test up to seven devices under test (DUTs).

### NOTE

Channels 5 and 10 should not be used to switch resistance measurements because of the high path resistance (approximately 240 Ω) of these two channels due to the factory-installed, current-limiting resistors.

**Figure 7: Typical connections for 2-wire resistance scanning**

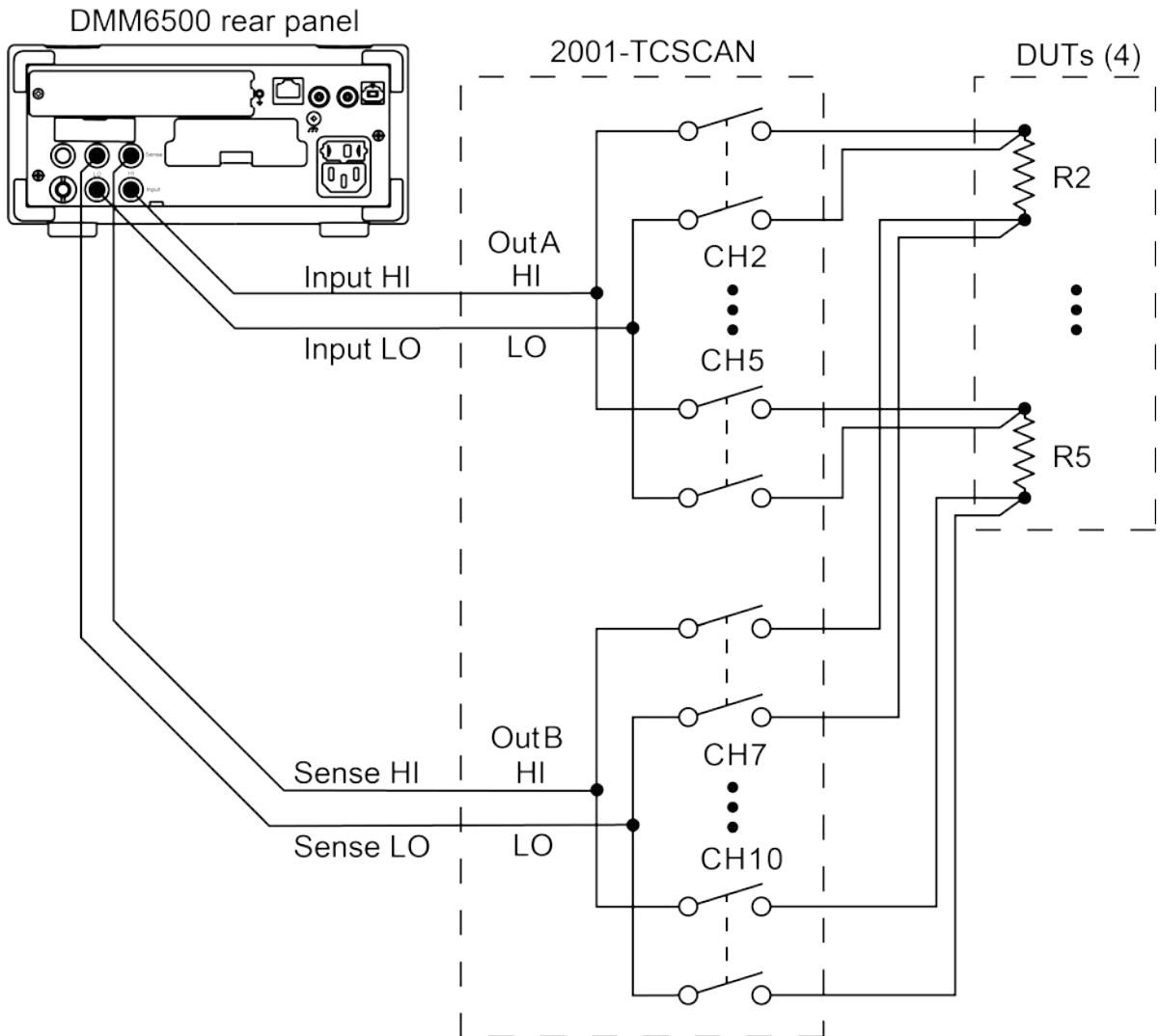


### Four-pole connections

The following figure shows a typical 4-pole resistance connection. This configuration can be used with channel pairs 2 to 5 and 7 to 10 in order to scan:

- Four-wire resistance measurements.
- Four-wire RTD temperature measurements.

**Figure 8: Typical connections for 4-wire resistance scanning**



## Card installation and removal

This section explains how to install and remove the 2001-TCSCAN scanner card from the DMM6500. All wiring connections must be complete before installing the 2001-TCSCAN.

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### **⚠ WARNING**

The information in this topic is intended only for qualified service personnel. Some of the procedures may expose you to hazardous voltages that could result in personal injury or death. Do not attempt to perform these procedures unless you are qualified to do so.

---

### **⚠ WARNING**

To prevent electric shock that could result in injury or death, never handle a scanner card that has power applied to it. Before installing or removing a scanner card, make sure the 2001-TCSCAN is turned off and disconnected from line power. If the scanner card is connected to a DUT, make sure power is removed from all external circuitry.

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### **⚠ WARNING**

If a card slot is unused, you must install slot covers to prevent personal contact with high voltage circuits. Failure to install slot covers could result in personal exposure to hazardous voltages, which could cause personal injury or death if contacted.

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### **NOTE**

If you have a 2000-SCAN or 2001-TCSCAN that was used in another Keithley Instruments product, such as the Model 2000, you can use your existing scan cards in the DMM6500. Follow the instructions in your original equipment documentation to remove the card from the instrument, then use the following instructions to install it in the DMM6500. You do not need to remove the wiring to the card.

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### **NOTE**

For inexperienced users, it is recommended that you do not connect a device under test (DUT) and external circuitry to the scanner card. 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.

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### **NOTE**

Select the rear inputs with the multimeter front-panel TERMINALS switch when using the scanner card.

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## Scanner card installation

### **⚠ WARNING**

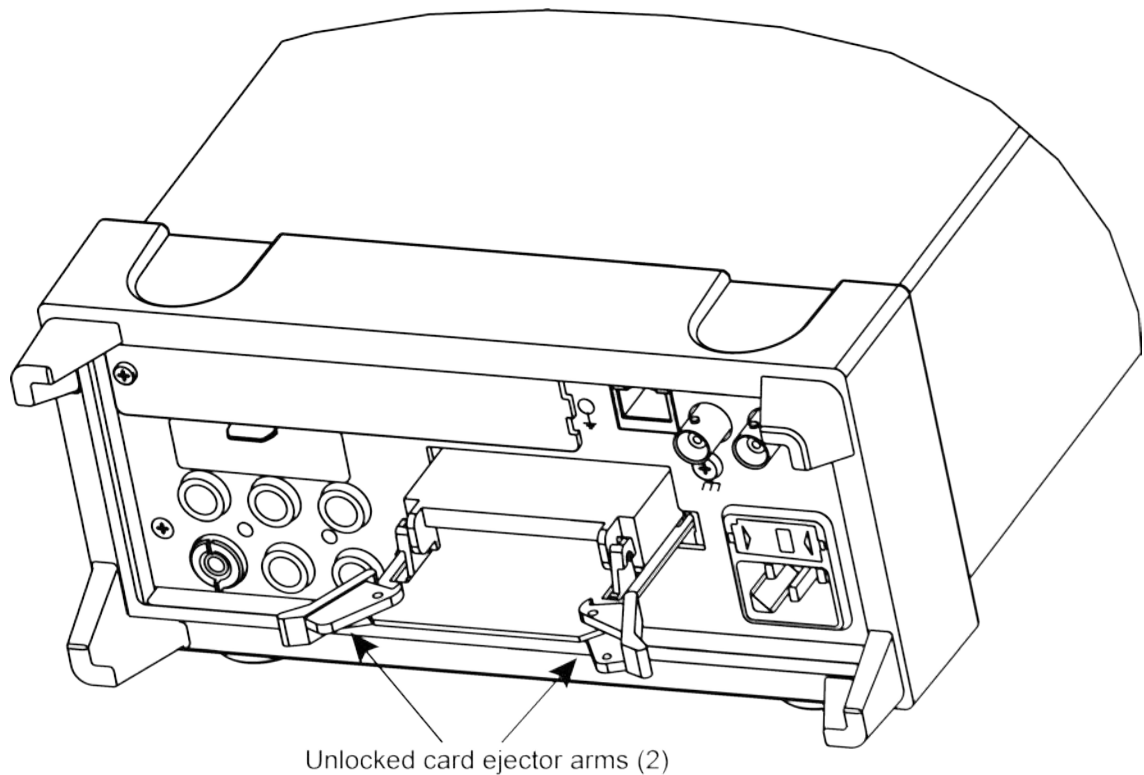
Turn off power to all instruments (including the multimeter), and disconnect all power cords. Make sure all power is removed and any stored energy in external circuitry is discharged.

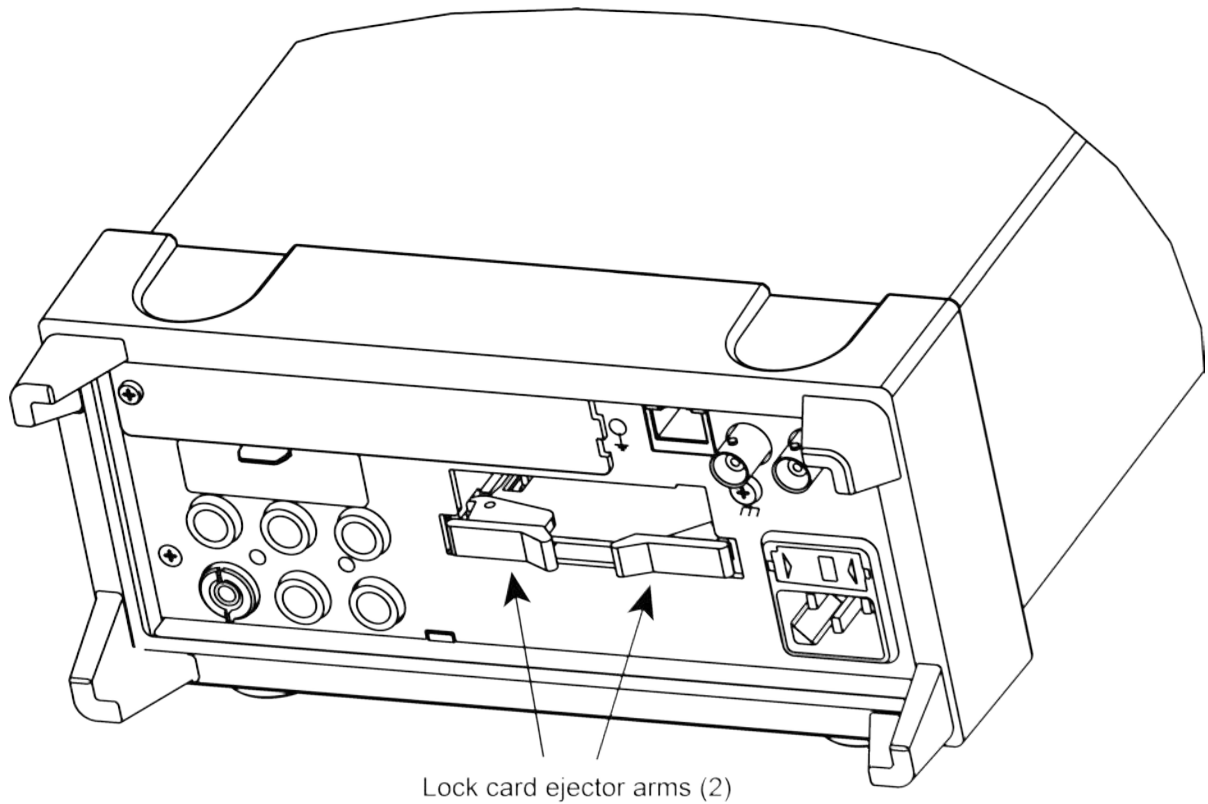
### **NOTE**

To prevent contamination of the 2001-TCSCAN that could degrade performance, handle the scanner card by the edges and covers only.

The figure below demonstrates the 2001-TCSCAN installation.

**Figure 9: Unlock card**



**Figure 10: Lock card****To install your 2001-TCSCAN:**

1. Remove power from the DMM6500.
2. Disconnect the power cord and any other cables that are connected to the rear panel.
3. Remove the cover plate from the Accessory Card Slot on the rear panel of the multimeter. To do so, move the tab on the cover plate up and out.
4. Slide the card edges into the guide rails inside the multimeter.
5. With the ejector arms in the unlocked position, carefully push the card all the way forward until the arms engage the ejector clips. Push both arms inward to lock the scanner card into the multimeter.
6. After installing your scanner card, make your output connections.

## Output connections to multimeter

After installing your scanner card, connect the scanner card output leads to the rear panel of the DMM.

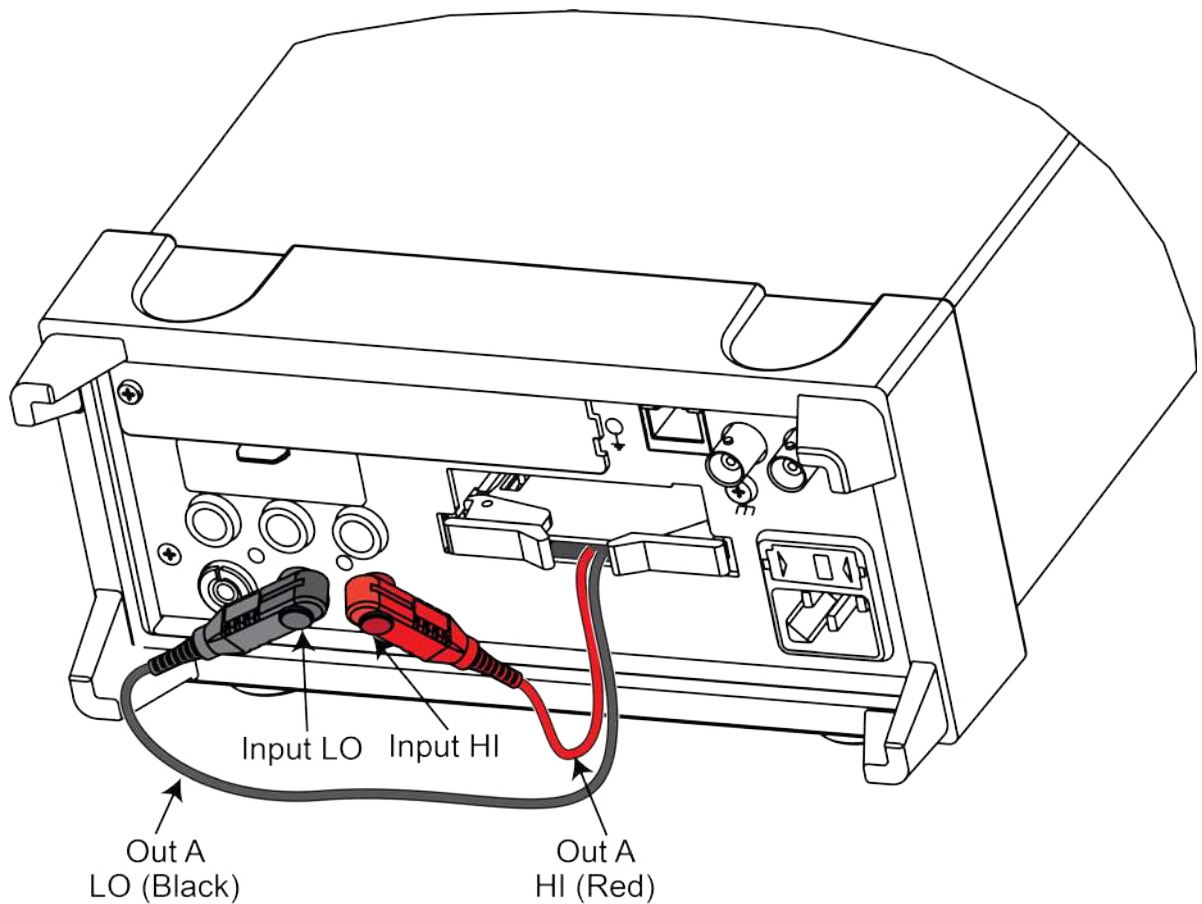
### NOTE

Be sure to select the rear inputs with the DMM front panel TERMINAL switch when using the scanner card.

#### **To make output connections for 2-pole operation:**

1. Connect OUT A HI (red) to INPUT HI.
2. Connect OUT A LOW (black) to INPUT LO.

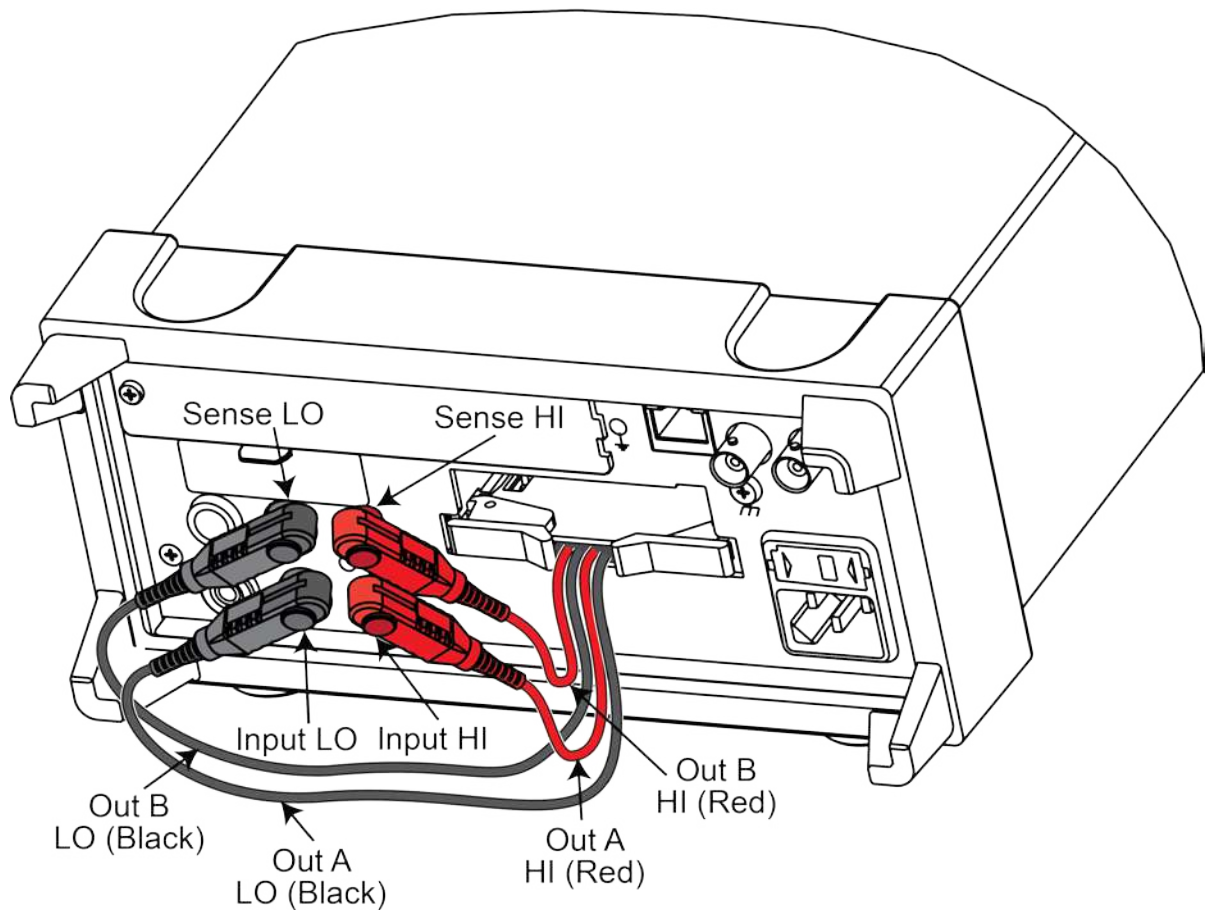
The figure below shows the output connections for 2-pole operation.



**To make output connections for 4-pole operation:**

1. Connect OUT A HI (red) to INPUT HI.
2. Connect OUT A LO (black) to INPUT LO.
3. Connect OUT B HI (red) to SENSE HI.
4. Connect OUT B LO (black) to SENSE LO.

The figure below shows the output connections for 4-pole operation.

**Figure 11: Four-pole output connections****Scanner card removal****⚠ WARNING**

Turn off power to all instrumentation, including the multimeter, and disconnect all line cords. Make sure all power is removed and any stored energy in external circuitry is discharged.

**To remove the scanner card from the multimeter:**

1. Unlock the scanner card by pulling the ejector arms outward.
2. Carefully slide the scanner card out of the multimeter.
3. If you will operate the DMM6500 without the scanner card installed, install the cover plate over the Accessory Card Slot.

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## Introduction

This section contains detailed information on front panel and remote interface operation of the 2001-TCSCAN.

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### CAUTION

**Before using the 2001-TCSCAN, you should be thoroughly familiar with the operation of the DMM6500 multimeter. See the DMM6500 User's and Reference Manuals for the necessary information.**

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## Signal limitation

To prevent overheating or damage to the relays, never exceed the following maximum input signal levels:

- DC signals
  - 110 V DC
  - 1 A switched
  - 30 VA (resistive load)
- AC signals
  - 125 V<sub>RMS</sub> OR 175 V AC<sub>PEAK</sub>
  - 1 A switched
  - 62.5 VA (resistive load)

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### NOTE

Channels 5 and 10 have a maximum power of 0.25 VA due to factory-installed, current-limited resistors.

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### NOTE

Before using the 2001-TCSCAN, you should be thoroughly familiar with the operation of the DMM6500 multimeter. See the DMM6500 User's and Reference Manuals for more information.

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## Scanner card detection

### Power-up detection

The scanner card is detected when the power is turned on. If the scanner card is plugged in after the power is turned on, the scanner card will not be recognized.

### CAUTION

Installing the scanner card with the multimeter powered on may result in damage to both the 2001-TCSCAN and the multimeter.

### Scanner option remote command

If the card is not present when powering on the instrument, scanner remote commands will generate an error, and front panel operations related to the scanner will inform you that no scanner card is present.

:SYSTem:CARD<n>:IDN? is a SCPI command that will determine whether scanner card is installed. The TSP command equivalent is `print(slot[n].idn)`. The response to this query indicates whether a scanner card is present as follows:

- 0 : Scanner not installed.
- 2000,10-Chan\Mux,0.0.0a,00000000 : Scanner installed

## Basic front-panel measurements

The following procedures show you how to make a measurement, access settings for the measurement, and view measurement data in a reading buffer. To build scans using the 2001-TCSCAN, you must make sure your DMM6500 is set to use the rear terminals.

### Opening and closing channels from the CHANNEL swipe screen

You can open and close channels on the DMM6500 from the CHANNEL and the SCAN swipe screens.

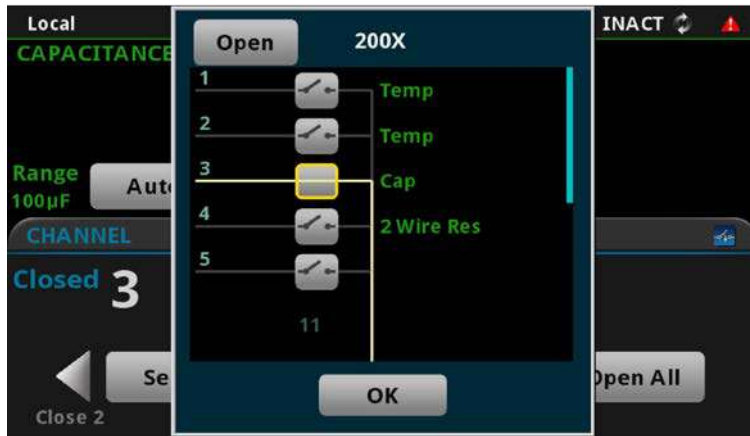
**To open and close channels from the CHANNEL swipe screen:**

1. From the Channel tab on the swipe screen, select the **SELECT** icon to access the 2001-TCSCAN channel list.



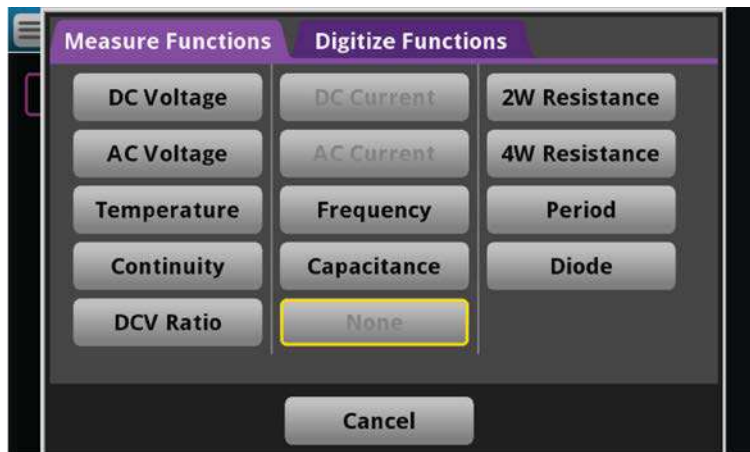
From the 2001-TCSCAN channel list, select the box next to the channel number to open or close it. Selecting the channel box again will open the channel, and the connection icon will move to the open state.

Figure 12: DMM6500 channel list



2. When closing a channel, select the measurement function for that channel from Measure Functions screen. Note that you will select a measurement function for each channel you close.

Figure 13: Measurement function screen



3. Select **OK**.

## Controlling channels using the remote interface

Use the SCPI command `:SENSE:FUNC` to program functions for the selected channels. For TSP, use the command `channel.setdmm()`. For example, to measure DC volts on channel 1, AC volts on channel 2, and 2-wire resistance on channel 3, you would use the following SCPI commands:

```
:SENS:FUNC "VOLT:DC", (@1)
```

```
:SENS:FUNC "VOLT:AC", (@2)
```

```
:SENS:FUNC "RES", (@3)
```

The TSP equivalent for the above commands are:

```
channel.setdmm("1", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_DC_VOLTAGE)
```

```
channel.setdmm("2", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_AC_VOLTAGE)
```

```
channel.setdmm("3", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_RESISTANCE)
```

To use the same function (DCV in this example) on all three channels, use a single SCPI command like the following example:

```
:SENS:FUNC "VOLT:DC", (@1:3)
```

The TSP equivalent for the above command is:

```
channel.setdmm("1:3", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_DC_VOLTAGE)
```

## Building a scan

Front panel scan controls are located on the SCAN swipe screen. Select **BUILD SCAN** to build a scan. If a scan is already configured, select the icon on the top right of the SCAN swipe screen to access the Scan menu.

Figure 14: DMM6500 SCAN swipe screen



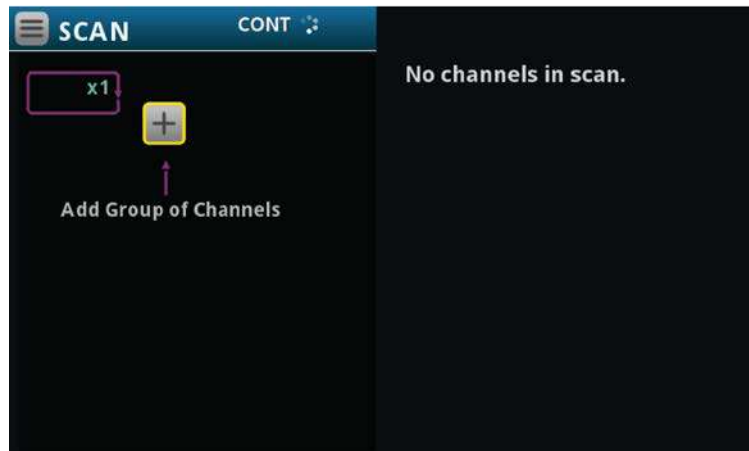
## Selecting channels for a scan

---

*To select channels from the front panel:*

1. From the Build Scan screen, select **Add Group of Channels** to access the 2001-TCSCAN channel list. If you selected the channels for your scan from the Channels tab on the swipe screen, you can skip this step.

**Figure 15: Add group of channels**



2. From the 2001-TCSCAN channel list, select the box next to the channel number to select your channels.
3. Select **OK** to proceed to the Measurement Functions/Digitize Functions screen.

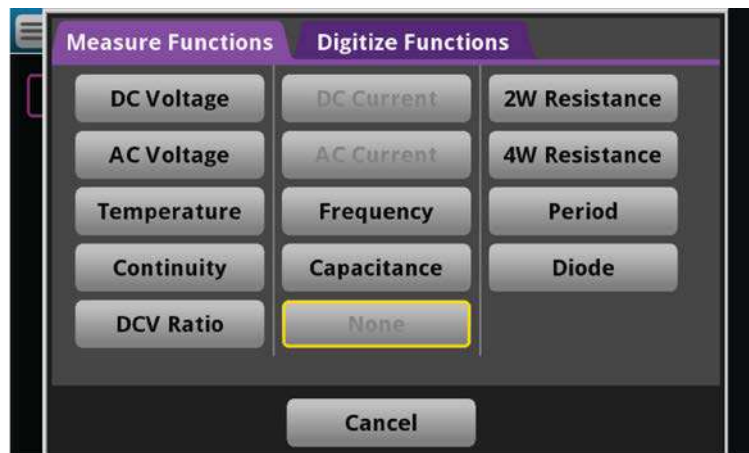
## Selecting a measurement function

---

After choosing the channels for your scan, the Measurement Functions screen opens. On this screen, you can select the required function for your scan.

The available measurement functions are shown below.

**Figure 16: Measurement functions**



Selecting a measurement function assigns it to the channel you selected. To assign the same measurement function to all selected channels, select the same measurement function for each channel.

---

## Run a scan

---

Once the scan is set up, you can run it.

*To start the scan from the front panel, use one of the following:*

- Press the **TRIGGER** key.
- On the Scan menu, select **Start**.
- On the Scan swipe screen, select **Start Scan**.
- From the trigger mode indicator on the home screen, select **Initiate Scan**.

You can pause the scan from scan swipe screen on the front panel. Select **Pause Scan**. To continue the scan, select **Resume Scan**.

---

## Stop a scan

---

You can stop a running scan.

When you stop a scan, the channels remain in the state they were in (opened or closed) when the scan was stopped.

*To stop a scan from the front panel:*

Select **Abort Scan** from the Scan menu, the Scan swipe screen, or the trigger mode indicator on the home screen.

- On the Scan menu, select **Abort Scan**.
- On the Scan swipe screen, select **Abort Scan**.
- From the trigger mode indicator on the home screen, select **Abort Scan**.

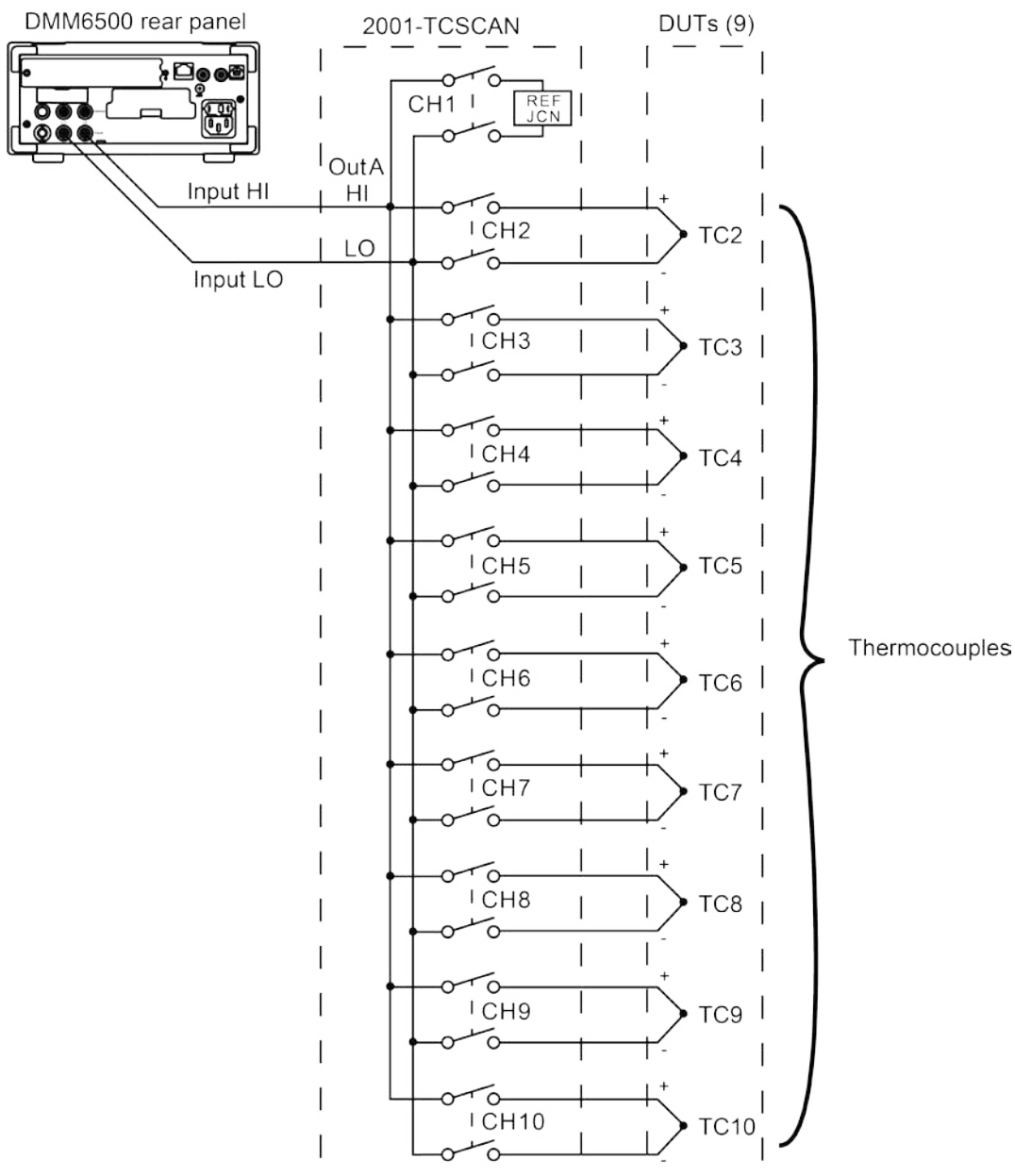
## Typical applications

### Temperature measurements

You can make temperature measurements from the front panel of DMM6500. Measurements can be made by either automatic scanning or by manually closing specific channels. You can use thermocouple types B, E, J, K, N, R, S, and T to make temperature measurements with your 2001-TCSCAN. The following procedure is for making thermocouple temperature measurements.

Connect the thermocouples to the scanner card input connectors using the general scheme based on the figure below before making temperature measurements.

**Figure 17: Typical connections for thermocouple scanning**



Use the SCPI commands below to set up your 2001-TCSCAN for temperature measurements on the DMM6500.

*RST	Puts the instrument in a known state
FUNC 'TEMP', (@1:10)	Sets the function to Temperature
TEMP:TRAN CJC2001, (@1)	Sets up the channel 1 reference junction
TEMP:TRAN TC, (@2:10)	Sets the transducer to thermocouples
TEMP:TC:TYPE K, (@2:10)	Sets the thermocouples to type K
TEMP:TC:RJUN:RSEL EXT, (@2:10)	Sets the reference junction to external
TEMP:UNIT FAHR, (@2:10)	Sets the units to Fahrenheit
ROUT:SCAN:INT 10, (@2:10)	Sets the interval delay to 10 s
ROUT:SCAN:COUN:SCAN 10	Sets the scan count
TRAC:CLE	Clears the reading buffer
TRAC:POIN 100, "defbuffer1"	Sets the buffer size
ROUT:SCAN:CRE (@1:10)	Sets the scan list
INIT	Initiates the scan

Below are equivalent TSP commands to set up your 2001-TCSCAN for temperature measurements on the DMM6500.

reset()	Puts the instrument in a known state
channel.setdmm("1:10", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_TEMPERATURE)	Sets function to Temperature
channel.setdmm("1", dmm.ATTR_MEAS_TRANSDUCER, dmm.TRANS_CJC2001)	Sets up the channel 1 reference junction
channel.setdmm("2:10", dmm.ATTR_MEAS_TRANSDUCER, dmm.TRANS_THERMOCOUPLE)	Sets the transducer to thermocouples
channel.setdmm("2:10", dmm.ATTR_MEAS_THERMOCOUPLE, dmm.THERMOCOUPLE_K)	Sets the thermocouples to type K
channel.setdmm("2:10", dmm.ATTR_MEAS_REF_JUNCTION, dmm.REFJUNCT_EXTERNAL)	Sets the reference junction to external
channel.setdmm("1:10", dmm.ATTR_MEAS_UNIT, dmm.UNIT_FAHRENHEIT)	Sets units to Fahrenheit
scan.scaninterval = 10.0	Sets the interval delay to 10 s
scan.scancount = 10	Sets the scan count
defbuffer1.clear()	Clears the reading buffer
defbuffer1.capacity = 100	Sets the buffer size
scan.create("1:10")	Sets the scan list
trigger.model.initiate()	Initiates the scan

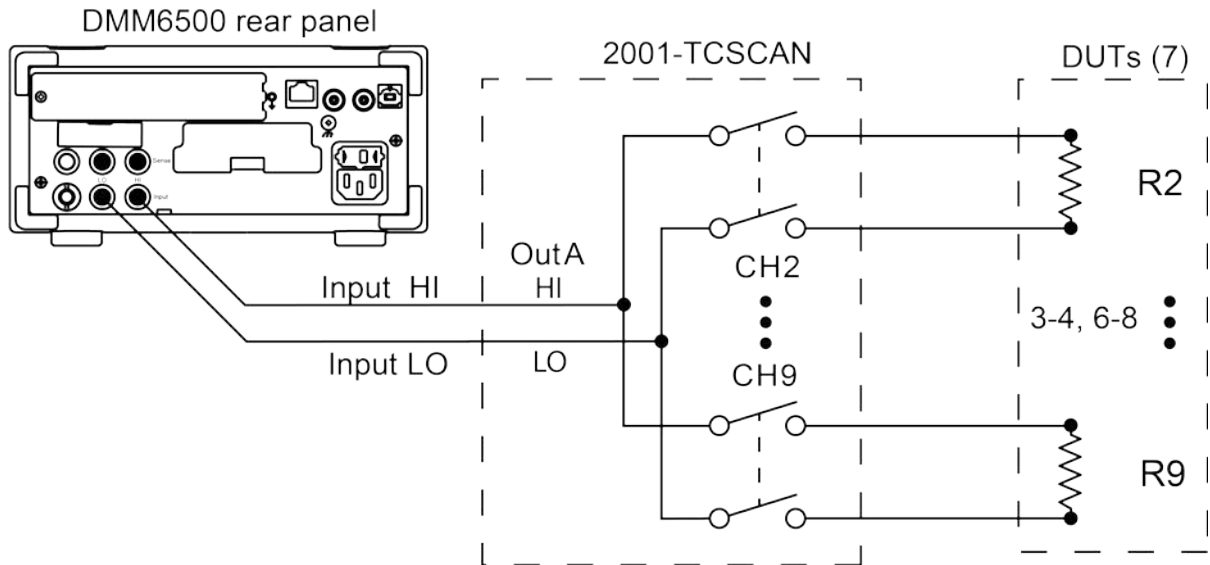
## Resistor testing

The 2001-TCSCAN scanner card can be used to test up to seven resistors using 2-wire measurements or up to four resistors using 4-wire measurements. Such tests use the DMM6500 2- and 4-wire resistance functions.

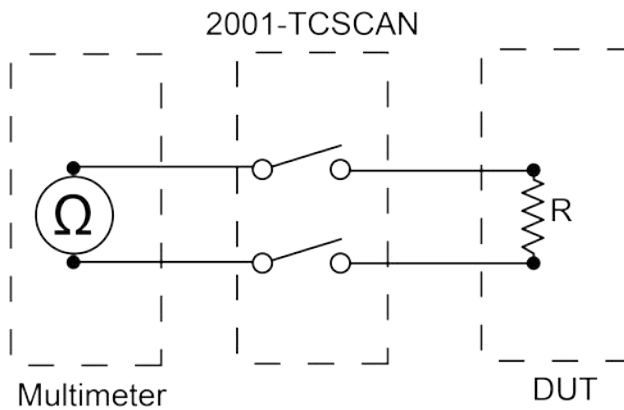
### Two-wire resistance tests

The figure below shows a typical setup for make 2-wire resistance measurements. The 2001-TCSCAN scanner card provides the switching function. The resistance measurements are made by the DMM6500. Since only 2-pole switching is required for this application, one 2001-TCSCAN can be used to switch up to seven resistors. However, the 240 Ω resistance of channels 5 and 10 may affect the measurement accuracy of 2-wire resistance measurements made using these channels. Generally, channels 5 and 10 should not be used for 2-wire resistance measurements unless the scanner card is modified.

**Figure 18: Two-wire resistance connections**



**Figure 19: Two-wire resistance test equivalent circuit**





Use the SCPI commands below to set up a 2-wire resistance test using the DMM6500 and your 2001-TCSCAN.

*RST	Puts the DMM in a known state
FUNC 'RES', (@2:4, 6:9)	Sets the channels for 2-wire measurements
RES:RANG 100e3, (@2:4, 6:9)	Sets the range to 100 k $\Omega$
ROUT:SCAN:CRE (@2:4, 6:9)	Creates the scan
TRAC:CLE	Clears the buffer
INIT	Initiates the scan

Below are equivalent TSP commands to set a 2-wire resistance test using the DMM6500 and your 2001-TCSCAN.

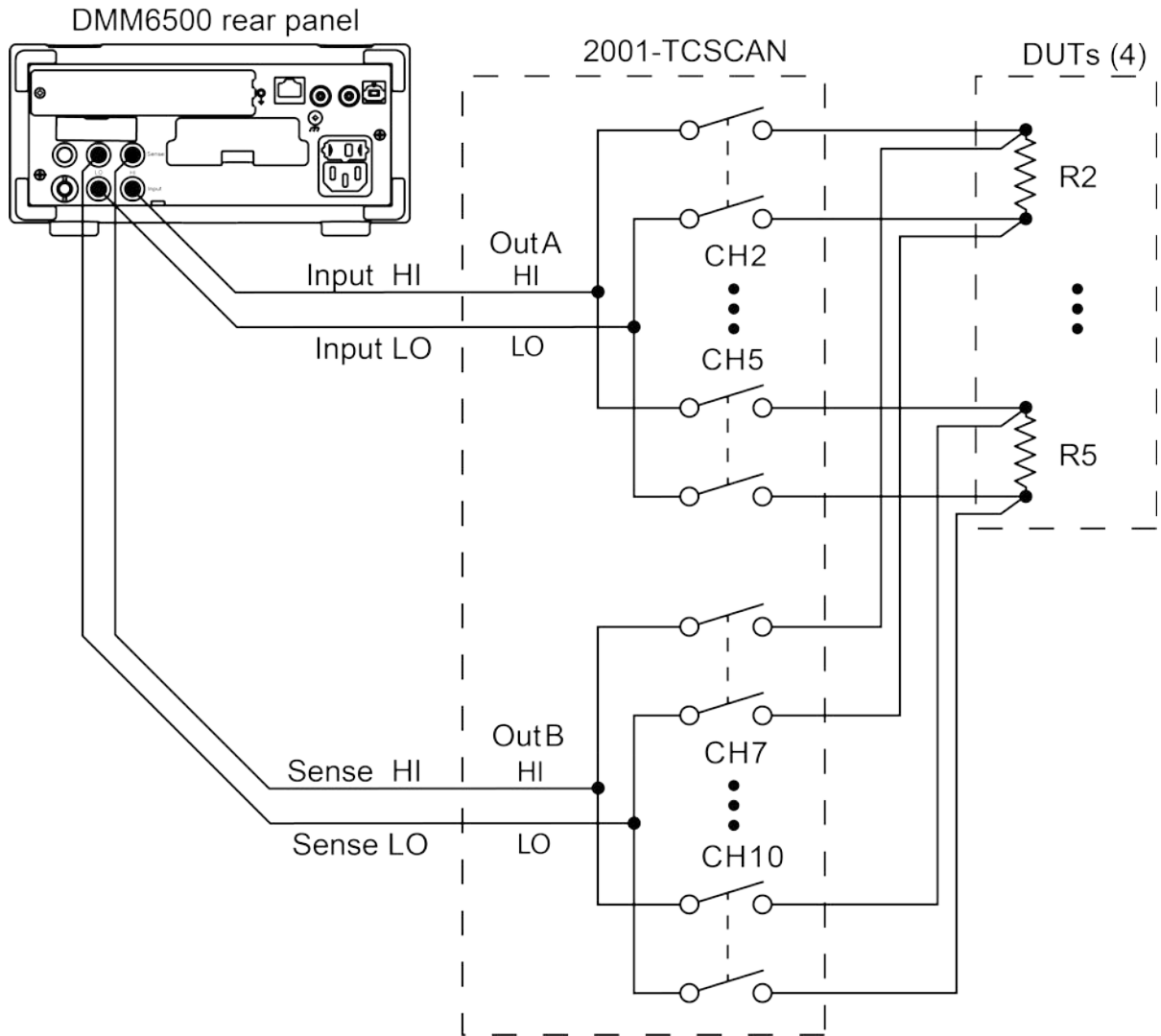
reset()	Puts the DMM in a known state
channel.setdmm("2:4, 6:9", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_RESISTANCE)	Sets the channels for 2-wire measurements
channel.setdmm("2:4, 6:9", dmm.ATTR_MEAS_RANGE, 100e3)	Sets the range to 100 k $\Omega$
scan.create("2:4, 6:9")	Creates the scan
defbuffer1.clear()	Clears the buffer
trigger.model.initiate()	Initiates the scan

Measurement accuracy can be optimized with minimal residual resistance. Make connecting wires as short as practical and limit the number of connectors to minimize path resistance. You can also short one of the scanner channel inputs, close the shorted channel, and enable the DMM REL feature to null the path resistance. REL must be enabled for the entire test.

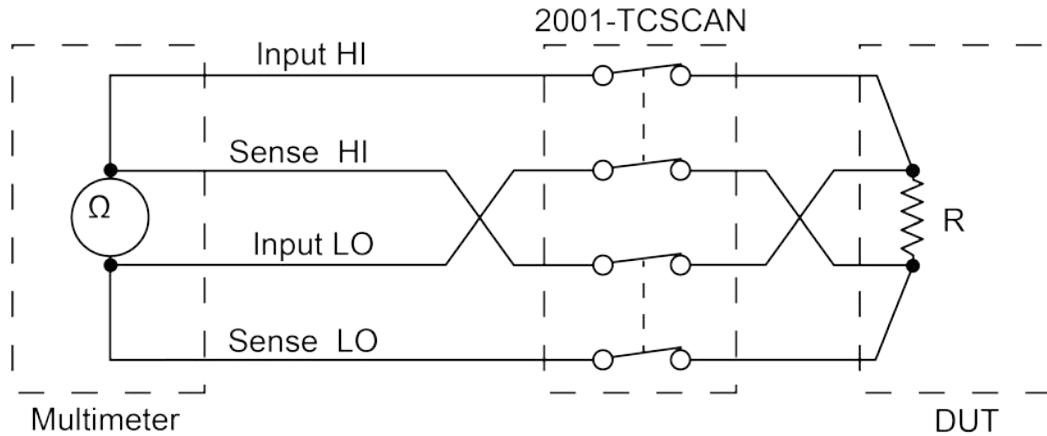
### Four-wire resistance tests

More precise measurements over a wide range of conditions can be obtained by using the 4-wire measurement scheme shown in the figure below. Sense leads are routed from the DMM through the scanner to the resistor under test. The extra set of sense leads minimizes the effects of voltage drops across the test leads and reduces measurement errors with lower DUT resistances. Note that two extra poles of switching are required for each resistor tested. For this reason, only four resistors can be tested using this configuration.

**Figure 20: Four-wire resistance connections**



**Figure 21: Four-wire resistance test equivalent circuit**



Use the SCPI commands below to set up a 4-wire resistance test using the DMM6500 and your 2001-TCSCAN.

*RST	Puts the DMM in a known state
FUNC 'FRES', (@2:5)	Sets up the channels for 4-wire measurements
FRES:OCOM ON, (@2:5)	Turns on offset compensation
FRES:RANG 100, (@2:3)	Sets the range to 100 Ω
FRES:RANG 10, (@4)	Sets the range to 10 Ω
FRES:RANG 1, (@5)	Sets the range to 1 Ω
ROUT:SCAN:CRE (@2:5)	Creates the scan
TRAC:CLE	Clears the buffer
INIT	Initiates the scan

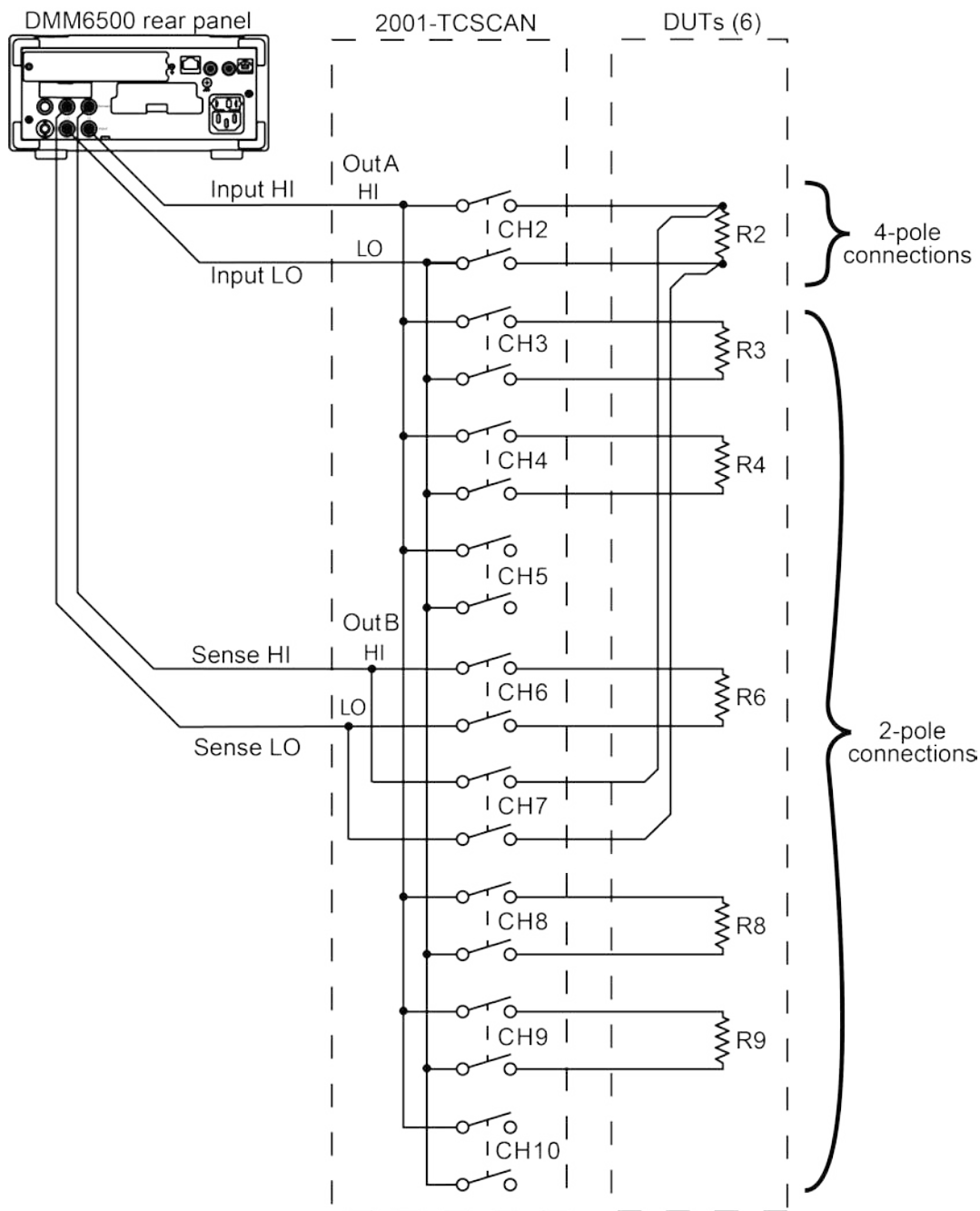
Below are equivalent TSP commands to set a 4-wire resistance test using the DMM6500 and your 2001-TCSCAN.

reset()	Puts the DMM in a known state
channel.setdmm("2:5", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_4W_RESISTANCE)	Sets up the channels for 4-wire measurements
channel.setdmm("2:5", dmm.ATTR_MEAS_OFFCOMP_ENABLE, dmm.OCOMP_ON)	Turns on offset compensation
channel.setdmm("2:3", dmm.ATTR_MEAS_RANGE, 100)	Sets the range to 100 Ω
channel.setdmm("4", dmm.ATTR_MEAS_RANGE, 10)	Sets the range to 10 Ω
channel.setdmm("5", dmm.ATTR_MEAS_RANGE, 1)	Sets the range to 1 Ω
defbuffer1.clear()	Creates the scan
scan.create("2:5")	Clears the buffer
trigger.model.initiate()	Initiates the scan

### Combining 2-pole and 4-pole switching

The 2001-TCSCAN scanner card can combine 2- and 4-pole switching. For example, your configuration may require 4-pole switching for only two resistors, while the remaining resistors can be tested using conventional 2-pole switching. The figure below shows a test configuration using mixed 2- and 4-pole switching. Four-pole switching is used only for the DUT connected to channels 2 and 7. Five more resistors are tested using 2-pole switching. Configure the channels for the 2- and 4-wire functions.

**Figure 22: Combining 2-pole and 4-pole switching**



Use the SCPI commands below to set up a combination 2- and 4-wire resistance test using the DMM6500 and your 2001-TCSCAN.

*RST	Puts the DMM in a known state
FUNC 'FRES', (@2)	Sets the channels for 4-wire measurements
FRES:OCOM ON, (@2)	Turns on offset compensation
FRES:RANG 100, (@2)	Sets the 4-wire range to 100 $\Omega$
FUNC 'RES', (@3, 4, 6, 8:9)	Sets the channels to 2-wire measurement
RES:RANG 100e3, (@3, 4, 6, 8:9)	Sets the 2-wire range to 100 k $\Omega$
ROUT:SCAN:CRE (@2:4, 6, 8:9)	Creates the scan
TRAC:CLE	Clears the buffer
INIT	Initiates the scan

Below are equivalent TSP commands to set a combination 2- and 4-wire resistance test using the DMM6500 and your 2001-TCSCAN.

reset()	Puts the DMM in a known state
channel.setdmm("2", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_4W_RESISTANCE)	Sets the channels for 4-wire measurements
channel.setdmm("2", dmm.ATTR_MEAS_OFFCOMP_ENABLE, dmm.OCOMP_ON)	Turns on offset compensation
channel.setdmm("2", dmm.ATTR_MEAS_RANGE, 100)	Sets the 4-wire range to 100 $\Omega$
channel.setdmm("3, 4, 6, 8, 9", dmm.ATTR_MEAS_FUNCTION, dmm.FUNC_RESISTANCE)	Sets the channels to 2-wire measurement
channel.setdmm("3,4,6,8,9", dmm.ATTR_MEAS_RANGE, 100e3)	Sets the 2-wire range to 100 k $\Omega$
scan.create("2:4,6,8:9")	Creates the scan
defbuffer1.clear()	Clears the buffer
trigger.model.initiate()	Initiates the scan

## Measurement considerations

### Thermocouple measurement error sources

The temperature measurement accuracy specification of the 2001-TCSCAN is the sum of the following error sources:

- Reference junction sensor error
- Temperature gradient across the card
- Relay offset voltage
- DMM measurement accuracy
- DMM temperature conversion algorithm

You can improve card performance by understanding how these error sources contribute to the specification.

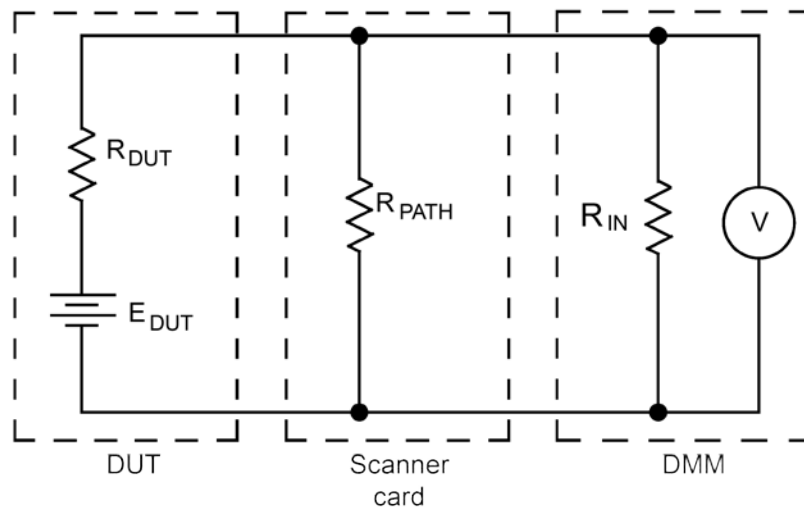
## Reference junction sensor

Operating temperature is the primary factor in determining reference junction accuracy. Using the 2001-TCSCAN in the 18 °C to 28 °C range, maximum sensor performance is achieved. The 2001-TCSCAN may also be used over 0 °C to 18 °C and 28 °C to 50 °C with reduced accuracy.

## Path isolation

Path isolation is the equivalent impedance between any two test paths in a measurement system. Theoretically, the path isolation should be infinite, but the actual resistance and distributed capacitance of cables and connectors results in less than infinite path isolation values for these devices.

**Figure 23: Path isolation resistance**



$R_{DUT}$  = source resistance of the DUT

$E_{DUT}$  = source EMF of the DUT

$R_{PATH}$  = path isolation of resistance

$R_{IN}$  = input resistance of the multimeter

Path isolation resistance forms a signal path that is in parallel with the equivalent resistance of the DUT, as shown in the figure above. For low-to-medium device resistance values, path isolation resistance is seldom a consideration; however, it may seriously degrade measurement accuracy when testing high-impedance devices. For example, the voltage measured across such a device can be substantially attenuated by the voltage divider action of the device source resistance and path isolation resistance, as shown in the previous figure. Also, leakage currents can be generated through these resistances by voltage sources in the system.

## Magnetic fields

When a conductor cuts through magnetic lines of force, a small current is generated. This may cause unwanted signals to occur in the test leads of a scanning system. If the conductor has sufficient length, even weak magnetic fields can create sufficient signals that affect low-level measurements.

Two ways to reduce these effects are to:

- Reduce the lengths of the test leads
- Minimize the exposed circuit area

In extreme cases, magnetic shielding may be required. Special metal with high-permeability at low flux densities, such as mu metal, is effective at reducing these effects.

Even when the conductor is stationary, magnetically-induced signals may still be a problem. Fields can be produced by various signals such as AC power line voltage. Large inductors, such as power transformers, can generate substantial magnetic fields. Care must be taken to give the switching and measuring circuits enough distance from these potential noise sources. At high-current levels, even a single conductor can generate significant fields. These effects can be minimized by using twisted pairs, which will cancel out most of the resulting fields.

## Electromagnetic interference (EMI)

The electromagnetic interference characteristics of the DMM6500 comply with the electromagnetic compatibility (EMC) requirements of the European Union (EU) directives as denoted by the CE mark. However, it is still possible for sensitive measurements to be affected by external sources. In these instances, special precautions may be required in the test setup.

Sources of EMI include:

- Radio and television broadcast transmitters.
- Communications transmitters, including cellular phones and hand-held radios.
- Devices using microprocessors and high-speed digital circuits.
- Impulse sources like arcing in high-voltage environments.

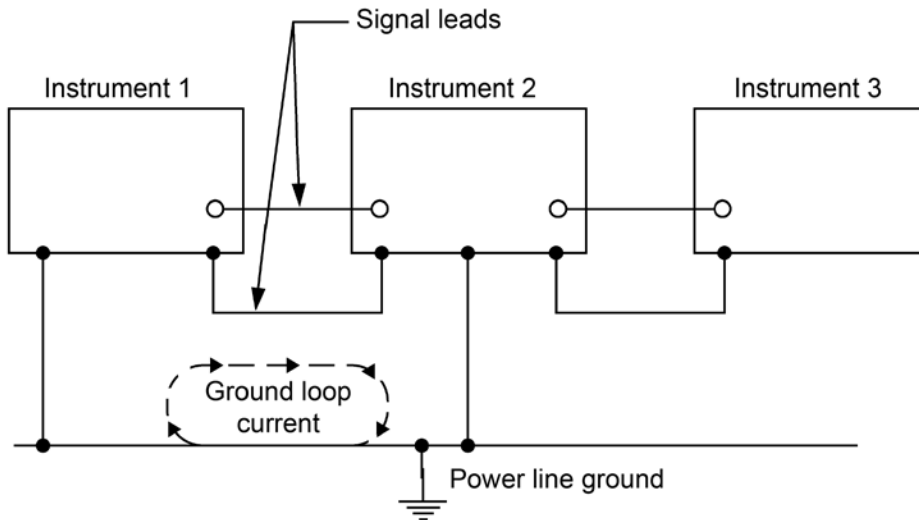
The instrument, measurement leads, and other cables should be kept as far away as possible from any EMI sources. Shielding measurement leads and the multimeter may reduce EMI to acceptable levels. In extreme cases, a specially-constructed screen room may be required to sufficiently attenuate troublesome signals.

Many cases use internal filtering that may help reduce EMI effects. In some cases, additional external filtering may be required. However, keep in mind that filtering may have negative effects on the measurement.

## Ground loops

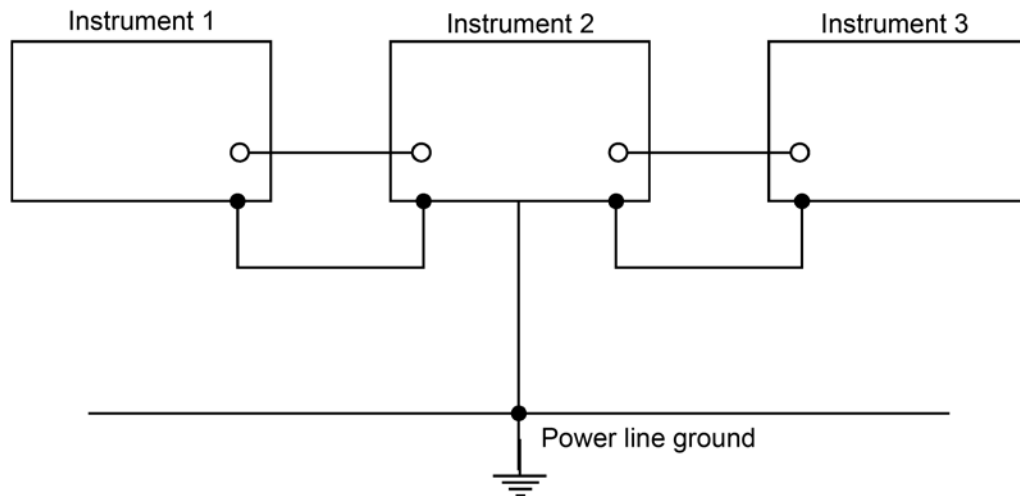
When two or more instruments are connected, you must take precautions to avoid unwanted signals from ground loops. Ground loops typically occur when sensitive instrumentation is connected to other instrumentation with more than one signal return path such as power line ground. As shown in the following figure, the resulting ground loop causes current to flow through the instrumentation LO signal leads and then back through the power line ground. This circulating current develops a small but unwanted voltage between the LO terminals of the two instruments. This voltage will be added to the source voltage, affecting the accuracy of the measurement.

**Figure 24: Power line ground loops**





The following figure shows how to connect several instruments together to eliminate this ground loop problem. Here, only one instrument is connected to the power line ground. Ground loops are not typically a problem with instruments with isolated LO terminals. However, all instruments in the test setup may not have isolated terminals. When in doubt, consult the manual for each instrument in the test setup.



## Keeping connectors clean

As is the case with any high-resistance device, the integrity of connectors can be compromised if they are not handled properly. If the connector insulation becomes contaminated, insulation resistance will be substantially reduced, affecting high-impedance measurement paths. Oils and salts from the skin can contaminate connector insulators, reducing their resistance. Also, contaminants present in the air can be deposited on the insulator surface. To avoid these problems, never touch the connector insulating material. In addition, the scanner card should be used only in clean, dry environments to avoid contamination.

If the connector insulators should become contaminated, either by inadvertent touching, or from airborne deposits, they can be cleaned with a cotton swab dipped in clean methanol. After thoroughly cleaning, they should be allowed to dry for several hours in a low-humidity environment before use, or they can be dried more quickly using dry nitrogen.

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