
Instruction Manual

Model 7014

39-Channel Thermocouple/ General Purpose Multiplexer Card

Contains Operating and Servicing Information

KEITHLEY

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Model 7014 Instruction Manual

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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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 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 the operating information carefully before using the product.

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, 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.

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.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users 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.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

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.

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

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


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


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


When fuses are used in a product, replace with 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.

Model 7014

39 Channel Thermocouple/General Purpose Multiplexer

MULTIPLEX CONFIGURATION: Four independent 1x10 2-pole multiplex banks. Adjacent banks can be connected together. Jumpers can be removed to isolate any bank from the backplane. Channel one in the bank A multiplexer is used for the cold junction sensor.

CONTACT CONFIGURATION: 2-pole Form A (Hi, Lo).

CONNECTOR TYPE:

Screw terminal, #16AWG maximum wire size, with .092 inch O.D. 28 conductors per card maximum. #22AWG typical wire size per conductor, with .062 inch O.D. 86 conductors per card maximum.

TOTAL REFERENCE JUNCTION MEASUREMENT ACCURACY

(1 Year):

$\pm 0.45^{\circ}\text{C}$ (18°C to 28°C);

$\pm 0.7^{\circ}\text{C}$ (0°C to 18°C and 28°C to 50°C).

REFERENCE OUTPUT: $+200\mu\text{V}/^{\circ}\text{C}$ ($+54.63\text{mV}$ at 0°C).

WARM UP: 2 hours to rated accuracy in mainframe.

MAXIMUM SIGNAL LEVEL:

DC Signals: 110V DC between any two pins, 1A switched, 30VA (resistive load).

AC Signals: 125V RMS and 175V AC peak, between any two pins, 1A switched, 60VA (resistive load).

COMMON MODE VOLTAGE: 175V peak, any pin to chassis.

CONTACT LIFE: Cold Switching: 10^6 closures.
At Maximum Signal Levels: 10^5 closures.

CHANNEL RESISTANCE (per conductor): $< 1\Omega$.

CONTACT POTENTIAL:

$< 1\mu\text{V}$ per channel contact pair

$< 2\mu\text{V}$ typical per single contact.

OFFSET CURRENT: $< 100\text{pA}$.

ACTUATION TIME: 3ms.

ISOLATION:

Bank: $> 10^9\Omega$, $< 25\text{pF}$.

Channel to Channel: $> 10^9\Omega$, $< 50\text{pF}$.

Differential: Configured as 1x10: $> 10^9\Omega$, $< 100\text{pF}$.

Configured as 1x40: $> 10^9\Omega$, $< 200\text{pF}$.

Common Mode: Configured as 1x10: $> 10^9\Omega$, $< 300\text{pF}$.

Configured as 1x40: $> 10^9\Omega$, $< 900\text{pF}$.

CROSSTALK (1MHz, 50 Ω Load): Bank: $< -40\text{dB}$.
Channel: $< -40\text{dB}$.

INSERTION LOSS (50 Ω Source, 50 Ω Load): $< 0.1\text{dB}$ below 1MHz, $< 3\text{dB}$ below 2MHz.

RELAY DRIVE CURRENT (per relay): 20mA.

ENVIRONMENT: Operating: 0° to 50°C , up to 35°C at 80% RH.
Storage: -25°C to 65°C .

Isothermal Connections

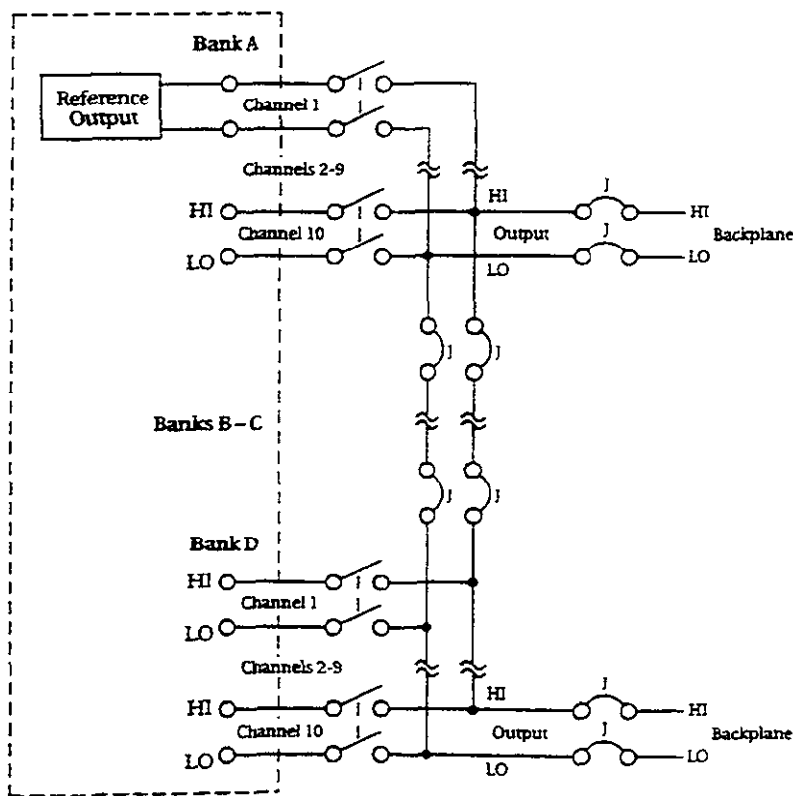


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1

General Information

1.1 Introduction

This section contains general information about the Model 7014 39-Channel Thermocouple/General Purpose Multiplexer Card.

The Model 7014 card is field-installable in the Model 7001 Switch System. Since it combines the functions of thermocouple switching and a uniform temperature reference, it is especially useful for scanning thermocouples.

The input terminals are covered by an aluminum cover that acts as an isothermal block to minimize temperature differences. An integrated circuit temperature transducer under the aluminum cover senses the reference (cold) junction temperature and converts it to a proportional voltage. The cold junction temperature is used to calculate the corrected thermocouple output. The output voltages of each thermocouple must be converted to temperature ($^{\circ}\text{C}$, $^{\circ}\text{F}$, or K) using appropriate thermocouple tables, polynomial equations, or a multimeter capable of temperature measurements, such as the Model 2001.

In addition, any channel can be used for monitoring low-level signals. The Model 7014 uses 2-pole Form A contacts for switching of DC signals up to 110V, 1A, 30VA (resistive load), and AC signals up to 125V RMS or 175V peak, 1A, 60VA (resistive load).

The rest of Section 1 is arranged in the following manner:

- 1.2 Features
- 1.3 Warranty information
- 1.4 Manual addenda
- 1.5 Safety symbols and terms
- 1.6 Specifications
- 1.7 Unpacking and inspection
- 1.8 Repacking for shipment
- 1.9 Optional accessories

1.2 Features

The Model 7014 is a low voltage, two-pole, quad, 1×10 multiplexer card. Some of the key features include:

- Low contact potential and offset current for minimal effects on low-level signals.
- The connector board detaches from the relay board allowing easy access to the screw terminals and jumpers.
- Easy jumper configuration of one, two, three or four multiplexer banks.

- Backplane jumpers. Cutting jumpers disconnects multiplexer bank outputs from the Model 7001 analog backplane.

1.3 Warranty information


Warranty information is located on the inside front cover of this instruction manual. Should your Model 7014 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the multiplexer card for repair, be sure to fill out and include the service form at the back of this manual in order to provide the repair facility with the necessary information.


1.4 Manual addenda

Any improvements or changes concerning the multiplexer card or manual will be explained in an addendum included with the card. Addenda are provided in a page replacement format. Simply replace the obsolete pages with the new pages.

1.5 Safety symbols and terms

The following symbols and terms may be found on an instrument or used in this manual.

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

The  symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this 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 used in this manual explains hazards that could damage the multiplexer card. Such damage may invalidate the warranty.

1.6 Specifications

Model 7014 specifications are found at the front of this manual. These specifications are exclusive of the multiplexer mainframe specifications.

1.7 Unpacking and inspection

1.7.1 Inspection for damage

The Model 7014 is packaged in a re-sealable, anti-static bag to protect it from damage due to static discharge and from contamination that could degrade its performance. Before removing the card from the bag, observe the following precautions on handling.

Handling Precautions:

1. Always grasp the card by the side edges and shields. Do not touch the board surfaces or components.
2. When not installed in a Model 7001 mainframe, 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.

1.7.2 Shipping contents

The following items are included with every Model 7014 order:

- Model 7014 39-Channel Thermocouple/General Purpose Multiplexer Card
- Model 7014 Instruction Manual
- Additional accessories as ordered.

1.7.3 Instruction manual

The Model 7014 Instruction Manual is three-hole drilled so that it can be added to the three-ring binder of the Model 7001 Instruction Manual. After removing the plastic wrapping, place the manual in the binder following the mainframe instruction manual. Note that a manual identification tab is included and should precede the multiplexer card instruction manual.

If an additional instruction manual is required, order the manual package, Keithley part number 7014-901-00. The manual package includes an instruction manual and any pertinent addenda.

1.7.4 Repacking for shipment

Should it become necessary to return the Model 7014 for repair, carefully pack the unit in its original packing carton or the equivalent, and include the following information:

- Advise as to the warranty status of the thermocouple card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.8 Optional accessories

The following accessories are available for use with the Model 7014:

Model 7014-ST — This isothermal screw terminal connector card is identical to the one provided with the Model 7014 assembly. An extra connector card allows you to wire a second test system.

Model 7401 — This thermocouple wire kit includes 30.5m (100 ft.) of type K (chromel-alumel) thermocouple wire.

2

Multiplexing Basics

2.1 Introduction

This section covers the basics for multiplex switching and is arranged as follows:

- 2.2 **Thermocouple measurement basics:** Describes the theory of thermocouple measurements and a measurement procedure.
- 2.3 **Basic multiplexer configurations:** Covers the basic multiplex configurations; quad 1 × 10 configuration, dual 1 × 20 configuration and single 1 × 40 configuration. The significance of the backplane jumpers is also covered here.
- 2.4 **Typical multiplexer switching schemes:** Explains some of the basic ways a multiplexer can be used to source or measure. Covers single-ended switching, differential (floating) switching and sensing.
- 2.5 **Multiplexer expansion:** Discusses the various configurations that are possible by using multiple cards.

2.2 Thermocouple measurements

2.2.1 Definitions

The following terms are defined as they relate to thermocouple circuits and thermocouple switching cards:

Cold junction — The junction that is held at a stable known temperature. Also known as the reference junction.

Hot junction — The junction of two dissimilar metals that is used to measure an unknown temperature. Also known as the measurement junction.

Isothermal block or cover — The metal block or cover that equalizes the temperature of thermocouple connections on a switching card.

Reference accuracy — The maximum error between sensor and channel inside the isothermal environment. Also known as temperature offset.

Reference channel — The channel that measures the temperature of the isothermal environment.

Reference output — The output signal that represents the temperature of the reference channel. Commonly specified by a temperature coefficient of $\mu\text{V}/^\circ\text{C}$ and an offset voltage in millivolts at 0°C .

2.2.2 Theory

A thermocouple is a junction formed between two dissimilar metals. If the temperature of the thermocouple junction connected to the Model 7014 is T , a voltage E is developed between leads A and B as shown in Figure 2-1. When connected to a voltmeter, two more junctions (C and D) are formed with the meter terminals,

which are usually copper. The measured voltage is proportional to the difference between temperatures T and T_1 .

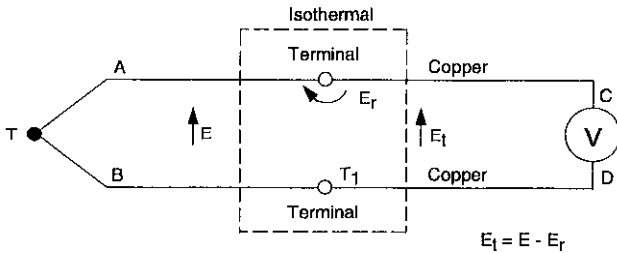


Figure 2-1
Thermocouple measurement

To determine the difference, the thermoelectric properties of the thermocouple are needed. Data is available to determine the voltage versus temperature relationship based on a reference temperature (T_1) of 0°C . Thus, if the thermocouple-to-copper junctions were maintained at 0°C , it would be possible to determine T by referring to the Thermocouple Reference Tables. (See NIST Monograph 125). The tables list temperature as a function of the meter reading E_r . Since these junctions are not 0°C , a voltage E_r is introduced, where:

$$E_t = E - E_r$$

2.2.3 Measurement procedure

The temperature of a thermocouple junction is determined by the following summarized procedure:

- Measure the reference voltage (E_1).
- Calculate the reference temperature (T_1).
- Determine the reference correction voltage (E_r).
- Measure the thermocouple voltage (E_t).
- Calculate the thermocouple correction voltage (E).
- Determine the thermocouple temperature (T).

The complete step-by-step procedure follows:

1. Read the voltage (E_1) developed by the Model 7014 reference junction. Assuming a temperature coefficient of $+200\mu\text{V}/^\circ\text{C}$, and an offset voltage of

$+54.63\text{mV}$ at 0°C , convert the voltage reading to temperature (T_1) with the formula:

$$T_1 = (E_1 - 54.63\text{mV}) / 0.2\text{mV per } ^\circ\text{C}$$

T_1 represents the temperature of the Model 7014 isothermal connections.

2. Using the thermocouple look-up tables or the following formula, convert the temperature (T_1) from step 1 to a voltage. Use tables matching the type of thermocouple connected to the Model 7014. E_r corresponds to the reference voltage that would result if an actual thermocouple were used as a reference junction.

$$E_r = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$$

3. Make a measurement of the voltage (E_t) developed by the thermocouple connected to the Model 7014.
4. Add the reference voltage derived in step 2 to the thermocouple voltage measured in step 3.

$$E = E_r + E_t$$

5. Convert the voltage sum (E) from step 4 to a temperature (T) using either thermocouple look-up tables or the formula:

$$T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$$

The values for a_0 through a_4 for the supported thermocouples are listed in tables located in Appendix A.

2.2.4 Measuring example

A measurement setup uses a Type J thermocouple. The voltage developed by the reference junction (channel 1) is 61.83mV . The voltage read from the thermocouple is $14476\mu\text{V}$.

1. Find the temperature of the isothermal connections. The voltage from the reference sensor is 61.83mV .

$$(61.83\text{mV} - 54.63\text{mV}) / 0.2\text{mV per } ^\circ\text{C} = 36^\circ\text{C}$$

2. Using the appropriate formula or thermocouple look-up tables (see Table 6.3.2 of NIST Monograph 125), find the equivalent voltage developed by a Type J thermocouple at 36°C . This voltage is found to be $1849.1\mu\text{V}$. The formula shown in Step 2 above would yield $1849.085\mu\text{V}$.

3. The voltage developed by the thermocouple is measured as $14476\mu\text{V}$.
4. The sum of the voltage is $14476 + 1849.1$, or $16325.1\mu\text{V}$.
5. Using the appropriate formula or thermocouple look-up tables (see Table A6.2.1 of NIST Monograph 125), find the temperature for a Type J thermocouple corresponding to $16325.1\mu\text{V}$. This temperature is 300.0°C . The formula shown in step 5 above would yield 299.995°C .

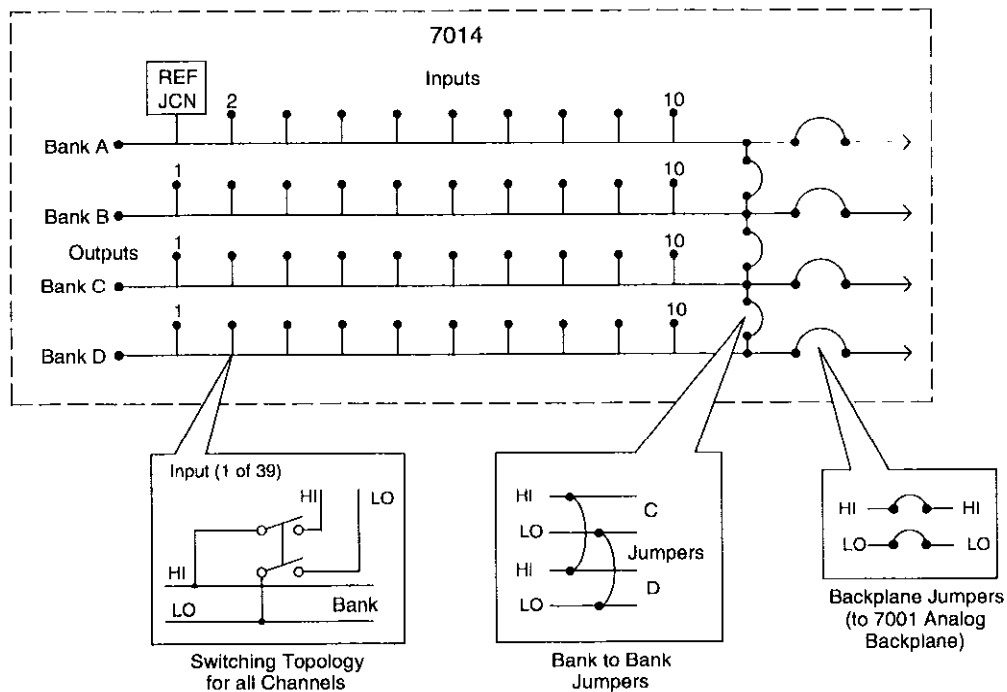
NOTE

A multimeter with a temperature function, such as a Keithley Model 2001, will perform the measurement

procedure automatically, except for closing and opening channels on external cards.

2.3 Basic multiplexer configurations

A simplified schematic of the Model 7014 Thermocouple Card is shown in Figure 2-2. It is organized as four 1×10 multiplexer banks. Each bank has 10 inputs and one output. (Note that Input 1 of Bank A is the reference junction.) Two-pole switching is provided for each multiplexer input, with HI and LO switched. Two or more banks can be jumpered together to expand multiplexer inputs, and backplane jumpers provide bank connections to a second card installed in a Model 7001 mainframe.



Note : Factory Configuration shown

Figure 2-2
Model 7014 simplified schematic

2.3.1 Multiplexer bank-to-bank jumpers

NOTE

When mixing applications on a Model 7014 card, bank jumpers can be removed to isolated different signal levels. However, switching different levels simultaneously may affect the card's reference accuracy.

Jumpers are installed on the connector card to connect multiplexer banks together to form a multiplexer of 1 × 39. Each jumper set connects two adjacent banks together. These jumper sets are included with the Model 7014.

The bank-to-bank jumpers allow you to configure the multiplexer card in a variety of ways. Typical multi-

plexer configurations include:

- Four 1 × 10 multiplexers; no jumpers installed (Figure 2-3).
- Two 1 × 20 multiplexers; Bank A jumpered to Bank B, Bank C jumpered to Bank D (Figure 2-4).
- One 1 × 40 multiplexer; all bank-to-bank jumpers installed (Figure 2-5).

Other combinations are possible, including multiplexers of various sizes (in multiples of 10 channels). For example, you could install jumpers to configure the card as one 1 × 30 and one 1 × 10 multiplexer.

Refer to Section 3 for information on installing bank-to-bank jumpers.

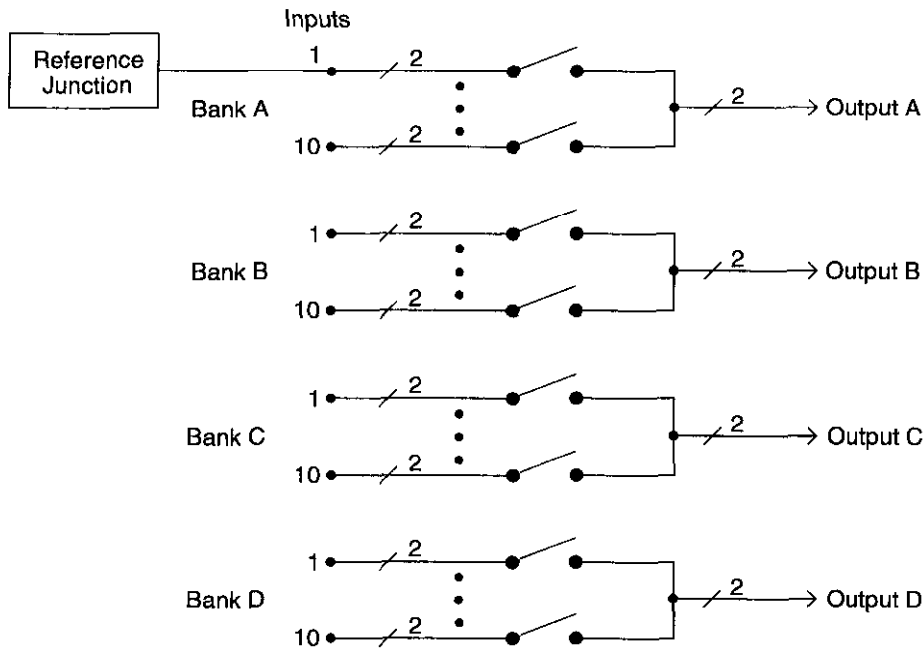


Figure 2-3
Four 1 × 10 multiplexer configuration (jumpers not installed)

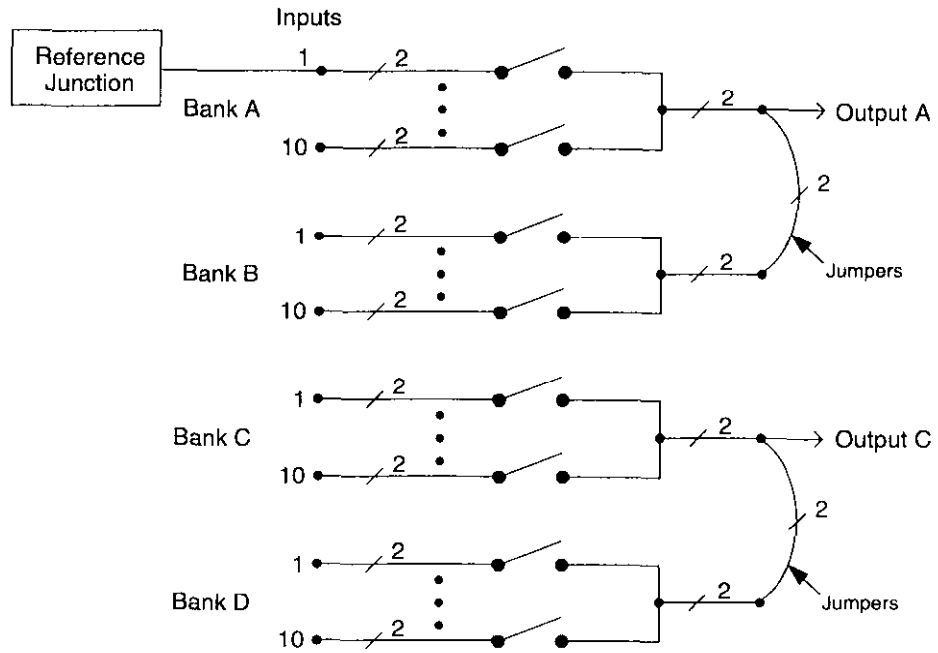


Figure 2-4
Two 1 × 20 multiplexer configuration (jumpers installed)

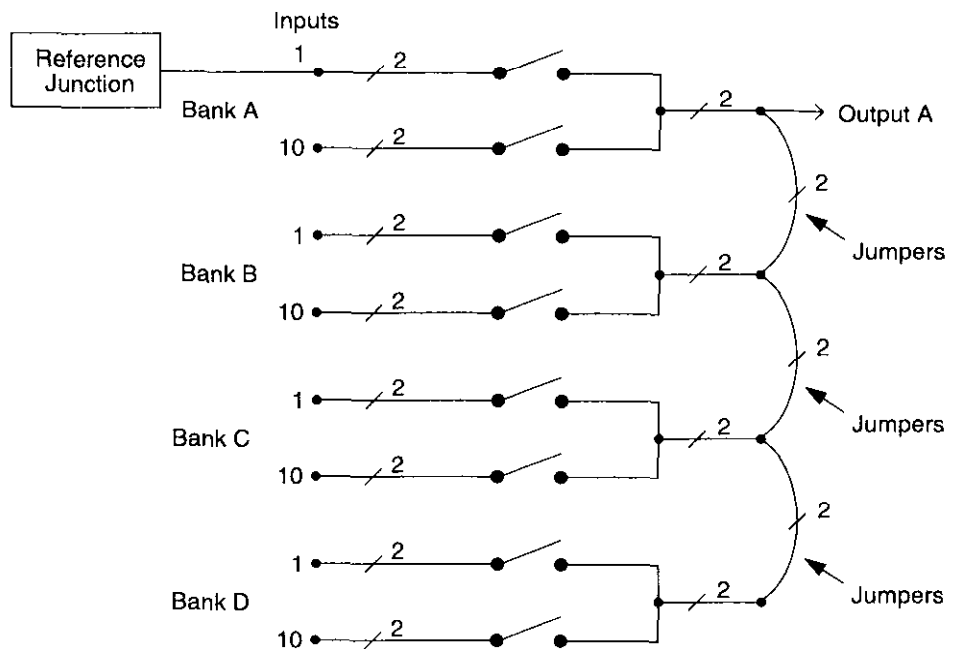


Figure 2-5
One 1 × 40 multiplexer configuration (jumpers installed)

2.3.2 Backplane jumpers

NOTE

When mixing applications in a Model 7001 mainframe, backplane jumpers on 701X-series cards can be removed to isolate different signal levels. However, switching different levels simultaneously may affect the card's reference accuracy.

the multiplexer card are connected to the analog backplane of the Model 7001 allowing expansion with a second 701X-series card installed in the mainframe. With the jumpers removed (cut), the multiplexer card is isolated from another card installed in the mainframe.

The three-pole analog backplane of the Model 7001 mainframe is shown in Figure 2-6. Through this analog backplane the banks of a Model 7014 multiplexer card, installed in one slot, can be connected to the banks (or rows) of a compatible card installed in the other slot of the mainframe.

There are four pairs of backplane jumpers located on the relay card. With the jumpers installed, the banks of

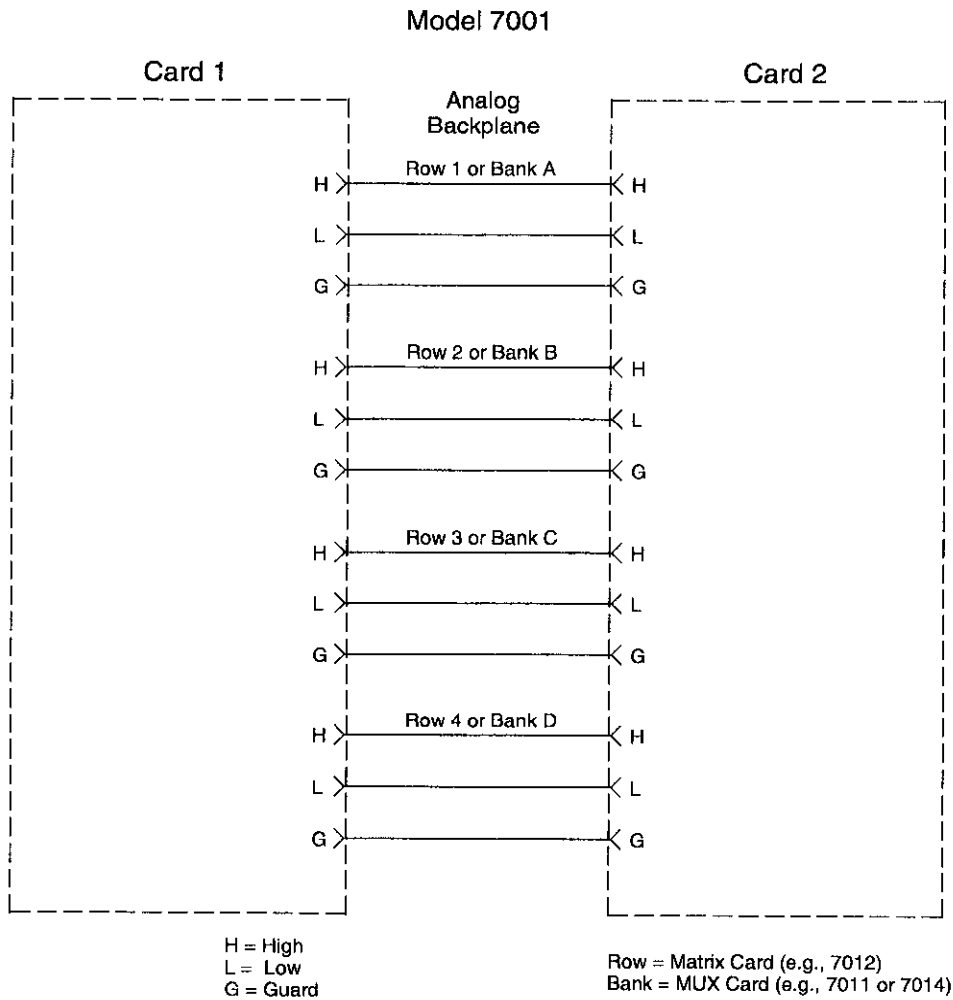


Figure 2-6
Model 7001 analog backplane

Figure 2-7 shows how each bank of the Model 7014 is connected to the backplane. Notice that since the Model 7014 is a two-pole card, there is no connection made to the Guard terminal of the backplane. The Model 7014 is shipped from the factory with the backplane jumpers installed.

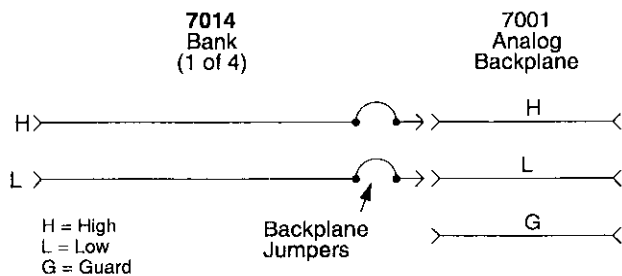


Figure 2-7
Bank connections to backplane

Removing (cutting) the backplane jumpers isolates the card from the backplane, and subsequently, any card installed in the other slot. For information on removing the jumpers, refer to Section 3.

NOTE

The Model 7001 does not provide an analog backplane for the non-701X se-

ries cards. As a result, any of these cards installed in one slot in the main-frame is electrically isolated from any card installed in the other slot. The only way to connect a Model 7014 to one of these cards is to wire them together.

2.4 Typical multiplexer switching schemes

The following paragraphs describe some basic switching schemes that are possible with a two-pole switching multiplexer. These switching schemes include some various shielding configurations to help minimize noise pick up in sensitive measurement applications. These shields are shown connected to chassis ground. For some test configurations, shielding may prove to be more effective connected to circuit common. Chassis ground is accessible at the rear panel of the Model 7001.

2.4.1 Thermocouple switching

In a typical switching configuration for thermocouples, all banks on the Model 7014 are connected together. As shown in Figure 2-7, the voltage measuring instrument is connected to one of the card outputs, and up to 39 thermocouples are connected to the inputs.

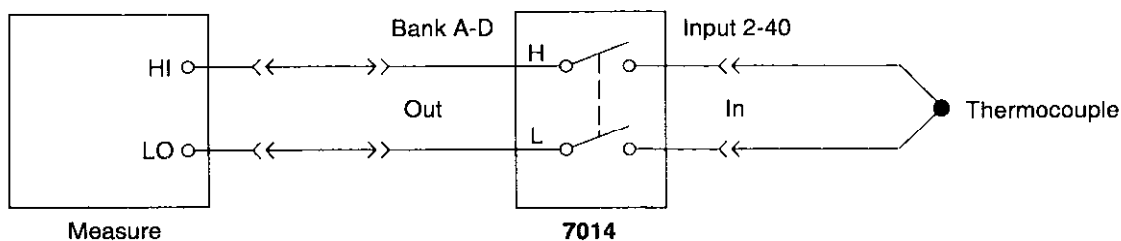


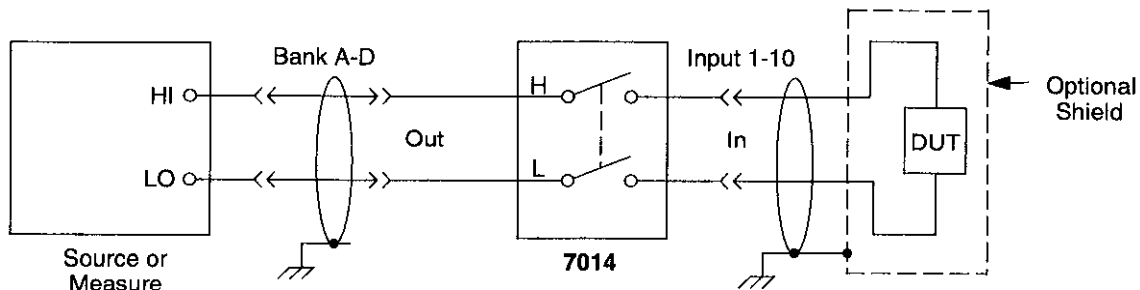
Figure 2-8
Thermocouple switching example

2.4.2 Single-ended switching

In the single-ended switching configuration, the source or measure instrument is connected to the DUT through a single pathway as shown in Figure 2-9. The instrument is connected to the output of one of the banks and the DUT is shown connected to one of the inputs for that bank.

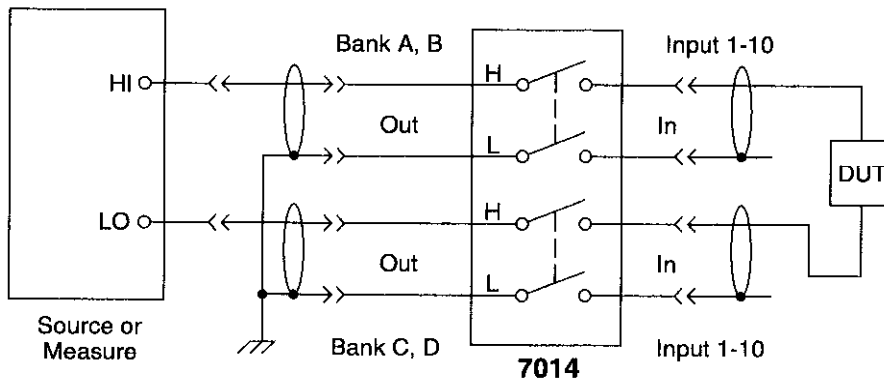
2.4.3 Differential switching

The differential or floating switching configuration is shown in Figure 2-10. The advantage of using this configuration is that the terminals of the source or measure instrument are not confined to the same pathway. Each terminal of the instrument can be switched to any available input in the test system.



Note: There are no user connections for the reference junction (Bank A, Input 1).

Figure 2-9
Single-ended switching example



Note: There are no user connections for the reference junction (Bank A, Input 1).

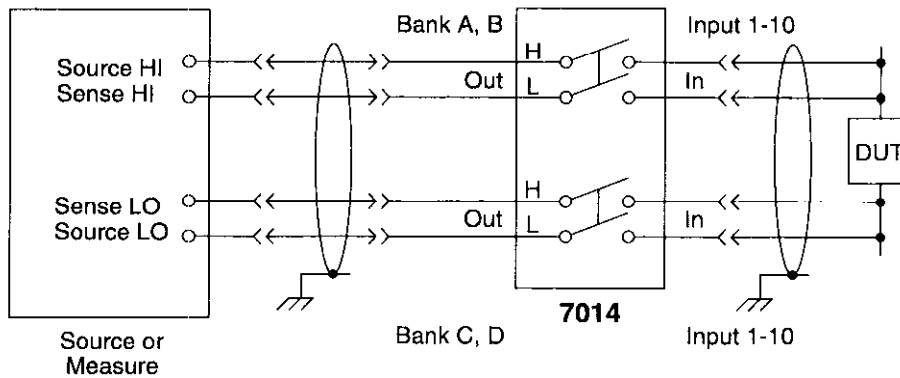
Figure 2-10
Differential switching example

2.4.4 Sensing

Figure 2-11 shows how the multiplexer card can be configured to use instruments that have sensing capability. The main advantage of using sensing is to cancel the effects of switch card path resistance ($<1\Omega$) and the resistance of external cabling. Whenever path resistance is a consideration, sensing should be used.

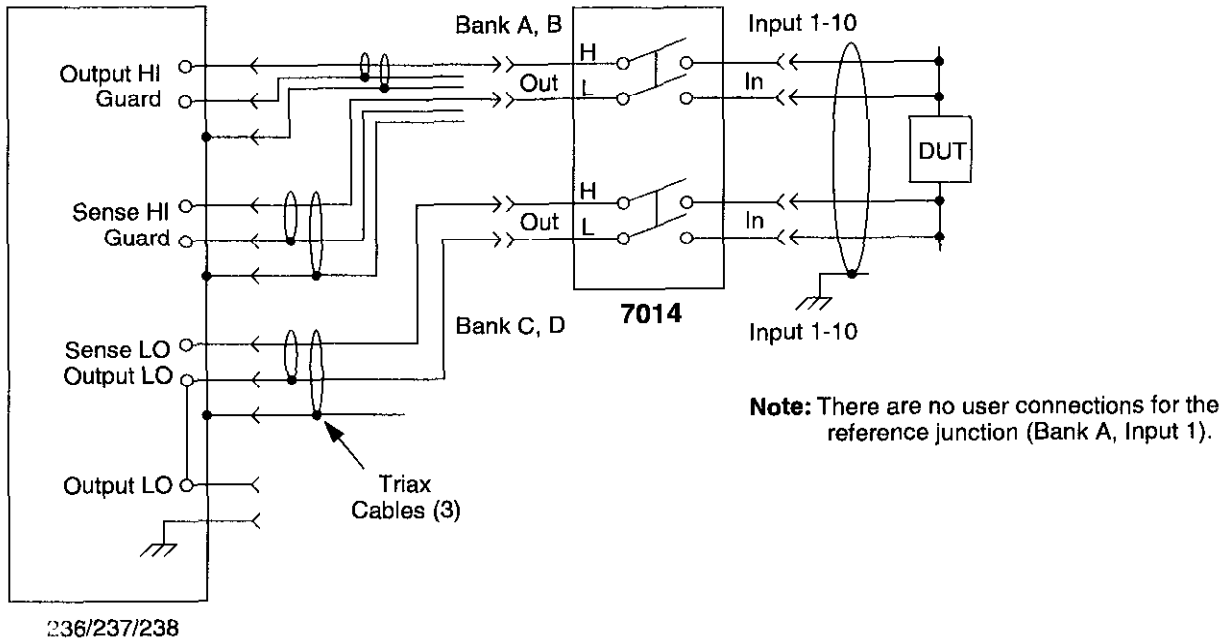
2.4.5 SMU connections

Figure 2-12 shows how to connect a Keithley Model 236, 237 or 238 Source Measure Unit to the multiplexer card. By using triax cables that are unterminated at one end, the driven guard and chassis ground are physically extended all the way to the card.



Note: There are no user connections for the reference junction (Bank A, Input 1).

Figure 2-11
Sensing example



WARNING : Hazardous voltages may be present on GUARD. Make sure all cable shields are properly insulated before applying power.

Figure 2-12
SMU connections

2.5 Multiplexer expansion

With the use of additional switching cards and mainframes, larger systems can be configured. Each Model 7001 Switch System mainframe will accommodate up to two cards, and up to six mainframes can be connected together. Thus, a switch system using as many as 12 cards can be configured.

2.5.1 Two-card switching systems

Each Model 7001 Switch System mainframe can accommodate two cards to allow the following switching configurations.

NOTE

When mixing applications in a Model 7001 mainframe, backplane jumpers on 701X-series cards can be removed to isolate different signal levels. However, switching different levels simultaneously may affect the card's reference accuracy.

Separate switching systems

Two single-card systems can be configured by removing the backplane jumpers from one of the cards. The two cards will be controlled by the same mainframe, but they will be electrically isolated from each other. Figure 2-13 shows an example using two Model 7014 multiplexer cards.

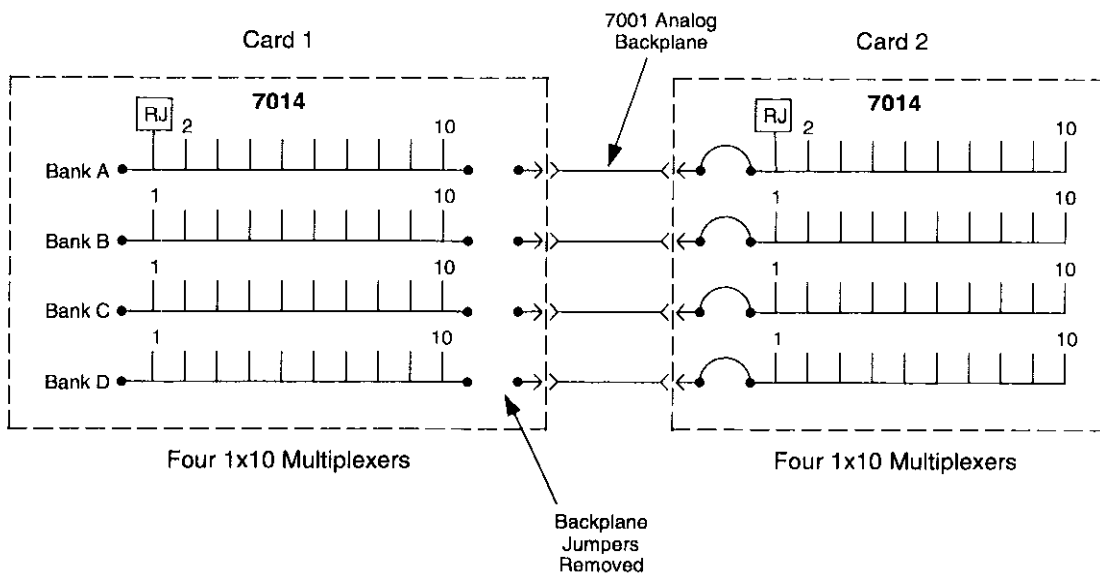


Figure 2-13
Two separate multiplexer systems

Multiplexer input expansion

You can double the number of multiplexer inputs by simply installing two "as shipped" Model 7014s in the Model 7001 mainframe. By leaving the backplane jumpers installed, the banks of the multiplexer card installed in slot 1 (CARD 1) are automatically connected to the banks of the multiplexer card installed in slot 2 (CARD 2) through the analog backplane.

Figure 2-14 shows an example of input expansion. Each Model 7014 card is configured as four 1 × 10 multiplexers. By connecting the banks together (via Model 7001 analog backplane), the resultant multiplexer system has 20 inputs for each of the four banks. Notice that if all the bank-to-bank jumpers (for both cards) were installed, the result would be a single 1 × 80 multiplexer.

Mixing card types

Different types of cards can be used together to create some unique switching systems. For example, you

could have a Model 7014 multiplexer card installed in one slot and a Model 7012 matrix card installed in the other slot.

Figure 2-15 shows a possible switching system using a matrix card and a multiplexer card. The backplane jumpers for both the matrix and multiplexer cards must be installed. This allows matrix rows to be connected to multiplexer banks. On the multiplexer card, the bank-to-bank jumpers must be removed to maintain isolation between matrix rows. See the instruction manual for the Model 7012 for complete information on the matrix card.

2.5.2 Mainframe multiplexer expansion

Multiplexer systems using up to 12 multiplexer cards are possible if you use six Model 7001 mainframes together. Each Model 7014 added to the system provides 39 additional inputs. Paragraph 3.4.3 explains how to connect a test system using two mainframes.

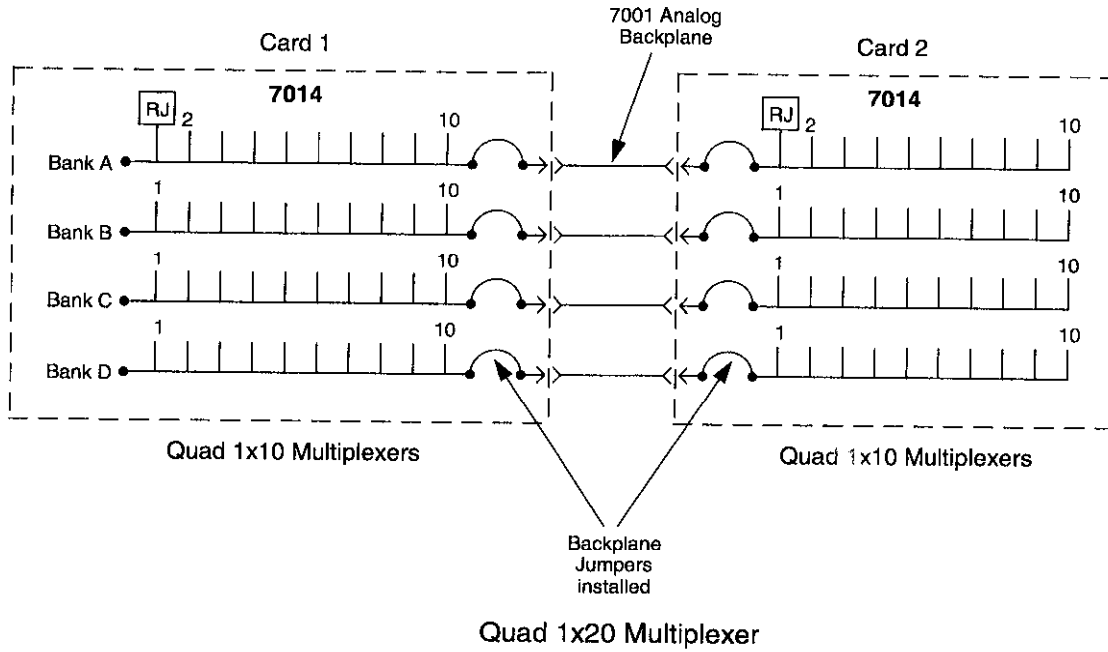
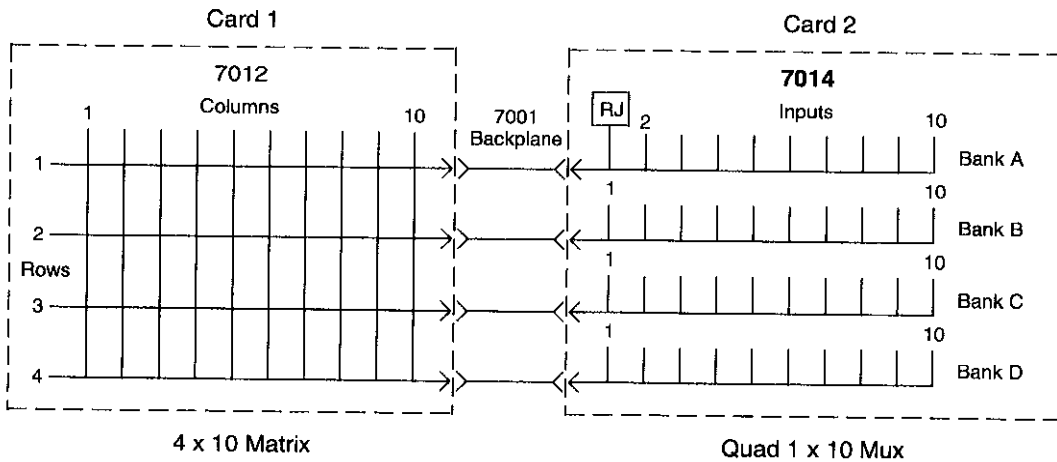


Figure 2-14
Multiplexer input expansion example



Notes : 1. Models 7014 and 7012 backplane jumpers must be installed.
2. Model 7014 bank-to-bank jumpers must be removed.

Figure 2-15
Mixed card type example

3

Card Connections & Installation

3.1 Introduction

WARNING

The procedures in this section are intended only for qualified service personnel. 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 information in this section is arranged as follows:

3.2 Handling precautions: Explains precautions that must be followed to prevent contamination to the multiplexer card assembly. Contamination could degrade the performance of the multiplexer card.

3.3 Connections: Covers the basics for connecting external circuitry to the isothermal screw terminal connector card.

3.4 Typical connection schemes: Provides some typical connection schemes for single card, two-card and two-mainframe system configurations.

3.5 Model 7014 installation: Provides a procedure to install the multiplexer card assembly in the Model 7001 mainframe.

3.2 Handling precautions

To maintain high impedance isolation, care should be taken when handling the relay card to avoid contamination from such foreign materials as body oils. Such contamination can substantially lower leakage resistances, thus degrading performance.

To avoid possible contamination, always grasp the relay and connector cards by the side edges or shields. Do not touch the board surfaces or components. On connectors, do not touch areas adjacent to the electrical contacts. Dirt build-up over a period of time is another possible source of contamination. To avoid this problem, operate the mainframe and multiplexer card in a clean environment.

If a card becomes contaminated, it should be thoroughly cleaned as explained in paragraph 5.2.

3.3 Connections

This paragraph provides the basic information needed to connect your external test circuitry to the multiplexer card. It includes the installation of the bank-to-bank jumpers on the connector card, installation/removal of backplane jumpers on the relay card, and detailed information on making external connections to the connector card.

WARNING

The following connection information is intended to be used by qualified service personnel. Failure to recognize and observe standard safety precautions could result in personal injury or death.

3.3.1 Bank-to-bank jumpers

As explained in paragraph 2.3.1, the banks of the multiplexer card can be connected together (using plug-in jumpers) to form larger multiplexers. The locations of the bank-to-bank jumper terminals are shown in Figure 3-1.

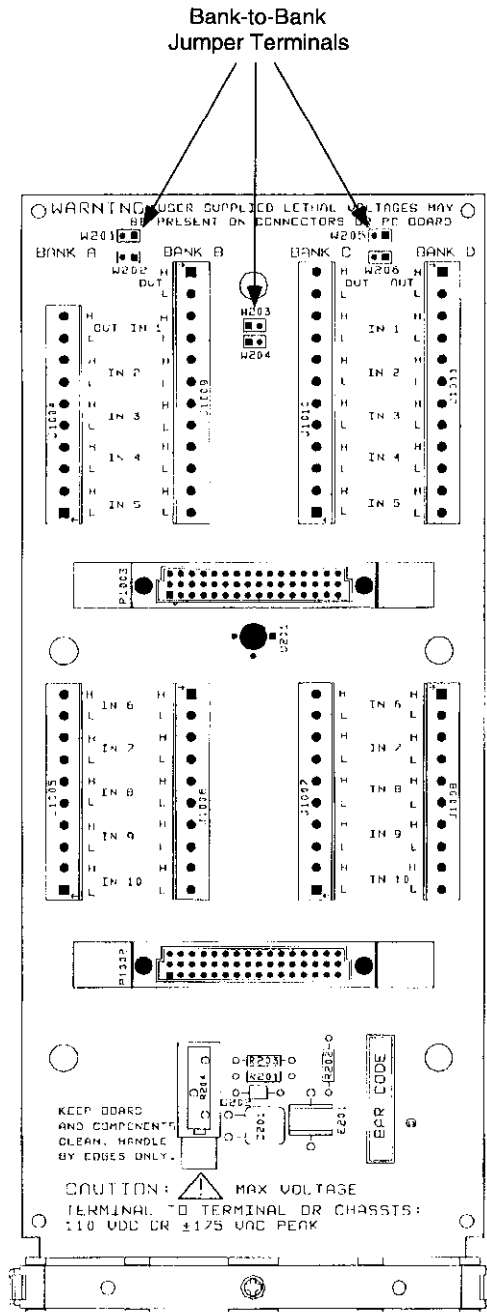


Figure 3-1
Bank-to-bank jumper locations

Terminal identification is provided by Figure 3-2. On the drawing, the six terminal pairs are labeled W201 through W206. The top three terminal pairs (W201, W203 and W205) are used to connect the HI terminals of the banks together. The bottom terminal pairs (W202, W204 and W206) are used to connect the LO terminals of the banks together. Table 3-1 summarizes the effects of each jumper.

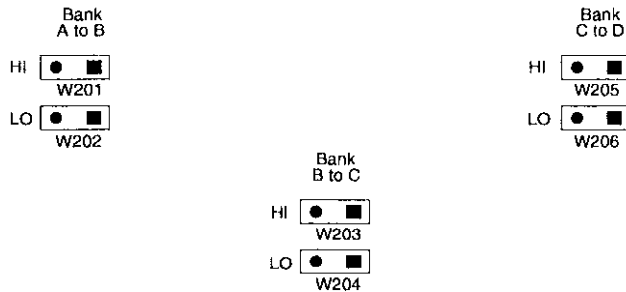


Figure 3-2
Bank-to-bank jumper terminal identification

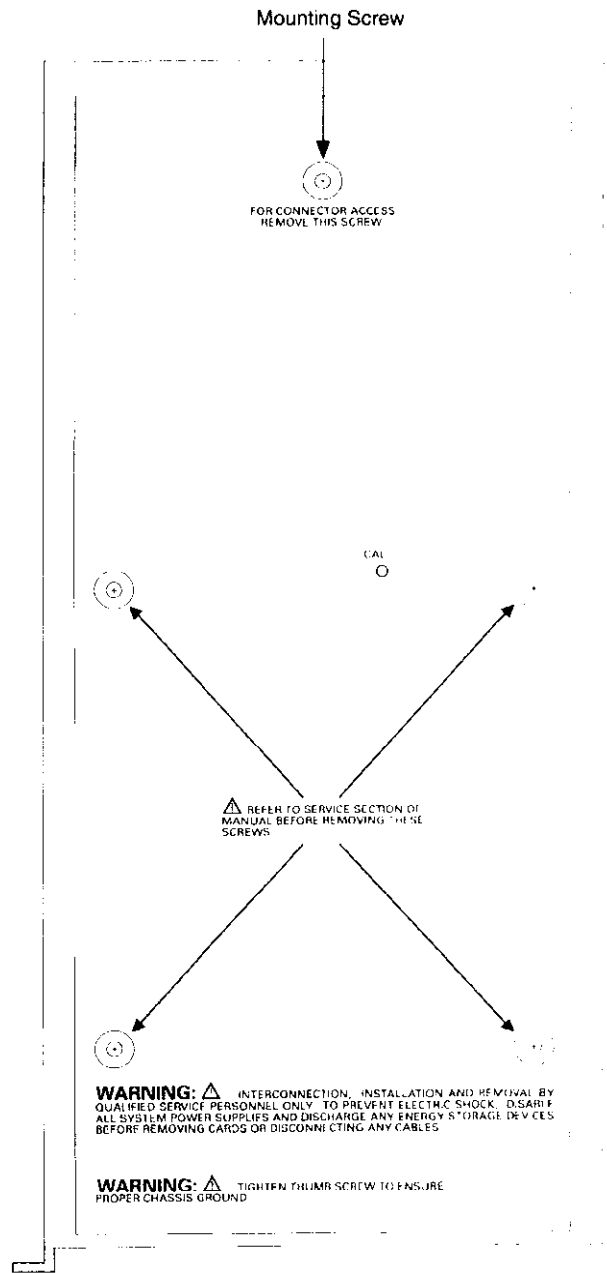
Table 3-1
Bank-to-bank jumpers (refer to Figure 3-2)

Installed jumper	Effect
W201 W202	Connect Bank A HI to Bank B HI Connect Bank A LO to Bank B LO
W203 W204	Connect Bank B HI to Bank C HI Connect Bank B LO to Bank C LO
W205 W206	Connect Bank C HI to Bank D HI Connect Bank C LO to Bank D LO

Referring to Figure 3-1 for jumper locations, perform the following steps to install bank-to-bank jumpers:

1. If mated together, separate the relay card from the connector card by removing the mounting screw and pulling the two cards away from each other (see Figure 3-4). Remember to only handle the cards by the edges and shields to avoid contamination.
2. Refer to Figure 3-2 and Table 3-1 to determine which jumpers to install.

3. Using Figure 3-4 as a guide, install the jumpers on the appropriate terminal pairs.



CAUTION: As shown on the connector board's isothermal cover, only one screw is removed to access the screw terminal blocks. The other four screws must remain to preserve the thermal integrity of the board. (Refer to the Service Information section for their removal.)

Figure 3-3
Connector card mounting screw

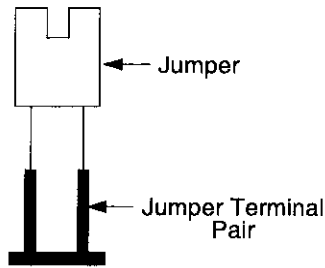


Figure 3-4
Bank-to-bank jumper installation

3.3.2 Backplane jumpers

The Model 7001 mainframe has an analog backplane that allows the banks of a Model 7014 multiplexer card to be internally connected to a compatible switching card installed in the other slot (see paragraph 2.5.1 for details).

The backplane jumpers for the multiplexer card assembly are located on the relay card as shown in Figure 3-5. The card is shipped from the factory with the jumpers installed.

Jumper removal

Perform the following steps to remove backplane jumpers:

1. If mated together, separate the relay card from the connector card by removing the mounting screw and pulling the two cards away from each other (see Figure 3-4). Remember to only handle the cards by the edges and shields to avoid contamination.
2. Use Figure 3-5 to locate the jumper(s) that are to be removed.
3. It is not necessary to physically remove the jumpers from the PC board. Using a pair of wire cutters, cut one lead of each jumper.

Jumper installation

Referring to Figure 3-5 for jumper locations, perform the following steps to install backplane row jumpers:

1. If mated together, separate the relay card from the connector card by removing the mounting screw and pulling the two cards away from each other (see Figure 3-4). Remember to only handle the cards by the edges and shields to avoid contamination.
2. Physically remove a cut jumper by unsoldering it from the PC board.
3. Install a new #22 AWG jumper wire (Keithley P/N J-15) and solder it to the PC board.
4. Remove the solder flux from the PC board. The cleaning procedure is explained in paragraph 5.2.

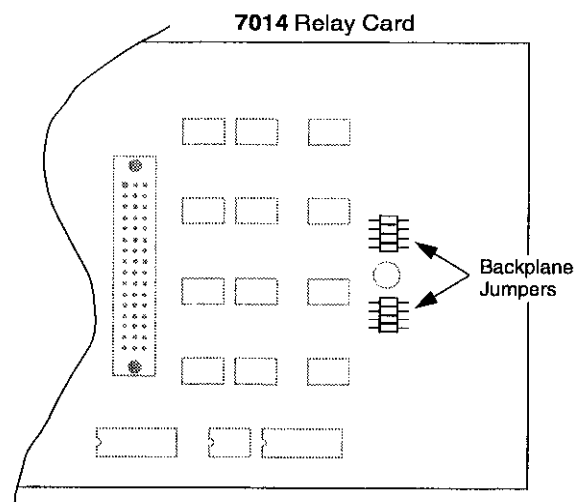


Figure 3-5
Backplane jumpers

3.3.3 Screw terminal connector card

The screw terminal connector card is shown in Figure 3-6. Connections are made directly to the screw terminals of the eight terminal blocks. Each screw terminal will accommodate #16-22 AWG wire.

Wiring procedure

Perform the following procedure to wire circuitry to the screw terminal connector card:

WARNING

Make sure all power is off and any stored energy in external circuitry is discharged.

1. If mated together, separate the connector card from the relay card by removing the mounting screw and pulling the two cards away from each other (see Figure 3-4). Remember to only handle the cards by the edges and shields to avoid contamination.
2. Using an insulated screwdriver, connect the circuitry to the appropriate terminals. Figure 3-7 shows how the output of Bank C would be connected to a DMM. (Use copper wire for the output connections.)

WARNING

Use properly insulated wire for applications exceeding 42.4V peak or 30V RMS.

3. Referring to Figure 3-8, remove the top half of the cable clamp as follows:
 - A. Loosen the cable clamp screw enough to disengage it from the bottom half of the cable clamp.
 - B. Using your thumb and forefinger, press the retaining clips inward and, with your other hand, remove the top half of the clamp.

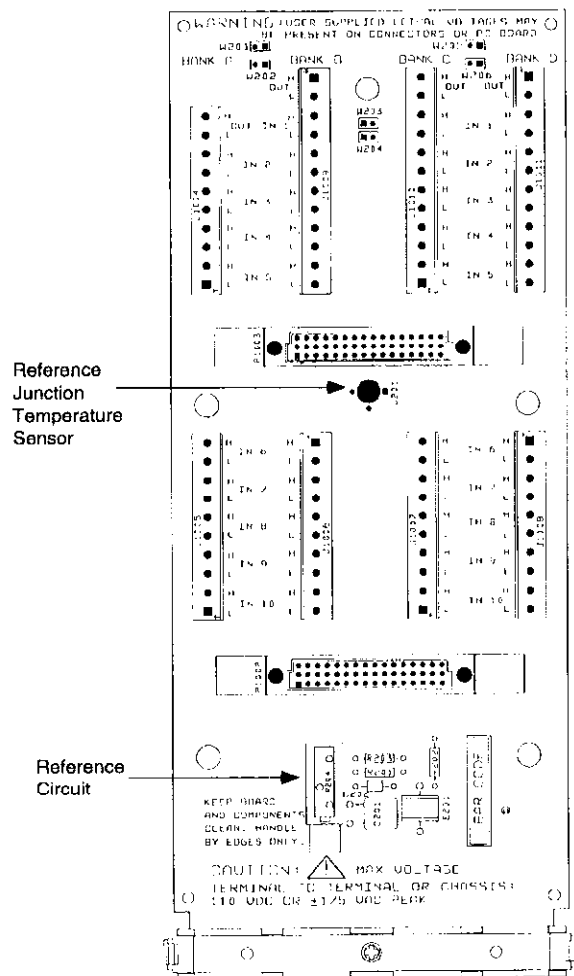


Figure 3-6
Model 7014 screw terminal connector card

4. Route wires under wire guide/ connector shim. Do not route wires across the reference circuit.
5. Route the wires through the bottom half of the cable clamp.
6. Replace the top half of the clamp. It simply snaps onto the bottom half of the clamp. Tighten the cable clamp screw. The clamp serves as a strain relief for terminal block wires.
7. Mate the connector card to the relay card and tighten the mounting screw. The Model 7014 is now ready to be installed in the Model 7001 mainframe. See paragraph 3.5 for details.

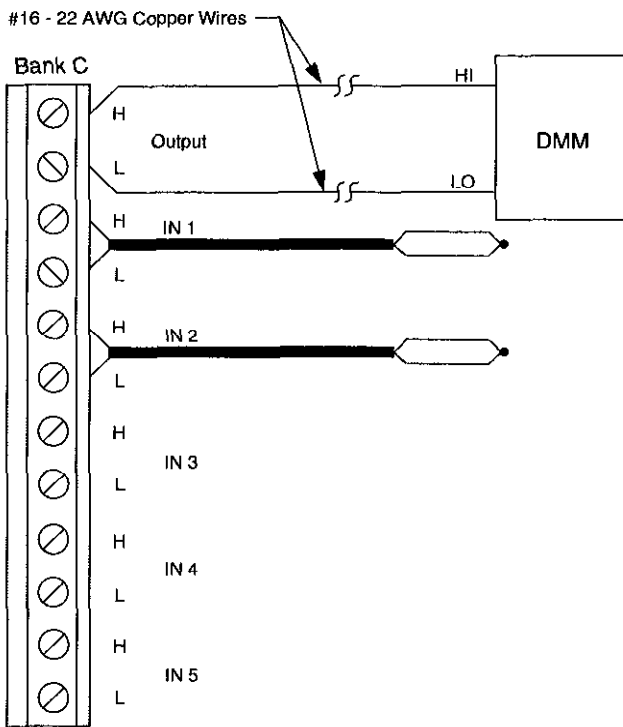


Figure 3-7
Typical screw terminal connections

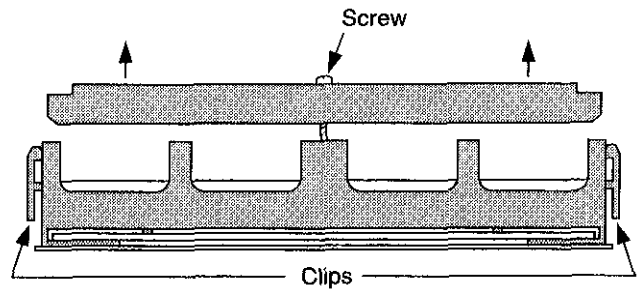


Figure 3-8
Cable clamp for screw terminal connector card

3.4 Typical connection schemes

The following information provides some typical connection schemes for single card, two-card and two-mainframe system configurations. Keep in mind that these are only examples to demonstrate various ways to wire a test system. Connection details are provided in paragraph 3.3.

3.4.1 Single card system

The single card systems in Figure 3-9 and Figure 3-10 use the isothermal screw terminal connector card. With this card, single conductor connections are made directly from the terminal blocks of the connector card to instrumentation and DUTs.

When using a single card system, you will want to make sure that the card remains electrically isolated from any other switching cards. There are several ways to ensure isolation for a single card in the Model 7001 mainframe:

1. Vacate the other mainframe slot. If there is a Model 701X card installed in the other slot, remove it.
2. Remove the backplane jumpers on the multiplexer card. This will disconnect the card from the analog backplane of the mainframe.
3. Remove the backplane jumpers from the switching card installed in the other slot.

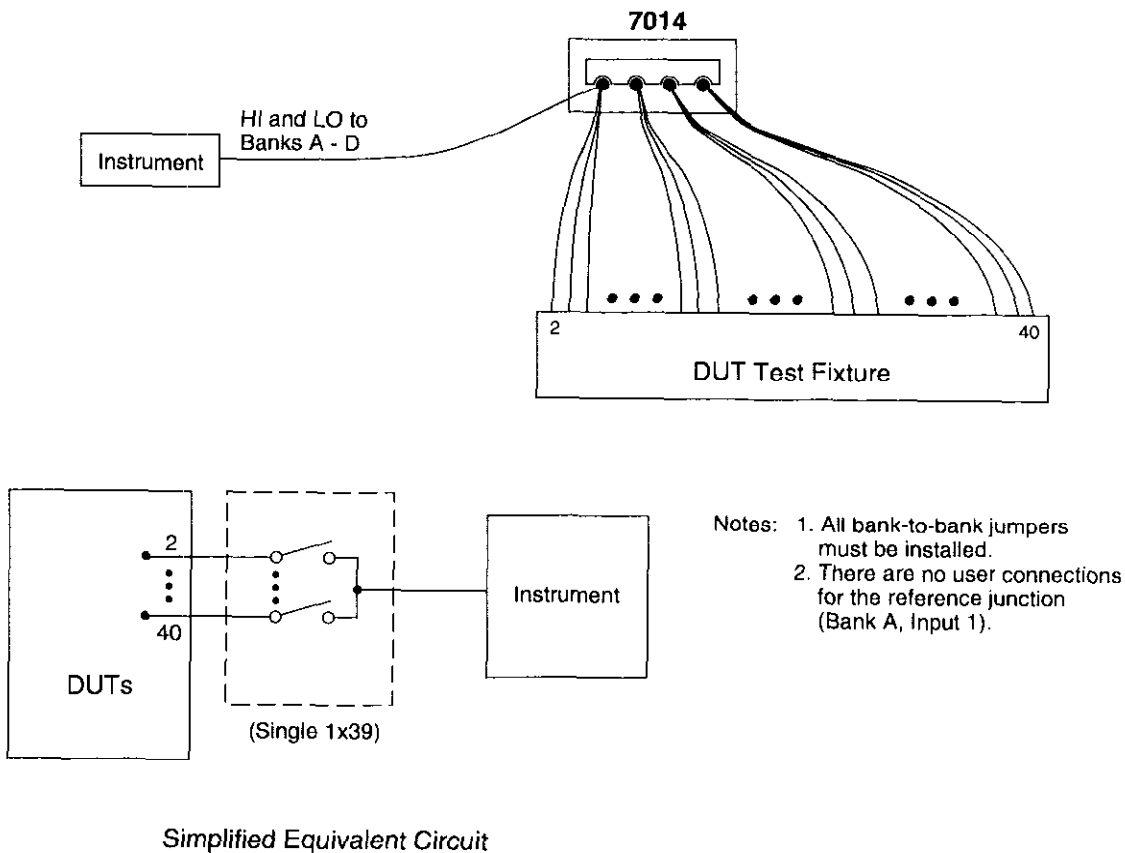
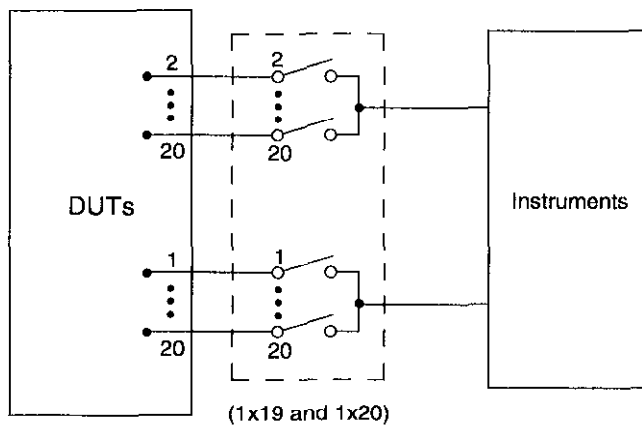
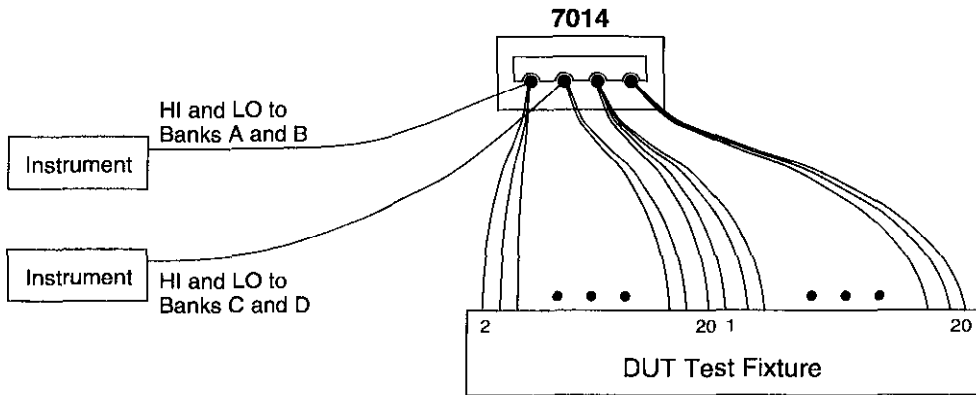


Figure 3-9
Single card (1 × 39) system example



- Notes: 1. Bank-to-bank jumpers installed as follows :
Bank A connected to Bank B
Bank C connected to Bank D
2. There are no user connections for the reference junction (Bank A, Input 1).

Figure 3-10
Single card (1 × 19 and 1 × 20) system example

3.4.2 Two-card system

Figure 3-11 shows a system using two multiplexer cards installed in one Model 7001 mainframe to configure a single 1×80 multiplexer system. Each card is configured as a single 1×40 multiplexer. To accomplish this, all bank-to-bank jumpers (both cards) are installed to connect Banks A, B, C, and D together. By leaving the backplane jumpers of both cards installed, the banks of Card 1 are connected to the banks of Card 2 through the analog backplane of the Model 7001 mainframe resulting in the 1×80 configuration.

Figure 3-11 shows how external connections can be made for the connector card. Single conductor connections are made directly from the screw terminals of the connector card to the instrument and DUT.

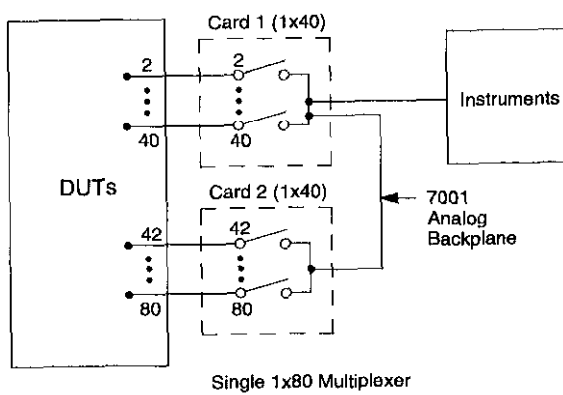
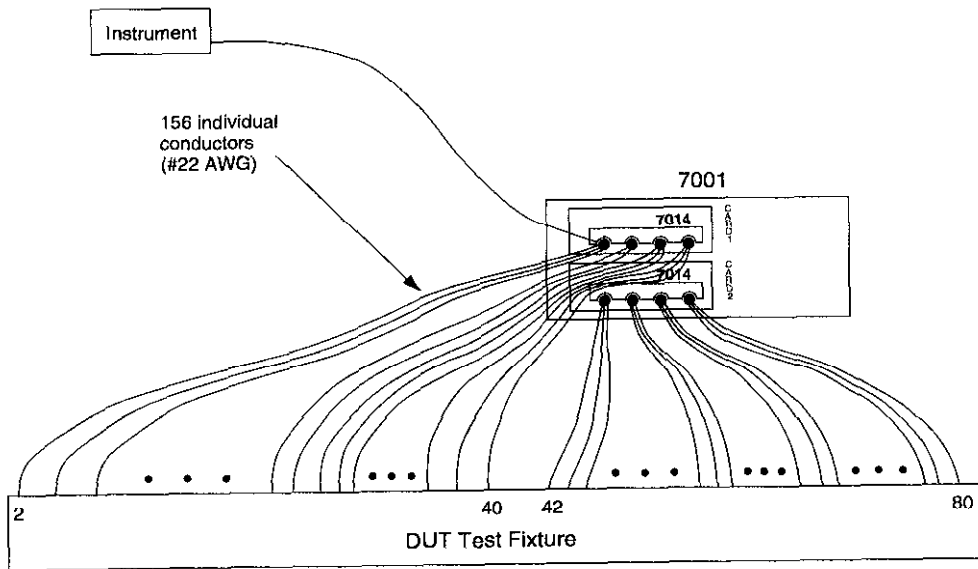
3.4.3 Two-mainframe system

Figure 3-12 shows a system using three multiplexer cards installed in two Model 7001 mainframes to con-

figure a single 1×120 multiplexer system. Each card is configured as a single 1×40 multiplexer. To accomplish this, bank-to-bank jumpers of all three cards must be installed to connect Banks A, B, C, and D together.

By leaving the backplane jumpers of the cards in mainframe #1 installed, the banks of Card 1 are connected to the banks of Card 2 through the analog backplane of the Model 7001 mainframe resulting in a 1×80 configuration. External bank connections from the instrument to the card in the second mainframe connect the banks of all three cards together to form the 1×120 multiplexer system. This system is similar to the Two-card System (see previous paragraph) except that a third multiplexer card (installed in a second mainframe) is added.

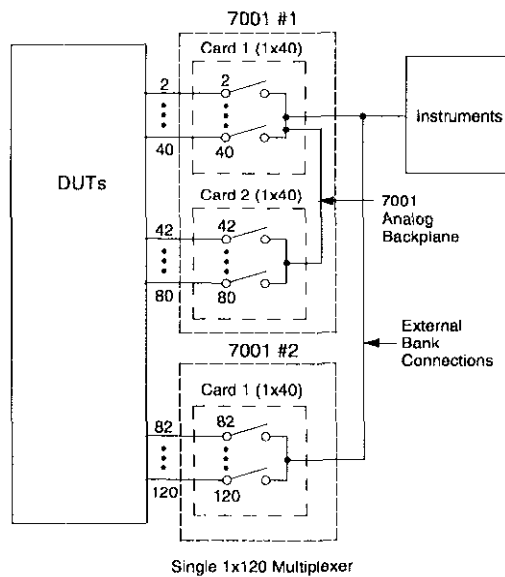
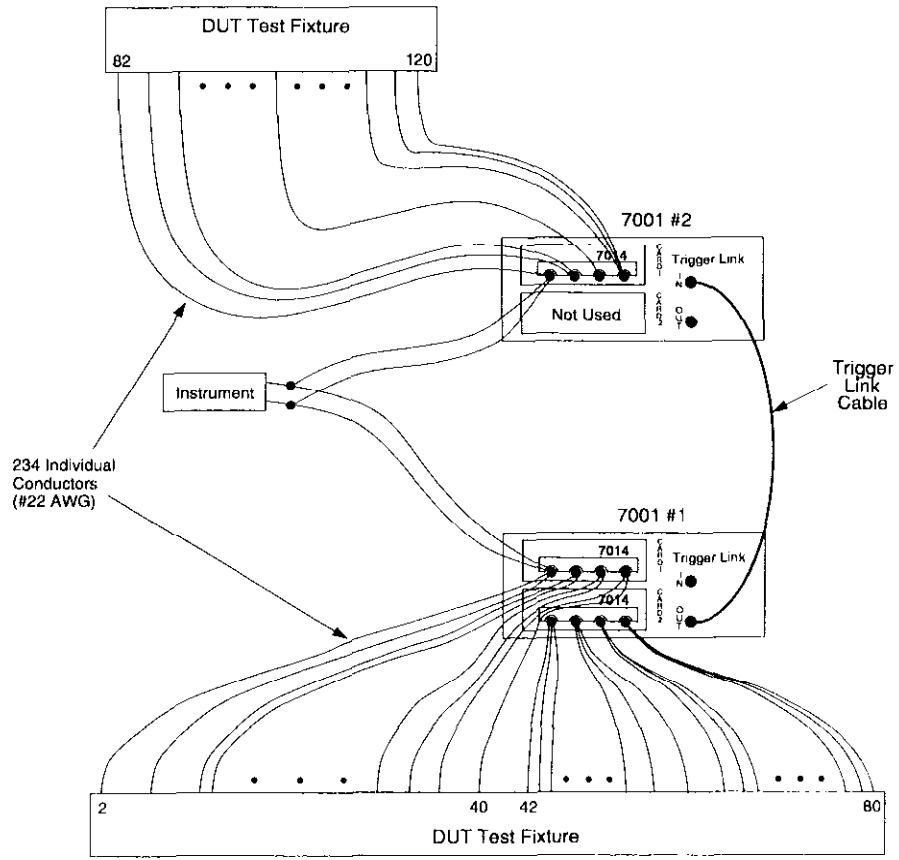
Figure 3-12 shows connections for the connector card. Single conductor connections are made directly from the screw terminals of the connector card to the instrument and DUT.



- Notes:
1. All bank-to-bank jumpers (both cards) must be installed.
 2. Backplane jumpers (both cards) must be installed.
 3. There are no user connections for the reference junctions (Bank A, input 1 of each card).

Simplified Equivalent Circuit

Figure 3-11
Two-card system example



- Notes:
1. Backplane jumpers for both cards installed in 7001 #1 must be installed.
 2. All bank-to-bank jumpers, on all three cards, must be installed.
 3. There are no user connections for the reference junction (Bank A, Input 1 of each card).

Simplified Equivalent Circuit

Figure 3-12
Two-mainframe system example

3.5 Model 7014 installation and removal

This paragraph explains how to install and remove the Model 7014 multiplexer card assembly from the Model 7001 mainframe.

WARNING

Installation or removal of the Model 7014 is to be performed by qualified service personnel. Failure to recognize and observe standard safety precautions could result in personal injury or death.

NOTE

Make sure your external circuitry is wired to the card (as explained in paragraph 3.3.1) before installing the card assembly in the Model 7001 mainframe.

CAUTION

To prevent contamination to the multiplexer card that could degrade performance, only handle the card assembly by the edges and shields.

Multiplexer card installation

Perform the following steps to install the multiplexer card assembly in the Model 7001 mainframe:

WARNING

Turn off power from all instrumentation (including the Model 7001 mainframe) and disconnect their line cords. Make sure all power is removed and any stored energy in external circuitry is discharged.

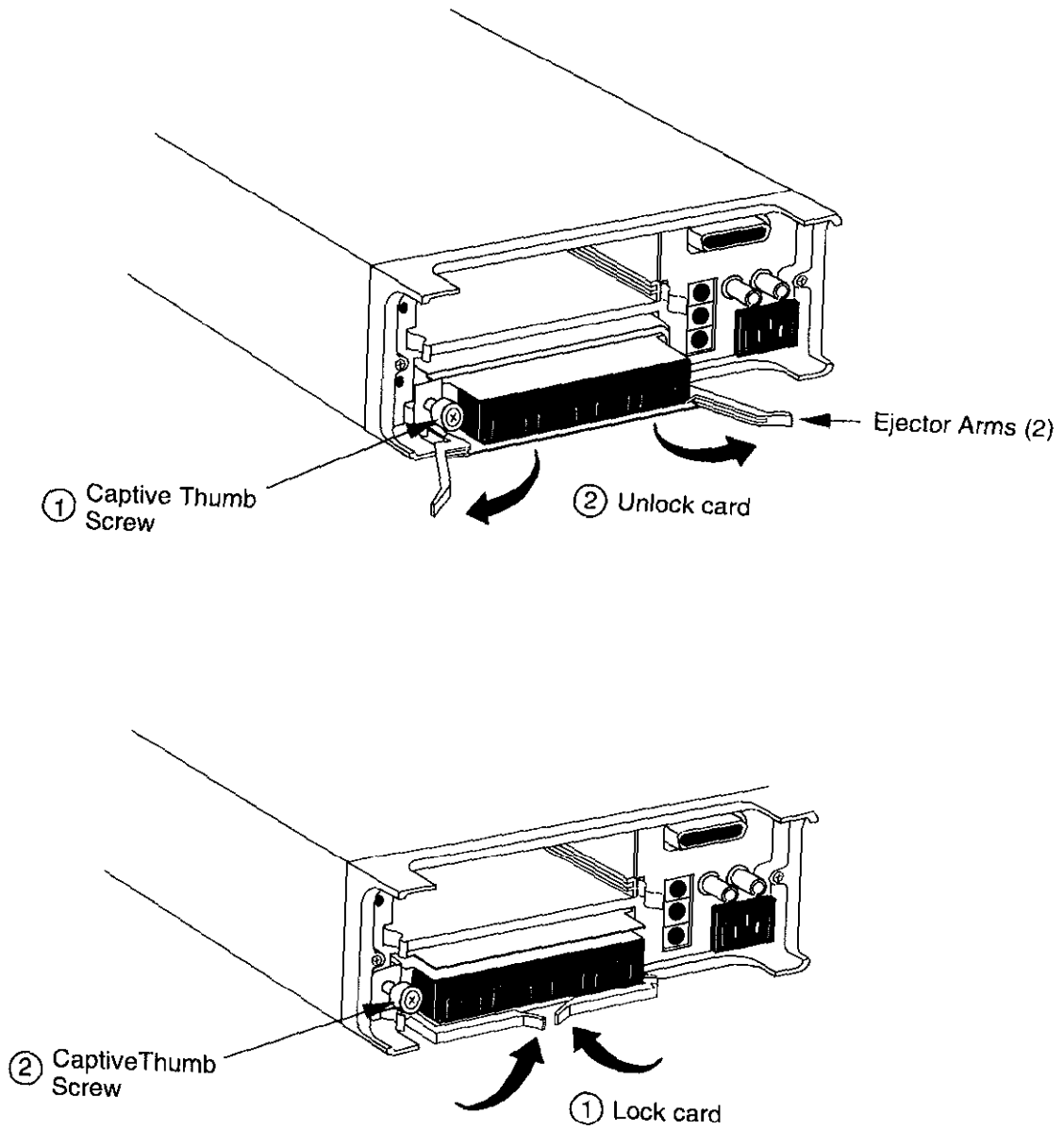
1. Mate the connector card to the relay card if they are separated. Install the supplied 4-40 screw at the end of the card to secure the assembly (see Figure 3-4). Make sure to handle the cards by the edges and shields to prevent contamination.
2. Facing the rear panel of the Model 7001, select the slot (CARD 1 or CARD 2) that you wish to install the card in.
3. Referring to Figure 3-13, feed the multiplexer card assembly into the desired slot such that the edges of the relay card ride in the rails.
4. With the ejector arms in the unlocked position, push the card assembly all the way into the mainframe until the arms engage into the ejector cups. Then push both arms inward to lock the card into the mainframe.
5. Tighten the thumb screw shown in Figure 3-13.

WARNING

Tighten the thumb screw to ensure proper chassis ground.

Multiplexer card removal

To remove the multiplexer card assembly, first loosen the thumb screw shown in Figure 3-13, then unlock the card by pulling the latches outward, and pull the card assembly out of the mainframe. Remember to handle the card assembly by the edges and shields to avoid contamination that could degrade performance.



WARNING: Tighten the thumb screw to ensure proper chassis ground.

Figure 3-13
7014 card installation in Model 7001

4

Operation

4.1 Introduction

The information in this section is formatted as follows:

- 4.2 Power limits:** Summarizes the maximum power limits of the Model 7014 multiplexer card assembly.
- 4.3 Mainframe control of multiplexer card:** Summarizes programming steps to control the multiplexer card from the Model 7001 Switch System mainframe.
- 4.4 Multiplexer switching examples:** Provides some typical applications for using the Model 7014.
- 4.5 Measurement considerations:** Reviews a number of considerations when using the Model 7014 to make measurements.

4.2 Power limits

CAUTION

To prevent damage to the card, do not exceed the maximum signal level specifications of the card.

Maximum signal levels

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

DC signals: 110V between any two pins (terminals), 1A switched, 30VA (resistive load).

AC signals: 125V rms or 175V AC peak between any two pins (terminals), 1A switched, 60VA (resistive load).

4.3 Mainframe control of multiplexer card

The following information pertains to the Model 7014 multiplexer card. It assumes that you are familiar with the operation of the Model 7001 mainframe.

If you are not familiar with the operation of the mainframe, it is recommended that you proceed to Getting Started (Section 3) of the Model 7001 Instruction Manual after reading the following information.

4.3.1 Channel assignments

The Model 7001 has a channel status display (Figure 4-1) that provides the real-time state of each available channel. The left portion of the display is for slot 1 (Card 1), and the right portion is for slot 2 (Card 2).

Multiplexer organization of the channel status display for each slot is shown in Figure 4-2. The card contains

40 channels and is made up of four banks (Bank A, B, C, and D) of 10 multiplexer inputs as shown in the illustration.

To control a multiplexer (mux) card from the mainframe, each multiplexer input must have a unique CHANNEL assignment, which includes the slot number that the card is installed in. The CHANNEL assignments for a multiplexer card are provided in Figure 4-3. Each CHANNEL assignment is made up of the slot designator (1 or 2) and the multiplexer channel. To be consistent with Model 7001 operation, the slot designa-

tor and mux input are separated by exclamation points (!). Some examples of CHANNEL assignments are as follows:

CHANNEL 1!2 = Slot 1, Channel 2 (Input 2 of Bank A)

CHANNEL 1!40 = Slot 1, Channel 40 (Input 10 of Bank D)

CHANNEL 2!23 = Slot 2, Channel 23 (Input 3 of Bank C)

CHANNEL 2!36 = Slot 2, Input 36 (Input 6 of Bank D)

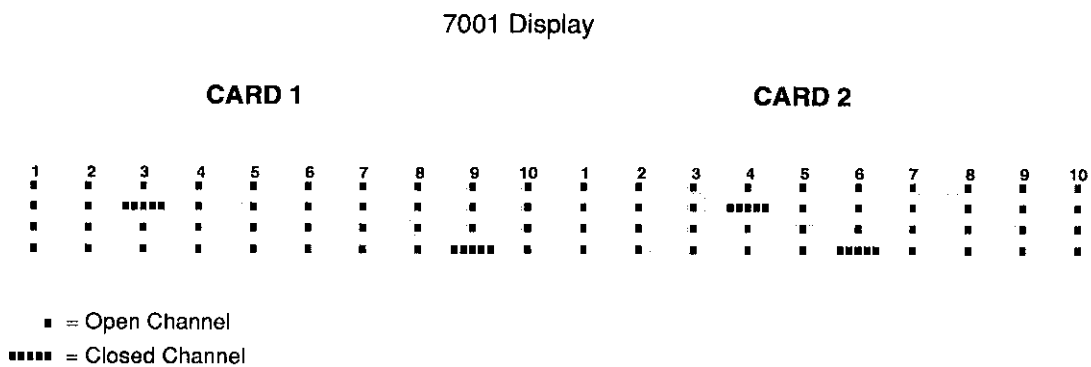


Figure 4-1
Channel status display

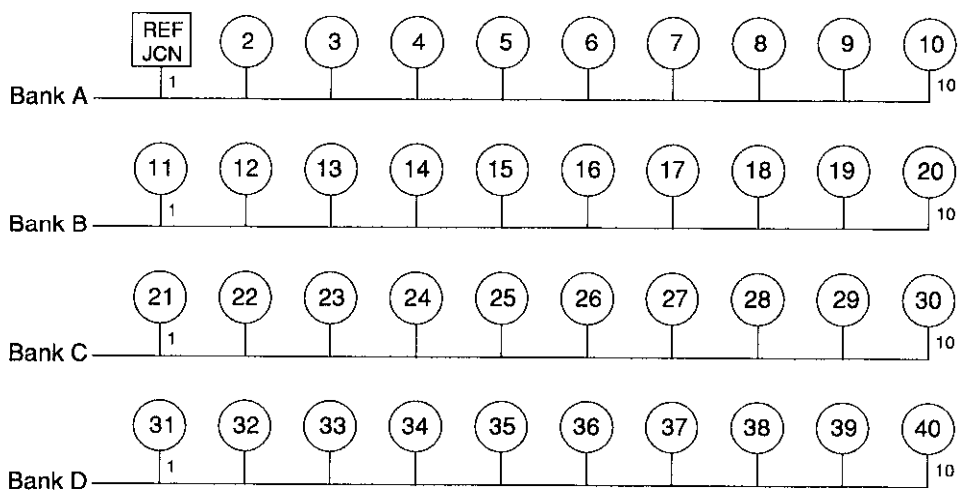
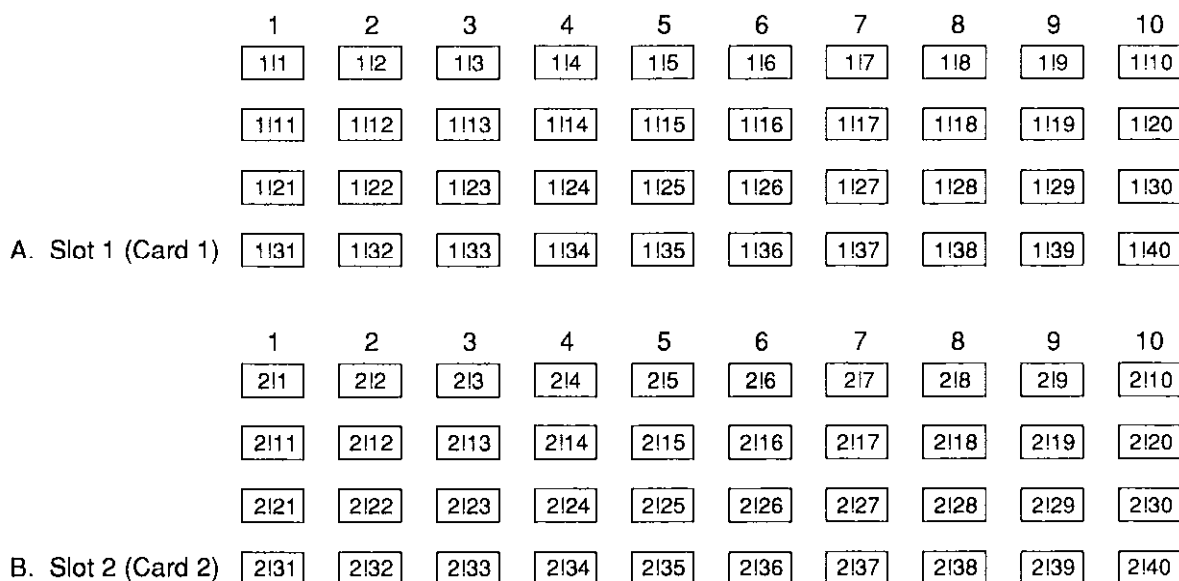


Figure 4-2
Display organization for multiplexer channels



Examples : 1|18 = Slot 1, Channel 18 (Input 8, Bank B)
 2|36 = Slot 2, Channel 36 (Input 6, Bank D)

Figure 4-3
 Model 7014 programming channel assignments

4.3.2 Front panel control

Closing and opening channels

A multiplexer channel is closed from the front panel by simply keying in the CHANNEL assignment and pressing CLOSE. For example, to close channel 36 (Input 6 of Bank D) of a multiplexer card installed in slot 2, key in the following channel list and press CLOSE:

```
SELECT CHANNELS 2|36
```

The above closed channel can be opened by pressing OPEN or OPEN ALL. The OPEN key opens only the channels specified in the channel list, and OPEN ALL opens all channels.

The following display is an example of a channel list that consists of several channels:

```
SELECT CHANNELS 2|1, 2|3, 2|22-2|25
```

Notice that channel entries are separated by commas (.). A comma is inserted by pressing ENTER or the right cursor key ▷. The channel range is specified by using the hyphen (-) key to separate the range limits. Pressing CLOSE will close all the channels specified in the channel list. Pressing OPEN (or OPEN ALL) will open the channels.

Scanning channels

Multiplexer channels are scanned by creating a scan list and configuring the Model 7001 to perform a scan. The scan list is created in the same manner as a channel list (see Closing and Opening Channels). However, the scan list is specified from the "SCAN CHANNEL" display mode. (The SCAN LIST key toggles between the channel list and the scan list.) The following shows an example of a scan list:

```
SCAN CHANNELS 2|1, 2|3, 2|21-2|25
```

When a scan is performed, the channels specified in the scan list will be scanned in the order that they are presented in the scan list.

A manual scan can be performed by using the RESET default conditions of the Model 7001. RESET is selected from the SAVESETUP menu of the main MENU. When RESET is performed, the mainframe is configured for an infinite number of manual scans. The first press of STEP takes the mainframe out of the idle state. The next press of STEP will close the first channel specified in the scan list. Each subsequent press of STEP will select the next channel in the scan list.

4.3.3 IEEE-488 bus operation

Bus operation is demonstrated using HP BASIC 4.0. The programming statements assume that the primary address of the mainframe is 07.

Closing and opening channels

The following SCPI commands are used to close and open channels:

```
:CLOSE <list>
:OPEN <list> | ALL
```

The following statement closes channels 1!1, and 1!3 through 1!11:

```
OUTPUT 707; ":clos (@ 1!1, 1!3:1!11)"
```

Notice that the colon (:) is used to separate the range limits.

Either of the following statements will open channels 1!1, and 1!3 through 1!11:

```
OUTPUT 707; ":open (@ 1!1, 1!3:1!11)"
OUTPUT 707; ":open all"
```

Scanning channels

There are many commands associated with scanning. However, it is possible to configure a scan using as lit-

tle as four commands. These commands are listed as follows:

```
*RST
:TRIGger:SEQuence:COUNt:AUTo ON"
:ROUte:SCAN <list>
:INIT
```

The first command resets the mainframe to a default scan configuration. The second command automatically sets the channel count to the number of channels in the Scan List, the third command defines the Scan List and the fourth command takes the Model 7001 out of the idle state.

The following program will perform a single scan through all 40 channels of a multiplexer card installed in slot 1:

```
10 OUTPUT 707; "*"RST"
20 OUTPUT 707; ":trig:seq:coun:auto on"
30 OUTPUT 707; ":scan (@ 1!1:1!40)"
40 OUTPUT 707; ":init"
50 END
```

Line 10 Selects a default configuration for the scan.

Line 20 Sets channel count to the scan-list-length.

Line 30 Defines the scan list.

Line 40 Take the Model 7001 out of the idle state. The scan is configured to start as soon as this command is executed.

When the above program is run, the scan will be completed in approximately 240 milliseconds (3msec delay for each relay close and a 3msec delay for each open), which is too fast to view from the front panel. An additional relay delay can be added to the program to slow down the scan for viewing. The program is modified by adding line 25 to slow down the scan. Also, Line 5 is added to the beginning of the program to ensure that all channels are open before the scan is started.

```
5 OUTPUT 707; ":open all"
10 OUTPUT 707; "*"RST"
20 OUTPUT 707; ":trig:seq:coun:auto on"
25 OUTPUT 707; ":trig:del 0.25"
30 OUTPUT 707; ":scan (@ 1!1:1!40)"
40 OUTPUT 707; ":init"
50 END
```

- Line 5 Opens all channels.
 Line 25 Sets a ¼ second delay after each channel closes.

4.4 Multiplexer switching examples

This paragraph presents some typical applications for the Model 7014. These include thermocouple scanning, resistor testing, and transistor testing.

CAUTION

Do not switch a current or voltage source to Channel 1 of the Model 7014. The temperature sensor of the reference junction does not have input protection. Specify Channel 1 as a "restricted channel" from the Model 7001 CONFIGURE SCAN menu so that it cannot be closed, except when switching thermocouples.

4.4.1 Thermocouple scanning

A test system to scan thermocouples consists of one or more thermocouple cards in a switching mainframe and a DMM, as shown in Figure 4-4. A multimeter with a temperature function, such as the Model 2001, is described because it derives temperature values from voltage readings.

Trigger signals are used to synchronize Model 7001 channel closures and Model 2001 measurements. In addition to BNC connections for external triggering, the Models 7001 and 2001 have a high-speed trigger link for controlling up to six instruments.

The Model 2001 is configured for thermocouple readings with the thermocouple type, reference junction channel, temperature coefficient, and voltage offset. These parameters are entered from its front panel or programmed from the IEEE-488 bus. See the Model 2001 Operator's Manual for details.

4.4.2 Resistor testing

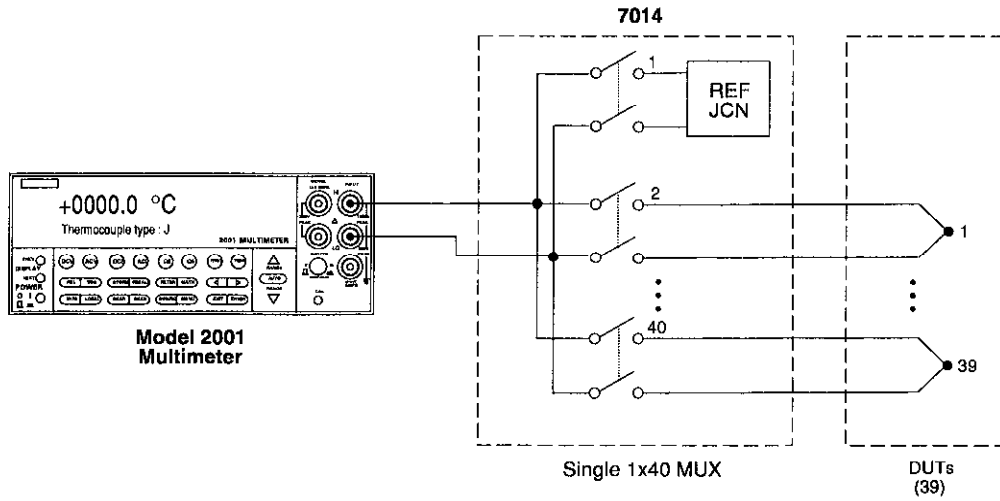
The Model 7014 can be used to test a large number of resistors using only one test instrument or group of instruments. Such tests include two-wire and four-wire resistance measurements using a DMM, and low-resistance measurements using a current source and sensitive digital voltmeter, as discussed in the following paragraphs.

Two-wire resistance tests

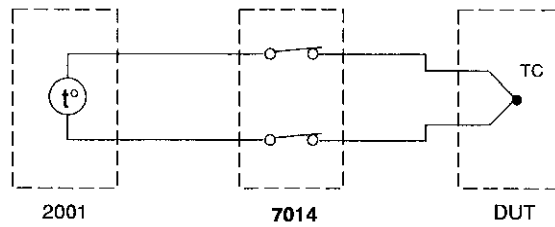
Figure 4-5 shows a typical test setup for making two-wire resistance measurements. The Model 7014 card provides the switching function, while the resistance measurements are made by a Model 199 DMM. Since only two-pole switching is required for this application, one Model 7014 card can be used to switch up to 39 resistors (additional multiplexer banks can be added, if desired, by adding more cards).

Accuracy of measurements can be optimized by minimizing stray resistance.

Make connecting wires as short as possible to minimize path resistance. Another technique is to short one of the multiplexer inputs, close the shorted channel and then enable the DMM zero feature to cancel path resistance. Leave zero enabled for the entire test.

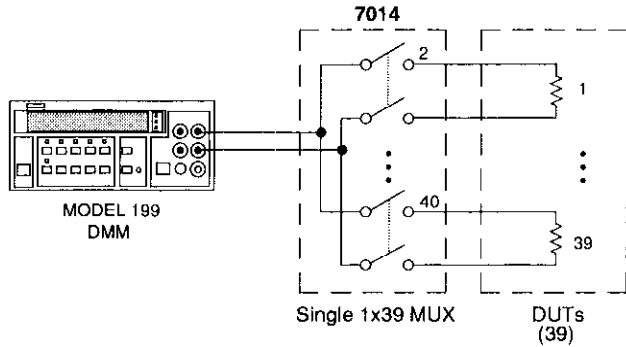


A. Test Configuration

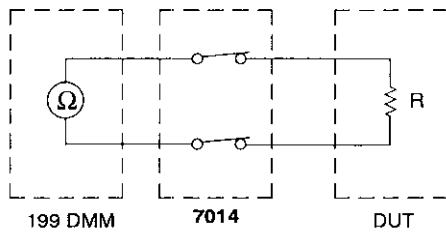


B. Simplified Equivalent Circuit

Figure 4-4
Thermocouple scanning



A. Test Configuration



B. Simplified Equivalent Circuit

Figure 4-5
2-wire resistance testing

Four-wire resistance tests

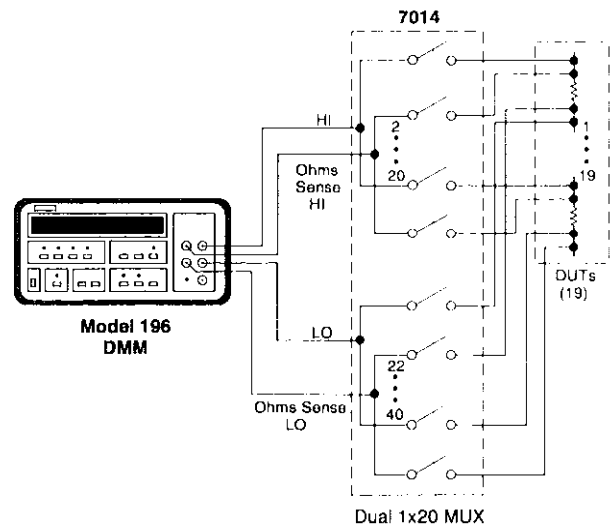
More precise measurements over a wider range of system and DUT conditions can be obtained by using the four-wire measurement scheme shown in Figure 4-6. Here, separate sense leads from the Model 196 DMM are routed through the multiplexer to the resistor under test. The extra set of sense leads minimizes the effects of voltage drops across the test leads. Note, however, that an extra two poles of switching are required for each resistor tested. For this reason, only 19 resistors per card can be tested using this configuration.

NOTE

Since Channel 1 of the Model 7014 is the reference junction, it cannot be

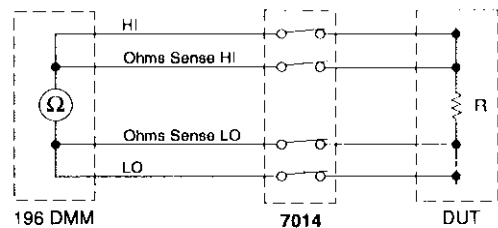
paired with Channel 21 in the 4-pole mode. Specify Channel 1 as a “restricted channel” from the Model 7001 CONFIGURE SCAN menu so that it cannot be closed.

The Model 7014 can be configured for 19 channels of 4-pole operation by isolating Banks A and B from Banks C and D, and by programming the Model 7001 main-frame for 4-pole mode. The resulting paired channels are shown in Table 4-1.



A. Test Configuration

Note: Jumpers between Banks B and C are removed.



B. Simplified Equivalent Circuit

Figure 4-6
4-wire resistance testing

Table 4-1
Paired Channels in 4-pole Operation

7001 channel assignment	Channel pair in 4-pole	Connection designations
2	2 and 22	Bank A, In 2 and Bank C, In 2
3	3 and 23	Bank A, In 3 and Bank C, In 3
4	4 and 24	Bank A, In 4 and Bank C, In 4
5	5 and 25	Bank A, In 5 and Bank C, In 5
6	6 and 26	Bank A, In 6 and Bank C, In 6
7	7 and 27	Bank A, In 7 and Bank C, In 7
8	8 and 28	Bank A, In 8 and Bank C, In 8
9	9 and 29	Bank A, In 9 and Bank C, In 9
10	10 and 30	Bank A, In 10 and Bank C, In 10
11	11 and 31	Bank B, In 1 and Bank D, In 1
12	12 and 32	Bank B, In 2 and Bank D, In 2
13	13 and 33	Bank B, In 3 and Bank D, In 3
14	14 and 34	Bank B, In 4 and Bank D, In 4
15	15 and 35	Bank B, In 5 and Bank D, In 5
16	16 and 36	Bank B, In 6 and Bank D, In 6
17	17 and 37	Bank B, In 7 and Bank D, In 7
18	18 and 38	Bank B, In 8 and Bank D, In 8
19	19 and 39	Bank B, In 9 and Bank D, In 9
20	20 and 40	Bank B, In 10 and Bank D, In 10

Bank jumper removal is described in paragraph 3.3.1. To configure the connector card for 4-pole operation, only remove the jumpers between Banks B and C (W203 and W204).

Selecting 4-pole operation for a Model 7001 card slot is discussed in Section 4 of the Model 7001 Instruction Manual. After the 4-pole mode is selected, the Model 7001 mainframe will display just 20 channels for the chosen card slot. Each closed channel will also close its paired channel on the card.

Although the four-wire connection scheme minimizes problems caused by voltage drops, there is one other potentially troublesome area associated with low resistance measurements: thermal EMFs caused by the relay contacts. In order to compensate for thermal EMFs, the offset-compensated ohms feature of the Model 196 DMM should be used. To use this feature, short the HI and LO terminals of one of the bank inputs, then close the relay. Enable zero on the Model 196, then select off-set-compensated ohms.

Low-level resistance measurements

Many times, it is necessary to make resistance measurements with either lower voltage sensitivity or higher currents than are available with ordinary DMMs. Examples of cases where low-level resistance measurements may be necessary include the testing of PC board traces, contacts, bus bars, and low resistance shunts.

Figure 4-7 shows a typical test configuration for a switching system capable of testing a number of low resistance devices. The Model 220 Current Source forces current through the device under test, while the Model 182 Sensitive Digital Voltmeter measures the resulting voltage across the device.

Since low voltage levels are being measured, thermal EMF offsets generated by relay and connector contacts will have a detrimental effect on measurement accuracy unless steps are taken to avoid them (the Model 7014 has been designed to keep relay EMF at a minimal level). Thermal EMF effects can be virtually eliminated by taking two voltage measurements, E_1 and E_2 , the first with the current, I , flowing in one direction, and the second with a current, I , of the same magnitude flow-

ing in the opposite direction. The resistance can then be calculated as follows:

$$R = \frac{E_2 - E_1}{2I}$$

Note that simply reversing the current source polarity will result in a 2× accuracy specification change. To avoid this problem, matrix switching could be added to the test system to reverse the current.

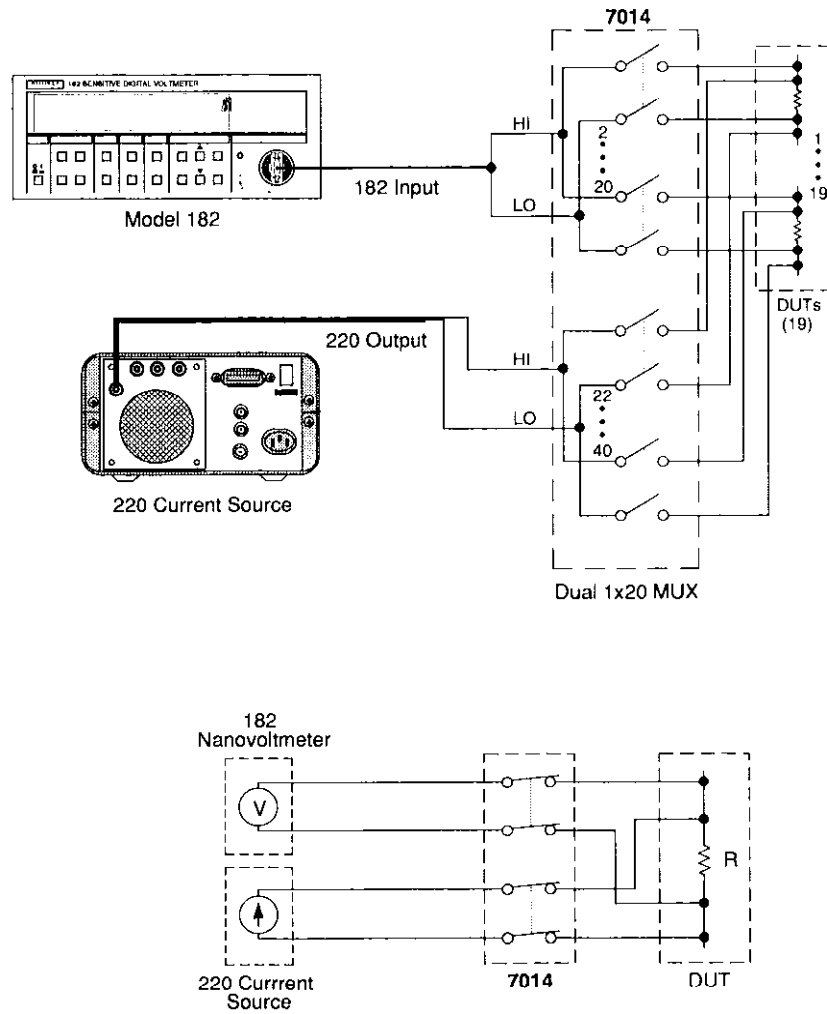


Figure 4-7
Low resistance testing

4.4.3 Transistor testing

Typical transistor tests that can be performed with the aid of the Model 7014 include current gain tests, leakage tests, as well as tests to determine the common-emitter characteristics of the device. The following paragraphs discuss these tests and give typical equipment configurations for the tests.

Current gain tests

The DC or static common-emitter current gain of a transistor can be determined by biasing the transistor for a specific value of base current, I_B , and then measuring the collector current, I_C . The DC common-emitter current gain, β , of the transistor is then determined as follows:

$$\beta = \frac{I_C}{I_B}$$

Figure 4-8 shows the test configuration and equivalent circuit for the current gain test. The Model 224 Current Source is used to source the base current, I_B . The Model 230 Voltage Source supplies the collector-emitter voltage, V_{CE} , and the collector current, I_C , is measured by the Model 196 DMM. Switching among the transistors being tested is, of course, performed by the Model 7014 multiplexer card.

In order to perform the current gain test, the voltage source is first set to the desired value of V_{CE} . The current source is then set to a base current value that will result in the desired value of I_C as measured by the DMM. The current gain can then be calculated as outlined above.

In order to reduce errors caused by voltage burden, use a higher current range on the Model 196 DMM. Doing so will result in the loss of one or two decades of resolution, but 3½ or 4½-digit resolution will probably be adequate for most situations.

4.4.4 Resistor temperature coefficient testing

Temperature coefficient is the rate of change of resistance with respect to temperature, typically expressed as ppm/°C (parts per million per degree centigrade).

For example, a resistor that measures exactly 100Ω at 25°C with a temperature coefficient of 100ppm/°C should not change more than 10mΩ per °C of temperature change. That resistor measured at 35°C should read between 99.900 and 100.100Ω (100Ω ±100mΩ).

Temperature coefficient is calculated from the following equation:

$$TC = \frac{(\Delta R) (10^6)}{(R) (\Delta T)}$$

where:

TC = temperature coefficient in ppm/°C

ΔR = change in resistance (reference resistance - test resistance)

R = actual resistance at the reference temperature

ΔT = change in temperature (reference temperature - test temperature)

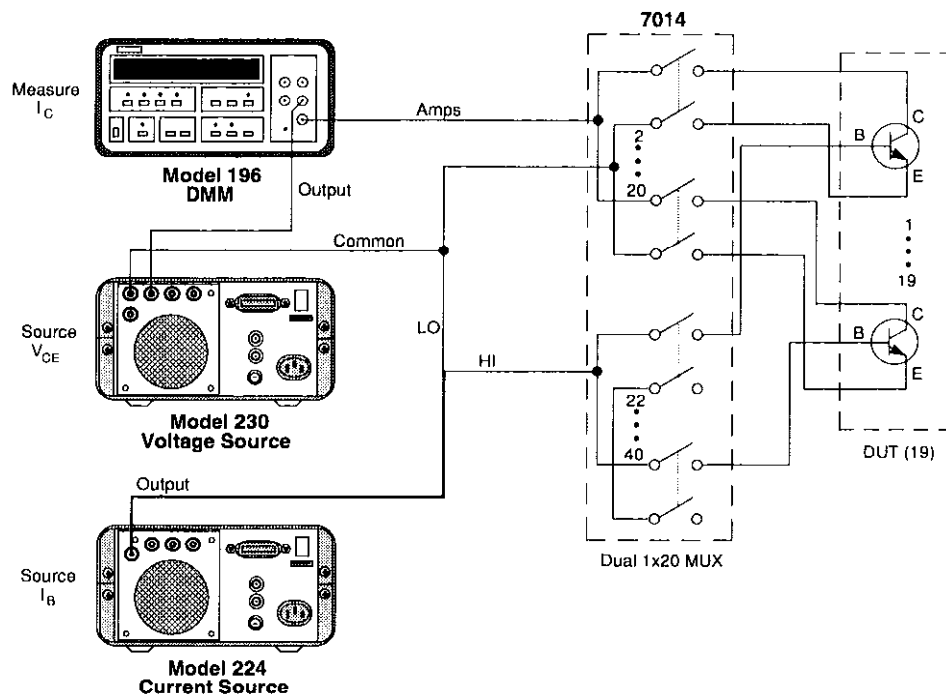
Typically, several samples of a particular resistor from a vendor will be tested to verify the specifications. The temperature coefficient is usually checked at several temperature points to ensure its integrity over a range of temperatures.

Evaluation of resistors can be done with a Model 7014 card in a Model 7001 mainframe, along with a Model 2001 multimeter to make temperature and 4-terminal resistance measurements. Temperature coefficients are calculated with respect to the resistance measurement made at a reference temperature. Thermal EMFs generated by connections in the test circuit are cancelled by the offset compensated ohms feature of the Model 2001.

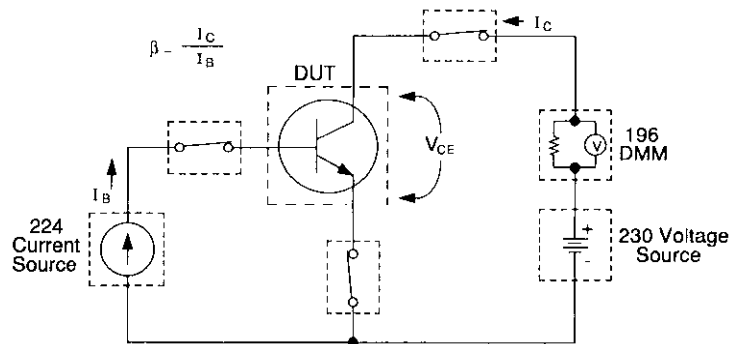
Figure 4-8 shows a system that can test accuracy and temperature coefficient of up to 29 resistors that have the same specifications (resistance and temperature coefficient).

For further information on resistor temperature coefficient testing, see the following reference:

Simplified Resistor Temperature Coefficient Test System Using Model 196. Keithley Instruments, Application Note 811, 1987.

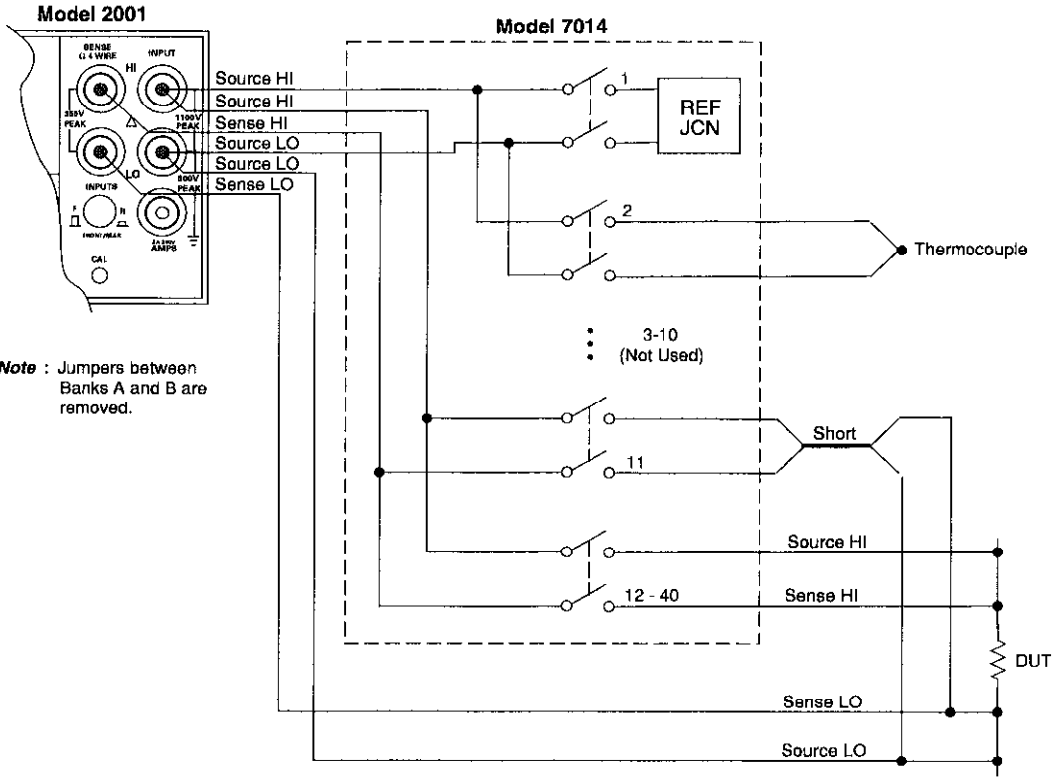


A. Test Configuration

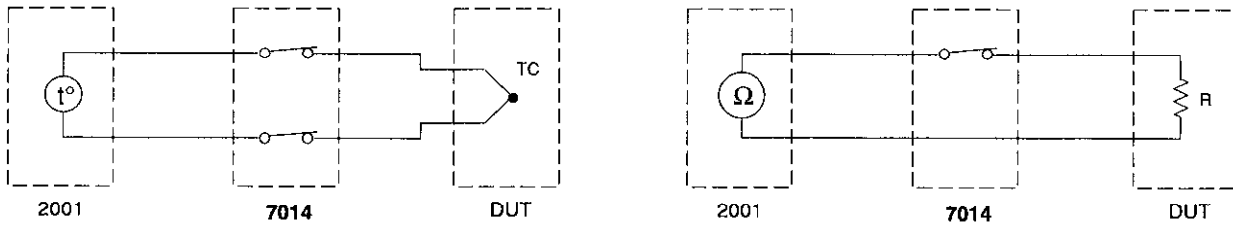


B. Simplified Equivalent Circuit

Figure 4-8
Configuration for current gain and common-emitter test



A. Test Configuration



B. Simplified Equivalent Circuit

Figure 4-9
 Resistor temperature coefficient testing

Common-emitter characteristic tests

Common-emitter characteristics are determined by setting the base current, I_B , to specific values. At each I_B value, the collector-emitter voltage, V_{CE} , is swept across the desired range at specific intervals, and the collector current, I_C , is then measured. When the data are plotted, the result is the familiar family of common-emitter curves (Figure 4-10).

The same test configuration that is used for current gain tests can be used for measuring common-emitter characteristics. The Model 224 is used to set the base current, I_B , to the desired values. The Model 230 Voltage Source provides the collector-emitter voltage, V_{CE} , and the Model 196 DMM measures the collector current, I_C .

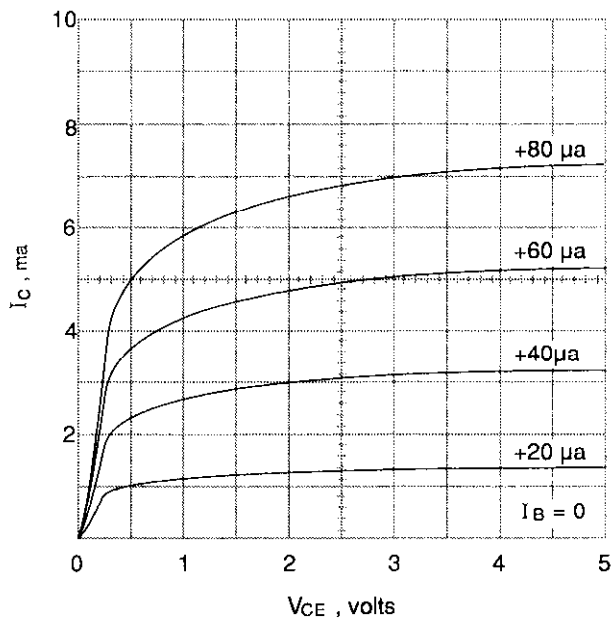


Figure 4-10
Typical common-emitter characteristics

4.5 Measurement considerations

Many measurements made with the Model 7014 are subject to various effects that can seriously affect low-level measurement accuracy. The following paragraphs discuss these effects and ways to minimize them.

4.5.1 Thermocouple measurement error sources

The reference accuracy specification of the Model 7014 is the sum of the following error sources:

- Reference junction sensor error
- Temperature gradient across the card
- Relay self-heating

You can achieve better card performance by understanding how these error sources contribute to the specification. The reference junction temperature and its associated circuitry are shown in Figure 3-6.

Reference junction sensor

The primary factor determining reference junction accuracy is the operating temperature. By using the Model 7014 in the 18°C to 28°C range, maximum sensor performance is achieved.

Temperature gradient

A temperature gradient of 0.32°C develops across the connector board ($\pm 0.16^\circ\text{C}$ on each side of the sensor). This gradient contributes to the reference error.

Channels that are close to the sensor have the least temperature gradient error (channels 5, 6, 15, 16, 25, 26, 35, and 36); channels farthest away have the most temperature gradient error (channels 2 and 40).

When making relative temperature measurements and not absolute measurements, it is advantageous to use adjacent channels, as follows:

- Adjacent channels on the same terminal block (e.g., channels 2 and 3) will have no more than 0.035°C error between them.
- Adjacent channels on different terminals block (e.g., channels 15 and 25) will have no more than 0.05°C error.

Relay self-heating

As channels are turned on, heat is dissipated from the relay coils. This can cause a measurement error up to 0.08°C. The following considerations reduce this error:

- Close only one channel at a time. (The single-channel mode of the Model 7001 can be used to prevent the simultaneous closure of multiple channels.)
- Keep channel closure time to a minimum. (Worst case is with a relay closed for five minutes.)
- Use the relays closest to the sensor. (Worst cases are channels 1, 10, 11, 20, 21, 30, 31, and 40.)
- Do not mix switching applications simultaneously, for example, thermocouple and high energy switching. The card's reference accuracy will be affected due to relay contact heating.

Other error sources

Thermocouple wire — In most cases, the major source of error is the thermocouple wire. For the standard grade of type K thermocouple wire, the error is 2.2°C or 0.75%, whichever is greater. For the special grade of type K wire, the error is 1.1°C or 0.4% error.

Offset voltage — The primary source of offset voltage is the contact potential of the relay, typically <500nV. Due to self-heating of the relay, the offset voltage could be 1μV if a channel is closed for five minutes. For a type K thermocouple, 1μV offset produces 0.024°C of error.

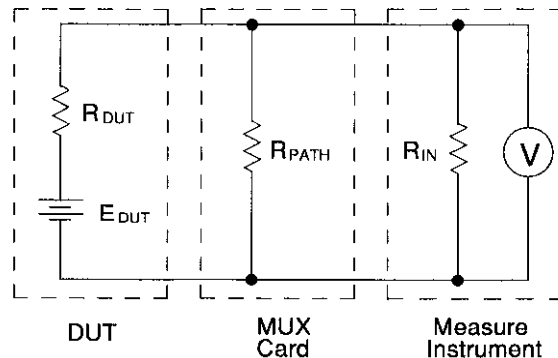
Measurement instrument — The voltage measurement accuracy and temperature conversion algorithm determine the accuracy of the instrument. The Model 2001 Multimeter has these parameters combined into one temperature specification. For type K thermocouples, the Model 2001 has 0.5°C accuracy.

Air drafts — For optimum performance, the card should be protected from drafts. Air currents can cause a temperature fluctuation under the connector card's isothermal cover.

4.5.2 Path isolation

The path isolation is simply the equivalent impedance between any two test paths in a measurement system. Ideally, 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.

Path isolation resistance forms a signal path that is in parallel with the equivalent resistance of the DUT, as shown in Figure 4-11. For low-to-medium device resistance values, path isolation resistance is seldom a consideration; however, it can seriously degrade measurement accuracy when testing high-impedance devices. The voltage measured across such a device, for example, can be substantially attenuated by the voltage divider action of the device source resistance and path isolation resistance, as shown in Figure 4-12. Also, leakage currents can be generated through these resistances by voltage sources in the system.

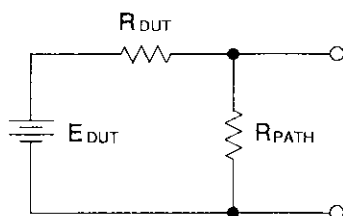


- R_{DUT} = Source Resistance of DUT
- E_{DUT} = Source EMF of DUT
- R_{PATH} = Path Isolation Resistance
- R_{IN} = Input Resistance of Measuring Instrument

Figure 4-11
Path isolation resistance

Any differential isolation capacitance affects DC measurement settling time as well as AC measurement accuracy. Thus, it is often important that such capacitance be kept as low as possible. Although the distributed ca-

capacitance of the matrix card is generally fixed by design, there is one area where you do have control over the capacitance in your system; the connecting cables. To minimize capacitance, keep all cables as short as possible



$$E_{OUT} = \frac{E_{DUT} R_{PATH}}{R_{DUT} + R_{PATH}}$$

Figure 4-12

Voltage attenuation by path isolation resistance

4.5.3 Magnetic fields

When a conductor cuts through magnetic lines of force, a very small current is generated. This phenomenon will frequently cause unwanted signals to occur in the test leads of a switching matrix system. If the conductor has sufficient length, even weak magnetic fields like those of the earth can create sufficient signals to affect low-level measurements.

Two ways to reduce these effects are: (1) reduce the lengths of the test leads, and (2) 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 the AC power line voltage. Large inductors such as power transformers can generate substantial magnetic fields, so care must be taken to keep the switching and measuring circuits a good distance away 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.

4.5.4 Radio frequency interference

RFI (Radio Frequency Interference) is a general term used to describe electromagnetic interference over a wide range of frequencies across the spectrum. Such RFI can be particularly troublesome at low signal levels, but it can also affect measurements at high levels if the problem is of sufficient severity.

RFI can be caused by steady-state sources such as radio or TV signals, or some types of electronic equipment (microprocessors, high speed digital circuits, etc.), or it can result from impulse sources, as in the case of arcing in high-voltage environments. In either case, the effect on the measurement can be considerable if enough of the unwanted signal is present.

RFI can be minimized in several ways. The most obvious method is to keep the equipment and signal leads as far away from the RFI source as possible. Shielding the switching card, signal leads, sources, and measuring instruments will often reduce RFI to an acceptable level. In extreme cases, a specially-constructed screen room may be required to sufficiently attenuate the troublesome signal.

Many instruments incorporate internal filtering that may help to reduce RFI effects in some situations. In some cases, additional external filtering may also be required. Keep in mind, however, that filtering may have detrimental effects on the desired signal.

4.5.5 Ground loops

When two or more instruments are connected together, care must be taken to avoid unwanted signals caused by ground loops. Ground loops usually occur when sensitive instrumentation is connected to other instrumentation with more than one signal return path such as power line ground. As shown in Figure 4-13, the resulting ground loop causes current to flow through the instrument LO signal leads and then back through

power line ground. This circulating current develops a small but undesirable voltage between the LO terminals of the two instruments. This voltage will be added to the source voltage, affecting the accuracy of the measurement.

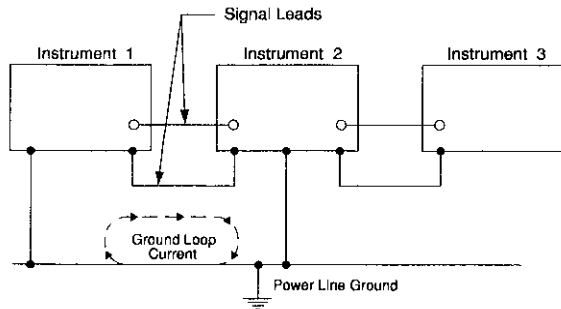


Figure 4-13
Power line ground loops

Figure 4-14 shows how to connect several instruments together to eliminate this type of ground loop problem. Here, only one instrument is connected to power line ground.

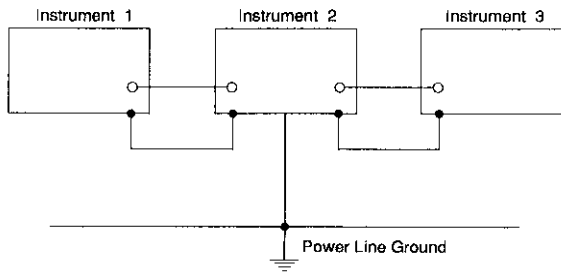


Figure 4-14
Eliminating ground loops

Ground loops are not normally a problem with instruments having isolated LO terminals. However, all instruments in the test setup may not be designed in this manner. When in doubt, consult the manual for all instrumentation in the test setup.

4.5.6 Keeping connectors clean

As is the case with any high-resistance device, the integrity of connectors can be damaged if they are not handled properly. If connector insulation becomes contaminated, the 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 multiplexer 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 air-borne 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.

4.5.7 AC frequency response

The AC frequency response of the Model 7014 is important in test systems that switch AC signals. Refer to the specifications at the front of this manual.

5

Service Information

WARNING

The information in this section 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.

5.1 Introduction

This section contains information necessary to service the Model 7014 multiplexer card and is arranged as follows:

- 5.2 **Handling and cleaning precautions:** Discusses handling precautions and methods to clean the card should it become contaminated.
- 5.3 **Performance verification:** Covers the procedures necessary to determine if the card meets stated specifications.
- 5.4 **Calibration:** Describes calibrating the card to its specified temperature accuracy.
- 5.5 **Special handling of static-sensitive devices:** Reviews precautions necessary when handling static-sensitive devices.
- 5.6 **Principles of operation:** Briefly discusses circuit operation.
- 5.7 **Troubleshooting:** Presents some troubleshooting tips for the Model 7014 including relay replacement precautions.

5.2 Handling and cleaning precautions

Because of the high-impedance areas on the Model 7014, care should be taken when handling or servicing the card to prevent possible contamination. The following precautions should be taken when servicing the card.

Handle the card only by the edges and shields. Do not touch any board surfaces or components not associated with the repair. Do not touch areas adjacent to electrical contacts. When servicing the card, wear clean cotton gloves.

Do not store or operate the card in an environment where dust could settle on the circuit board. Use dry nitrogen gas to clean dust off the board if necessary.

Should it become necessary to use solder on the circuit board, use an OA-based (organic activated) flux. Remove the flux from the work areas when the repair has been completed. Use pure water along with clean cot-

ton swabs or a clean soft brush to remove the flux. Take care not to spread the flux to other areas of the circuit board. Once the flux has been removed, swab only the repaired area with methanol, then blow dry the board with dry nitrogen gas.

After cleaning, the card should be placed in a 50°C low humidity environment for several hours before use.

5.3 Performance verification

CAUTION

Do not switch a current or voltage source to Channel 1 of the Model 7014. The temperature sensor of the reference junction does not have input protection. Specify Channel 1 as a "restricted channel" from the Model 7001 CONFIGURE SCAN menu so that it cannot be closed, except when scanning thermocouples.

The following paragraphs discuss performance verification procedures for the Model 7014, including path resistance, offset current, contact potential, and isolation.

With the Model 7014's backplane jumpers installed, the performance verification procedures must be performed with only one multiplexer card (the one being checked) installed in the Model 7001 mainframe. These

conditions do not apply if the backplane jumpers are removed.

CAUTION

Contamination will degrade the performance of the card. To avoid contamination, always grasp the card by the side edges. Do not touch the connectors, and do not touch the board surfaces or components. On plugs and receptacles, do not touch areas adjacent to the electrical contacts.

NOTE

Failure of any performance verification test may indicate that the multiplexer card is contaminated. See paragraph 5.2 to clean the card.

5.3.1 Environmental conditions

All verification measurements should be made at an ambient temperature between 18° and 28°C, and at a relative humidity of less than 70%.

5.3.2 Recommended equipment

Table 5-1 summarizes the equipment necessary for performance verification, along with an application for each unit.

Table 5-1
Verification and calibration equipment

Description	Model or part	Specifications	Applications
DMM	Keithley Model 196 (or Model 2001)	300Ω; 0.01% 300mV; 0.008%	Path resistance Reference junction
Electrometer w / voltage source	Keithley Model 617	10pA, 100pA; 1.6% 100V source; 0.2%	Offset current, path isolation
Sensitive Digital Voltmeter	Keithley Model 182	3mV; 60ppm	Contact potential
Triax cable (unterminated)	Keithley Model 7025	—	Offset current
Low thermal cable (unterminated)	Keithley Model 1484	—	Contact potential
Thermistor probe	Thermometrics Series CSP A207A	±0.005°C accuracy	Reference junction, calibration
Reference thermometer	—	±0.01°C with thermistor	Reference junction, calibration
Distilled water ice bath (Dewar flask or Thermos)	—	±0.1°C	Calibration

5.3.3 Reference junction test

This procedure verifies that the card is operating within its temperature specification. A Model 7001 Switch System is used to close Channel 1 of the card.

1. Turn on a Model 196 and set it to the 300mVDC range. Short the test leads together. Zero the multimeter after the thermals have stabilized (two hours if from cold-start). A Model 2001 can be used on the 200mVDC range; let it warm up for one hour.
2. Set up the test equipment as shown in Figure 5-1 and let it warm up one hour. Remove the cover of the Model 7001 as explained in paragraph 7.5 of the Model 7001 Instruction Manual. Insert a Model 7014 card and protect it from air drafts.

Use a probe with a specified accuracy of ±0.005°C. The combination of the probe and reference thermometer should be accurate to ±0.01°C.

3. Coat the probe with a thermally conductive compound and insert it into the 0.110" hole marked "CAL" in the isothermal cover.
4. Use the Model 7001 front panel to close Channel 1!1.
5. Take a reading from the reference thermometer. Use the following equation to calculate the equivalent reference junction output voltage (V_{REF}):

$$V_{REF} = (T_J + 273.15) \times 0.0002$$

6. Read the voltage across the output of Bank A. Compare the measured and calculated voltages. If they differ by more than 52μV (0.26°C), perform the calibration procedure of paragraph 5.4.1.

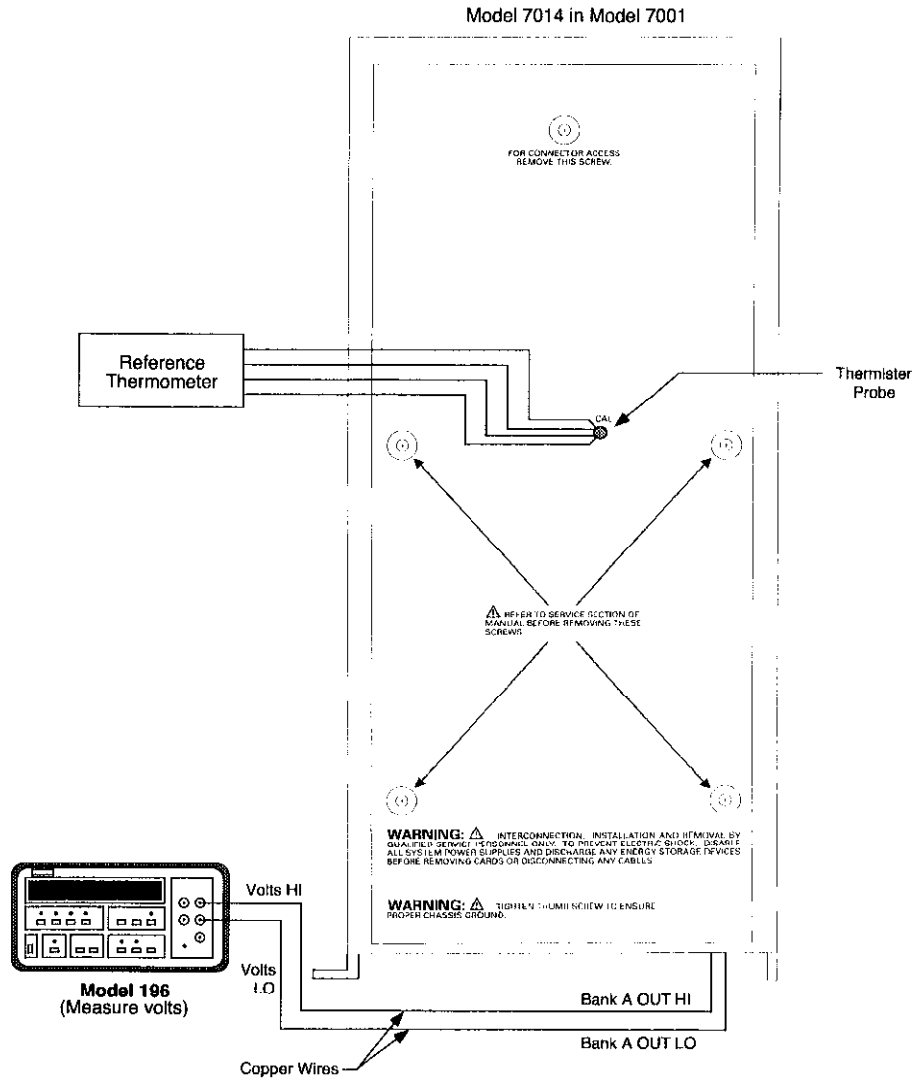


Figure 5-1
Reference junction test

5.3.4 Channel resistance tests

Perform the following steps to verify that each contact of every relay is closing properly and that the resistance is within specification.

1. Turn off the Model 7001 if it is on.
2. Turn on the Model 196, and allow it to warm up for one hour before making measurements.
3. Connect all input terminals of Bank A together to form one common terminal, as shown in Figure 5-2.
4. Set the Model 196 to the 300Ω range and connect the four test leads to the OHMS and OHMS SENSE input jacks.
5. Short the four test leads together and zero the Model 196. Leave zero enabled for the entire test.
6. Connect OHMS HI and OHMS SENSE HI of the Model 196 to the common terminal (jumper on Bank A inputs). It is recommended that the physical connections be made at inputs 2 and 10 of Bank A, as shown in Figure 5-2.
7. Connect OHMS LO and OHMS SENSE LO to the HI (H) terminal of Bank A.
8. Install the Model 7014 in slot 1 (CARD 1) of the Model 7001.
9. Turn on the Model 7001 and program it to close Channel 1!2 (Bank A, Input 2). Verify that the resistance of this path is $<1\Omega$.
10. Open Channel 1!2 and close Channel 1!3 (Bank A, Input 3). Verify that the resistance of this path is $<1\Omega$.
11. Using the basic procedure in steps 9 and 10, check the resistance of Bank A HI (H) terminal paths for Inputs 4 through 10 (Channels 1!4 through 1!10).
12. Turn off the Model 7001 and move the OHMS LO and OHMS SENSE LO test leads to the LO (L) terminal of Bank A.
13. Repeat steps 9 through 11 to check the LO (L) terminal paths of Bank A (Channels 1!2 through 1!10).
14. Repeat the basic procedure in steps 1 through 13 for Banks B through D (Channels 1!11 through 1!40).

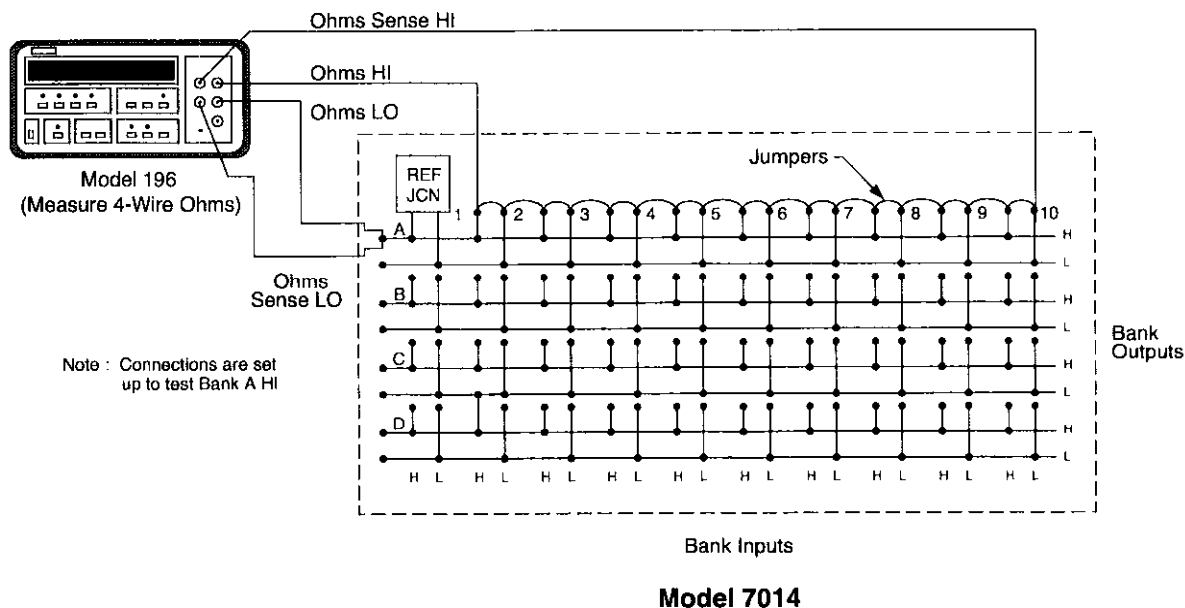


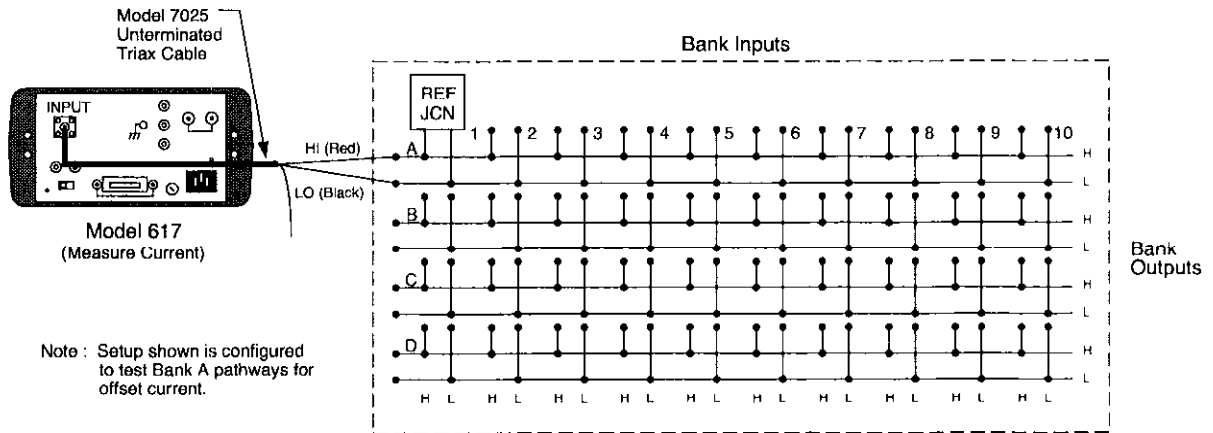
Figure 5-2
Path resistance test connections

5.3.5 Offset current tests

These tests check leakage current between HI (H) and LO (L) (differential offset current) and from HI (H) and LO (L) to chassis (common-mode offset current) of each pathway. In general, these tests are performed by simply measuring the leakage current with an electrometer. In the following procedure, the Model 617 is used to measure the leakage current. Test connections are shown in Figure 5-3.

Perform the following procedure to check offset current:

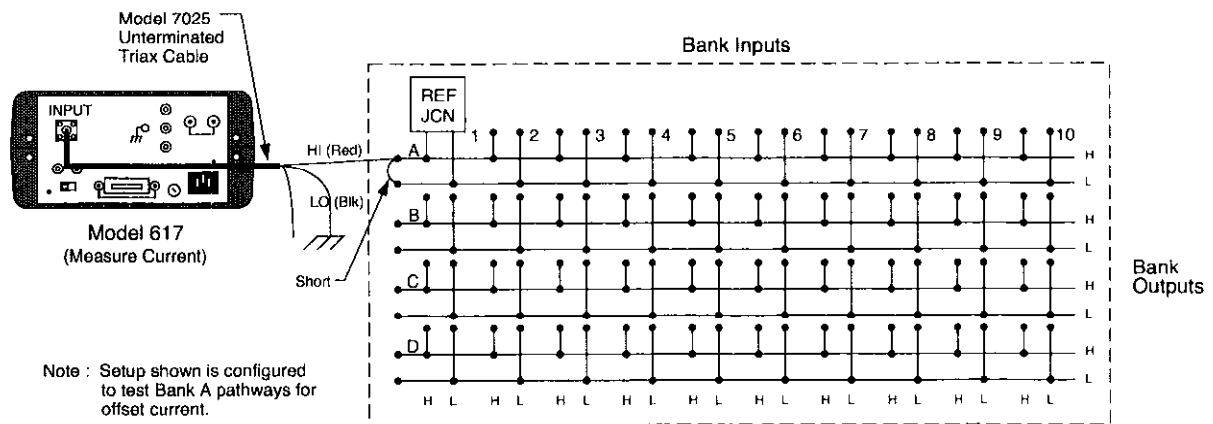
1. Turn off the Model 7001 if it is on, and remove any jumpers or wires connected to the multiplexer card.
2. Connect the triax cable to the Model 617, but do not connect it to the multiplexer card at this time.
3. Turn on the Model 617 and allow the unit to warm up for two hours before testing. After warm up, select the 200pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure. Also, be certain that V-Ω, GUARD is OFF and ground strap is connected to LO.
4. Connect the triax cable to Bank A HI and LO, as shown in Figure 5-3A.
5. Install the Model 7014 in slot 1 (CARD 1) of the Model 7001.
6. Turn on the Model 7001 and program the unit to close Channel 1!2 (Bank A, Input 2).
7. On the Model 617, disable zero check and allow the reading to settle. Verify that the reading is <100pA. This specification is the offset (leakage) current of the pathway.
8. Enable zero check on the Model 617 and open Channel 1!2 from the front panel of the Model 7001.
9. Repeat the basic procedure in steps 6 through 8 to check the rest of the pathways (Inputs 3 through 10) of Bank A (Channels 1!3 through 1!10).
10. Turn off the Model 7001 and change the electrometer connections to Bank B.
11. Repeat the basic procedure in steps 6 through 10 to check Bank B, Inputs 1 through 10 (Channels 1!11 through 1!20).
12. Repeat the basic procedure in steps 6 through 11 for Banks C and D (Channels 1!21 through 1!40).
13. Turn off the Model 7001 and change the electrometer connections, as shown in Figure 5-3B. Note that electrometer HI is connected to HI and LO of the Bank A output, which are jumpered together. Electrometer LO is connected to chassis.
14. Repeat steps 6 through 12 to check that the common mode offset current is <100pA.



Note : Setup shown is configured to test Bank A pathways for offset current.

Model 7014

A) Differential



Note : Setup shown is configured to test Bank A pathways for offset current.

Model 7014

B) Common-Mode

Figure 5-3
Differential offset current test connections

5.3.6 Contact potential tests

These tests check the EMF generated by each relay contact pair (H and L) for each pathway. The tests simply consist of using a sensitive digital voltmeter (Model 182) to measure the contact potential. See Figure 5-4.

Perform the following procedure to check contact potential of each path:

1. Turn off the Model 7001 if it is on.
2. Place jumpers between Banks A-B, B-C, and C-D.
3. Turn on the Model 182 and allow the unit to warm up to achieve rated accuracy.
4. Place a short between HI to LO on each input (Channels 2-40).
5. Place a short between HI to LO on output Bank D (long enough to cut with wire cutters).
6. Connect the Model 182 input leads to HI and LO output Bank A using copper wires.

7. Install the Model 7014 in the Model 7001 slot 1, and turn on the Model 7001.
8. Allow Models 7001, 7014 and 182 to warm up for two hours.
9. Select the 3mV range on the Model 182.
10. Press REL READING (on the Model 182) to null out internal offsets. Leave REL READING enabled for the entire procedure.
11. Turn off the Model 7001. Remove the Model 7014 from slot 1. Cut the short on B and D output HI to LO.
12. Install the Model 7014 in the Model 7001 slot 1, and turn power on.
13. Wait 15 minutes.
14. Program the Model 7001 to close Channel 1!2.
15. After settling, verify that reading on the Model 182 is $<1\mu\text{V}$. This measurement represents the contact potential of the pathway.
16. From the Model 7001, open Channel 1!2.
17. Repeat steps 12 through 14 for all 39 channels.

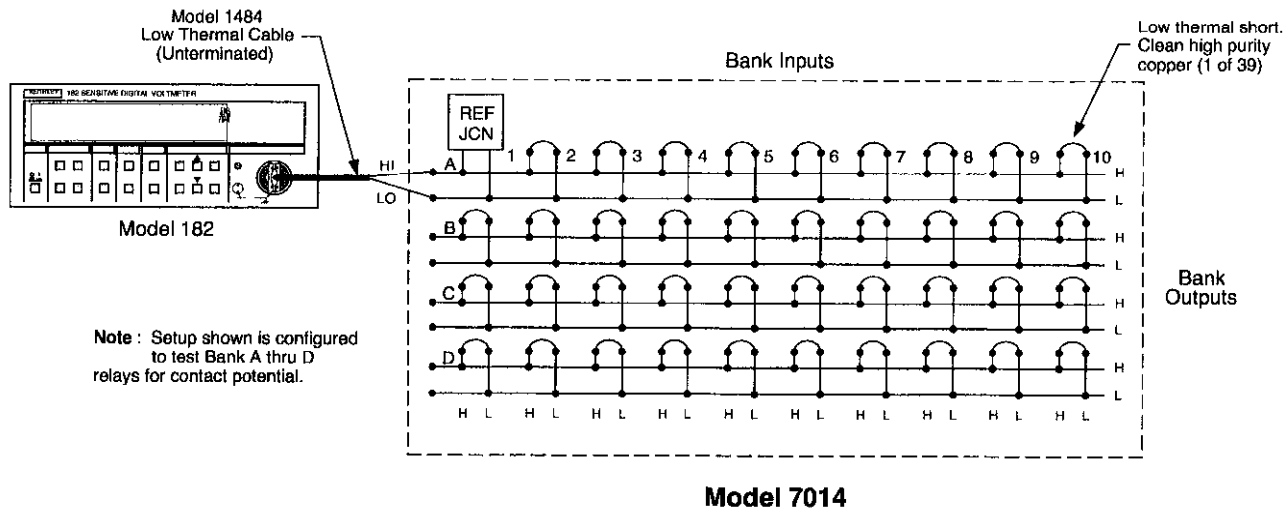


Figure 5-4
Contact potential test connections

5.3.7 Bank and channel-to-channel isolation tests

Bank isolation tests check the leakage resistance between adjacent banks. Channel-to-channel isolation tests check the leakage resistance between a Bank Output connection and a Bank Input connection with an adjacent Bank Input relay closed. In general, the tests are performed by applying a voltage (100V) across the leakage resistance and then measuring the current. The isolation resistance is then calculated as $R = V/I$. In the following procedure, the Model 617 functions as both a voltage source and an ammeter. In the V/I function, the Model 617 internally calculates the resistance from the known voltage and current levels and displays the resistive value.

Perform the following steps to check bank and channel-to-channel isolation:

1. Turn off the Model 7001 if it is on, and remove any jumpers or test leads connected to the multiplexer card.
2. Turn on the Model 617 and allow the unit to warm up for two hours before testing.
3. On the Model 617, select the 2pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.
4. Connect the electrometer to the Model 7014, as shown in Figure 5-5.
5. Install the Model 7014 in slot 1 (CARD 1) of the Model 7001 and turn on the mainframe.
6. On the Model 617, select the 20pA range and release zero check.
7. On the Model 617, press SUPPRESS to cancel offset current, then enable zero check.

WARNING

The following steps use high voltage (100V). Be sure to remove power from the circuit before making connection changes.

8. On the Model 617, set the voltage source for +100V, and select the 20nA current range. Make sure the voltage source is in standby.
9. Place the Model 617 in the V/I measurement function by pressing SHIFT OHMS.
10. Program the Model 7001 to close Channels 1!2 and 1!13 (Bank A, Input 2 and Bank B, Input 3).

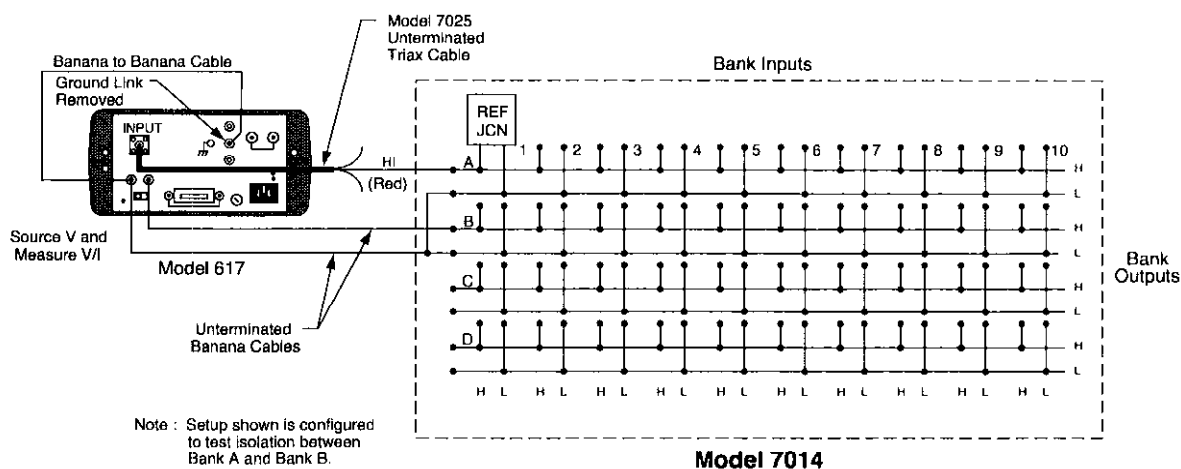


Figure 5-5
Bank isolation test connections

11. On the Model 617, disable zero check and press OPERATE to source +100V.
12. After allowing the reading on the Model 617 to settle, verify that it is $>1G\Omega$ ($10^9\Omega$). This measurement is the leakage resistance (bank isolation) between Bank A, Input 2 and Bank B, Input 3.
13. Place the Model 617 voltage source in standby and enable zero check.
14. Turn off the Model 7001 and move the electrometer connections to Banks B and C.
15. Install the Model 7014 in slot 1 of the mainframe and turn on the Model 7001.
16. Program the Model 7001 to close Channels 1!11 and 1!22 (Bank B, Input 1 and Bank C, Input 2).
17. On the Model 617, disable zero check and press OPERATE to source +100V.
18. After allowing the reading on the Model 617 to settle, verify that it is $>1G\Omega$ ($10^9\Omega$).
19. Place the Model 617 voltage source in standby and enable zero check.
20. Turn off the Model 7001 and move the electrometer connections to Banks C and D.
21. Install the Model 7014 in slot 1 of the mainframe, and turn on the Model 7001.
22. Using Table 5-2 as a guide, repeat the basic procedure of steps 16 through 18 for the rest of the path pairs (test numbers 3 through 9 in the table).
23. Place the Model 617 voltage source in standby and enable zero check.

NOTE

Refer to the following procedure to check channel-to-channel isolation.

24. Turn off the Model 7001 and connect the Model 617 to the card as shown in Figure 5-6.
25. Install the Model 7014 in slot 1 of the Model 7001, and turn on the mainframe.
26. Program the Model 7001 to close Channel 1!3 (Bank A, Input 3). Make sure all other channels are open.
27. On the Model 617, disable zero check and press OPERATE to source 100V.
28. After allowing the reading on the Model 617 to settle, verify that it is $>1G\Omega$ ($10^9\Omega$).
29. Place the Model 617 voltage source in standby, and enable zero check.
30. Using Table 5-3 as a guide, perform tests 2 through 8 for the remaining Bank A Inputs. Remember to move Bank Input connections as indicated in the table.
31. Use Table 5-3 (test numbers 9 through 35) and the above procedure to test Banks B, C, and D.

Table 5-2
Bank isolation test summary

Test number	Bank isolation	Test equipment location	Channels closed*
1	Bank A, Input 2 to Bank B, Input 3	Bank A and Bank B	1!2 and 1!13
2	Bank B, Input 1 to Bank C, Input 2	Bank B and Bank C	1!11 and 1!22
3	Bank C, Input 3 to Bank D, Input 4	Bank C and Bank D	1!23 and 1!34
4	Bank C, Input 4 to Bank D, Input 5	Bank C and Bank D	1!24 and 1!35
5	Bank C, Input 5 to Bank D, Input 6	Bank C and Bank D	1!25 and 1!36
6	Bank C, Input 6 to Bank D, Input 7	Bank C and Bank D	1!26 and 1!37
7	Bank C, Input 7 to Bank D, Input 8	Bank C and Bank D	1!27 and 1!38
8	Bank C, Input 8 to Bank D, Input 9	Bank C and Bank D	1!28 and 1!39
9	Bank C, Input 9 to Bank D, Input 10	Bank C and Bank D	1!29 and 1!40

*Assumes Model 7014 installed in slot 1 of mainframe. Programmed as slot (1) and channel.

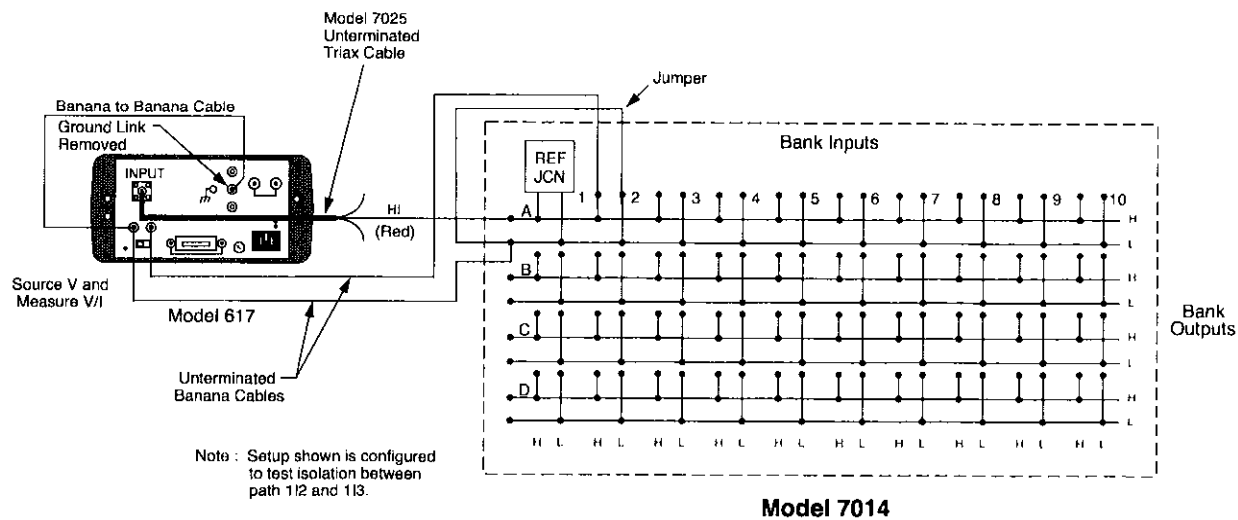


Figure 5-6
Channel-to-channel isolation test connections

Table 5-3
Channel-to-channel isolation test summary

Test number	Channel-to-channel isolation	Test equipment location	Channel closed*
1	Bank A, Input 2 to Bank A, Input 3	Bank A and Input 2	1!3
2	Bank A, Input 3 to Bank A, Input 4	Bank A and Input 3	1!4
3	Bank A, Input 4 to Bank A, Input 5	Bank A and Input 4	1!5
4	Bank A, Input 5 to Bank A, Input 6	Bank A and Input 5	1!6
5	Bank A, Input 6 to Bank A, Input 7	Bank A and Input 6	1!7
6	Bank A, Input 7 to Bank A, Input 8	Bank A and Input 7	1!8
7	Bank A, Input 8 to Bank A, Input 9	Bank A and Input 8	1!9
8	Bank A, Input 9 to Bank A, Input 10	Bank A and Input 9	1!10
9	Bank B, Input 1 to Bank B, Input 2	Bank B and Input 1	1!12
10	Bank B, Input 2 to Bank B, Input 3	Bank B and Input 2	1!13
11	Bank B, Input 3 to Bank B, Input 4	Bank B and Input 3	1!14
12	Bank B, Input 4 to Bank B, Input 5	Bank B and Input 4	1!15
13	Bank B, Input 5 to Bank B, Input 6	Bank B and Input 5	1!16
14	Bank B, Input 6 to Bank B, Input 7	Bank B and Input 6	1!17
15	Bank B, Input 7 to Bank B, Input 8	Bank B and Input 7	1!18
16	Bank B, Input 8 to Bank B, Input 9	Bank B and Input 8	1!19
17	Bank B, Input 9 to Bank B, Input 10	Bank B and Input 9	1!20
18	Bank C, Input 1 to Bank C, Input 2	Bank C and Input 1	1!22
19	Bank C, Input 2 to Bank C, Input 3	Bank C and Input 2	1!23
20	Bank C, Input 3 to Bank C, Input 4	Bank C and Input 3	1!24
21	Bank C, Input 4 to Bank C, Input 5	Bank C and Input 4	1!25
22	Bank C, Input 5 to Bank C, Input 6	Bank C and Input 5	1!26
23	Bank C, Input 6 to Bank C, Input 7	Bank C and Input 6	1!27
24	Bank C, Input 7 to Bank C, Input 8	Bank C and Input 7	1!28
25	Bank C, Input 8 to Bank C, Input 9	Bank C and Input 8	1!29
26	Bank C, Input 9 to Bank C, Input 10	Bank C and Input 9	1!30
27	Bank D, Input 1 to Bank D, Input 2	Bank D and Input 1	1!32
28	Bank D, Input 2 to Bank D, Input 3	Bank D and Input 2	1!33
29	Bank D, Input 3 to Bank D, Input 4	Bank D and Input 3	1!34
30	Bank D, Input 4 to Bank D, Input 5	Bank D and Input 4	1!35
31	Bank D, Input 5 to Bank D, Input 6	Bank D and Input 5	1!36
32	Bank D, Input 6 to Bank D, Input 7	Bank D and Input 6	1!37
33	Bank D, Input 7 to Bank D, Input 8	Bank D and Input 7	1!38
34	Bank D, Input 8 to Bank D, Input 9	Bank D and Input 8	1!39
35	Bank D, Input 9 to Bank D, Input 10	Bank D and Input 9	1!40

*Assumes Model 7014 installed in slot 1 of mainframe. Programmed as slot (1) and channel.

5.3.8 Differential and common-mode isolation tests

These tests check the leakage resistance (isolation) between HI (H) and LO (L) (differential), and from HI (H) and LO (L) to chassis (common-mode) of every bank and channel. In general, the test is performed by applying a voltage (100V) across the terminals and then measuring the leakage current. The isolation resistance is then calculated as $R = V/I$. In the following procedure, the Model 617 functions as a voltage source and an ammeter. In the V/I function, the Model 617 internally calculates the resistance from the known voltage and current levels, and displays the resistance value.

Perform the following steps to check differential and common mode isolation:

1. Turn off the Model 7001 if it is on, and remove any jumpers and test leads connected to the multiplexer card.
2. Turn on the Model 617 and allow the unit to warm up for two hours for rated accuracy.
3. On the Model 617, select the 2pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.

WARNING

The following steps use high voltage (100V). Be sure to remove power from the circuit before making connection changes.

4. On the Model 617, set the voltage source for +100V, and select the 200nA current range. Make sure the voltage source is still in standby.
5. Place the Model 617 in the V/I measurement function by pressing SHIFT OHMS.
6. With the Model 617 in standby, connect the electrometer to Bank A of the multiplexer card, as shown in Figure 5-7.
7. Install the Model 7014 in slot 1 (CARD 1) of the mainframe, and turn on the Model 7001.
8. Make sure all the relays are open. (Press OPEN ALL on the Model 7001.)
9. On the Model 617, disable zero check, and press OPERATE to source 100V.
10. After allowing the reading on the Model 617 to settle, verify that it is $>1G\Omega$ ($10^9\Omega$). This measurement is the differential leakage resistance (isolation) of Bank A.
11. Place the Model 617 in standby and enable zero check.

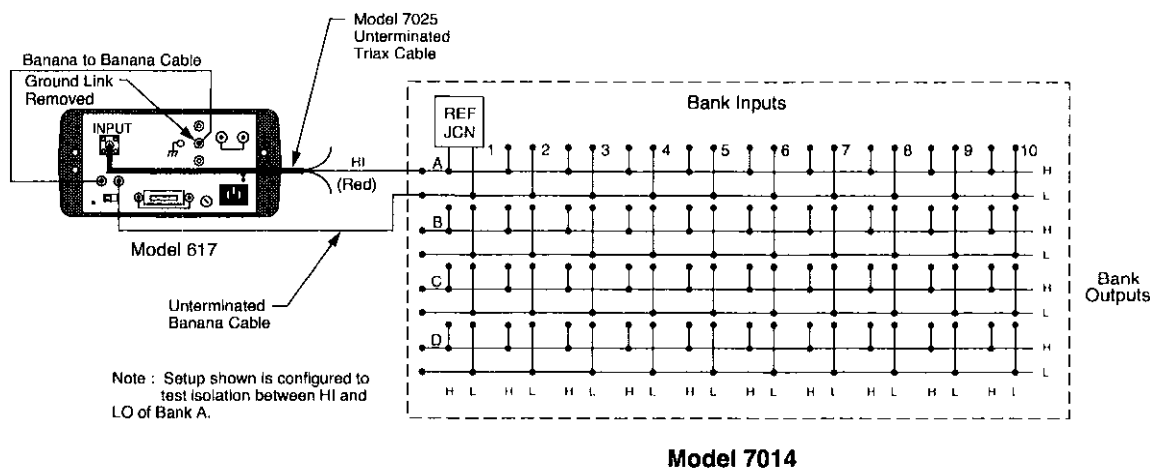


Figure 5-7
Differential isolation test connections

12. Program the Model 7001 to close Channel 1!2 (Bank A, Input 2).
13. On the Model 617, disable zero check and press OPERATE to source +100V.
14. After allowing the reading on the Model 617 to settle, verify that it is also $>1G\Omega$ ($10^9\Omega$). This measurement checks the differential isolation of Input 2.
15. Using Table 5-4 as a guide, repeat the basic procedure in steps 11 through 14 to test Inputs 3 through 10 of Bank A (test numbers 3 through 10 of the table).
16. Use Table 5-4 (test numbers 11 through 43) and the above procedure to test Banks B, C and D.
17. Place the Model 617 voltage source in standby and enable zero check.

NOTE

Refer to Figure 5-8 for the following procedure to check common mode isolation.

18. Turn off the Model 7001, and connect the electrometer to the Model 7014 as shown in Figure 5-8.
19. Repeat steps 4 through 16 to check common mode isolation. Verify that each reading is $>1G\Omega$ ($10^9\Omega$).

Table 5-4
Differential and common-mode isolation testing

Test number	Differential or common mode isolation	Channel closed*
1	Bank A	None
2	Bank A, Input 2	1!2
3	Bank A, Input 3	1!3
4	Bank A, Input 4	1!4
5	Bank A, Input 5	1!5
6	Bank A, Input 6	1!6
7	Bank A, Input 7	1!7
8	Bank A, Input 8	1!8
9	Bank A, Input 9	1!9
10	Bank A, Input 10	1!10
11	Bank B	None
12	Bank B, Input 1	1!11
13	Bank B, Input 2	1!12
14	Bank B, Input 3	1!13
15	Bank B, Input 4	1!14
16	Bank B, Input 5	1!15
17	Bank B, Input 6	1!16
18	Bank B, Input 7	1!17
19	Bank B, Input 8	1!18
20	Bank B, Input 9	1!19
21	Bank B, Input 10	1!20
22	Bank C	None
23	Bank C, Input 1	1!21
24	Bank C, Input 2	1!22
25	Bank C, Input 3	1!23
26	Bank C, Input 4	1!24
27	Bank C, Input 5	1!25
28	Bank C, Input 6	1!26
29	Bank C, Input 7	1!27
30	Bank C, Input 8	1!28
31	Bank C, Input 9	1!29
32	Bank C, Input 10	1!30
33	Bank D	None
34	Bank D, Input 1	1!31
35	Bank D, Input 2	1!32
36	Bank D, Input 3	1!33
37	Bank D, Input 4	1!34
38	Bank D, Input 5	1!35
39	Bank D, Input 6	1!36
40	Bank D, Input 7	1!37
41	Bank D, Input 8	1!38
42	Bank D, Input 9	1!39
43	Bank D, Input 10	1!40

*Assumes Model 7014 installed in slot 1 of mainframe. Programmed as slot (1) and channel.

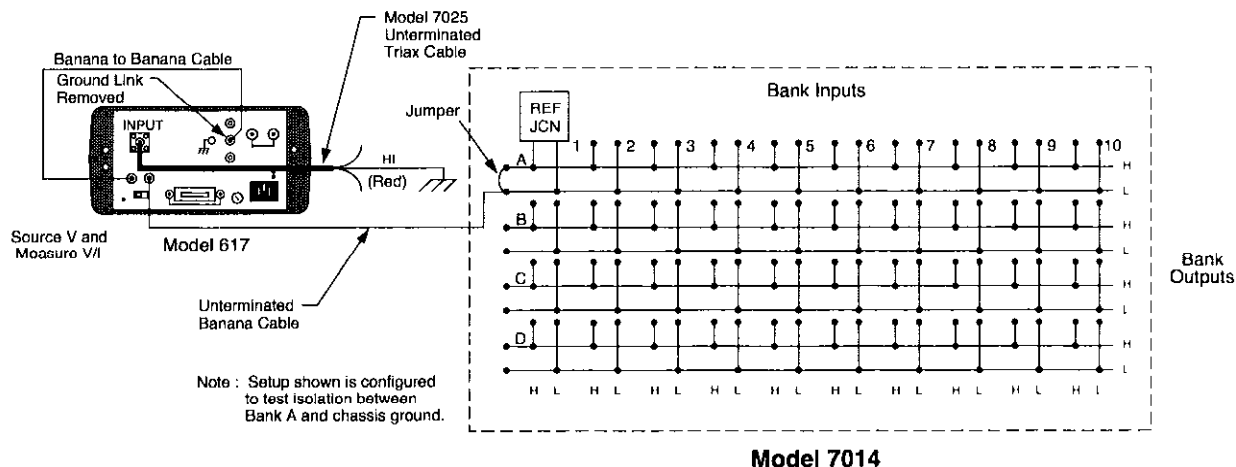


Figure 5-8
Common-mode isolation test connections

5.4 Calibration

There are two calibration procedures given here. The first procedure establishes the specified accuracy of the Model 7014 card with a calibrated thermistor probe monitoring the temperature under the isothermal cover. The second procedure establishes an ice-point reference for a piece of thermocouple wire from the spool intended for a Model 7014 application.

Both calibration procedures should be performed at an ambient temperature of $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$, and a relative humidity of less than 70%.

NOTE

It is recommended that the Model 7014 is calibrated in the same Model 7001 mainframe being used for normal applications.

5.4.1 Calibration with thermistor probe

This procedure requires a calibrated thermistor probe (Thermometrics Series CSP A207A or equivalent). The test can be automated with a bus controller.

Bench reset conditions are assumed for the Models 7001 and 2001. In general, the procedure has the following steps:

1. Set a Model 196 DMM on the $300\text{k}\Omega$ range, or a Model 2001 Multimeter on the $200\text{k}\Omega$ range. (The short circuit currents are $50\mu\text{A}$ and $7\mu\text{A}$, respectively. Due to the self-heating effects of the thermistor probe at higher current, do not use a lower resistance range.) Let the Model 196 warm up for two hours; the Model 2001 for one hour.
2. Set another Model 196 on the 300mVDC range, or a Model 2001 on the 200mVDC range. Insert a 2-terminal low thermal shorting bar into the voltages inputs. Zero the Model 196 after two hours (one hour for the Model 2001) and remove the shorting bar.
3. Set up the test equipment as shown in Figure 5-9. Remove the cover of the Model 7001 as explained in paragraph 7.5 of the Model 7001 Instruction Manual.
4. Unscrew and remove the top clamp on the connector card of the Model 7014 to allow access to trimmer R204. Insert the card into the Model 7001 and protect it from air drafts.
5. Coat the probe with a thermally conductive compound and insert it into the $0.110''$ hole marked "CAL" in the isothermal cover.

6. Take a reading of the probe resistance when it stabilizes.
7. Using the lookup tables for the CSP A207A probe, find the Celsius temperature that corresponds to the above probe resistance. This is the temperature under the isothermal cover as measured by the probe.
8. The following equation calculates the equivalent reference junction output voltage (V_{REF}):

$$V_{REF} = (T_J + 273.15) \times 0.0002$$

9. Close Channel 1 on the Model 7014 card and read the output voltage; it should equal the V_{REF} just calculated. Adjust trimmer R204 until the equivalent temperature equals:

$$(\text{probe temp.} + 0.04^\circ\text{C}) \pm 0.05^\circ\text{C}$$

10. Check the probe resistance again, and find the corresponding temperature with the lookup tables. If the new value differs by more than 0.01°C from the temperature found in step 7, repeat steps 8 and 9.

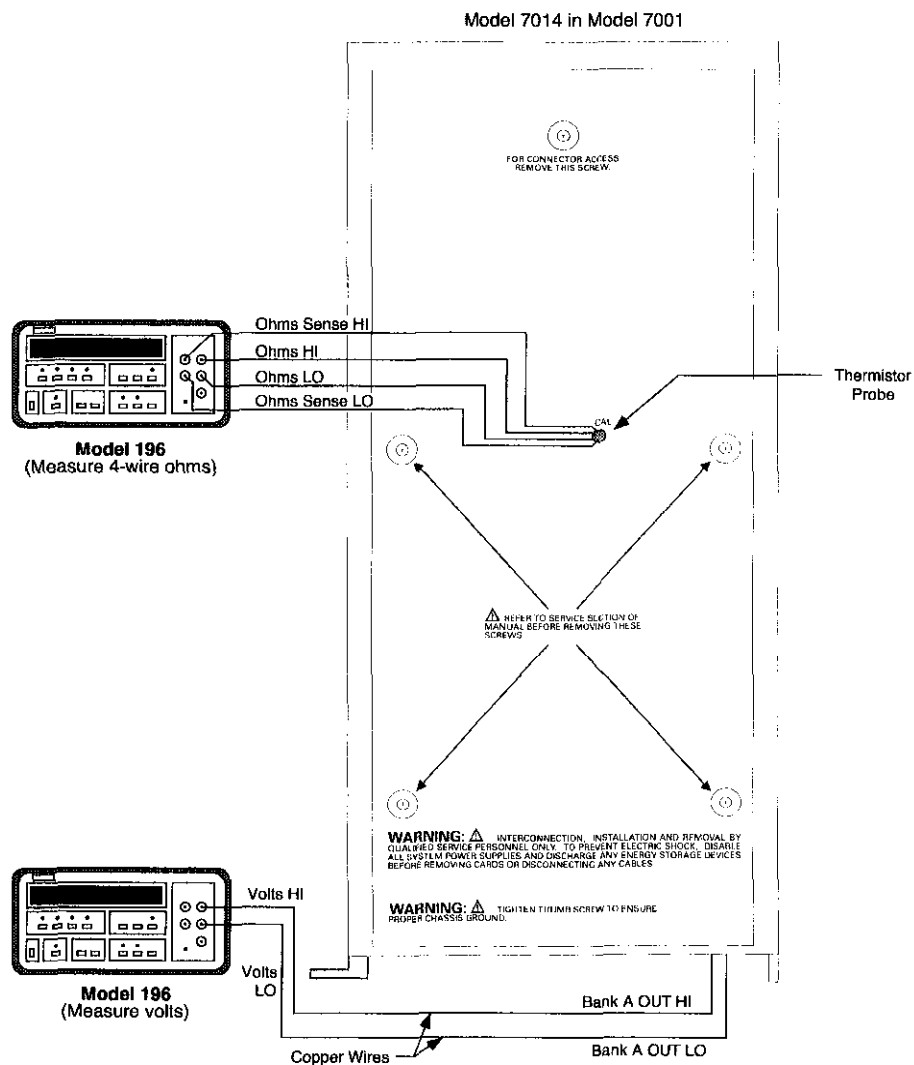


Figure 5-9
Calibration with thermistor probe

5.4.2 Calibration with thermocouple wire

This procedure compensates for errors of the reference junction circuitry and establishes a compensation factor for the offset of the particular piece of thermocouple wire. Because of an inherent error source, the thermocouple wire used in measuring the ice-point, absolute calibration accuracy cannot be guaranteed.

Assuming the homogeneity of the thermocouple wire spool, errors due to thermocouple offset voltages will be significantly reduced for the entire system. For subsequent applications of this particular Model 7014 card, the same spool of wire should be used on the same channel (or one on the same terminal strip), otherwise the Model 7014 should be recalibrated.

This procedure assumes bench reset conditions on the Models 7001 and 2001.

1. On a Model 7014, connect the thermocouple positive lead to Channel 2 HI and the negative lead (red insulation) to Channel 2 LO. Connect copper wires to the HI and LO outputs of Bank A. Route all wires through the cable clamp and insert a small non-metallic screwdriver to adjust trimmer R204. See Figure 5-10.
2. Insert the Model 7014 into a Model 7001. Connect the output wires to the INPUT HI and LO terminals of the Model 2001.
3. Turn on both instruments and allow them to warm up for at least one hour.
4. Fill a Dewar flask or Thermos half full with pea-sized ice made from distilled water. Fill up the flask with distilled water. Stir the contents.
5. Place a twisted or welded thermocouple junction into the volume of the flask occupied by ice. Cover the flask and stir contents occasionally. Allow 20 minutes for temperature stabilization. Add more ice as necessary.
6. On the Model 2001, select the TEMP function and configure it:
 - Select a temperature sensor of **thermocouple** and its type.
 - Configure reference junction #1 with the temperature coefficient (+00.20mV/°C) and offset voltage (+54.63mV @ 0°C) of a Model 7014.
 - Select temperature units of DEG-F (to yield better resolution than DEG-C).
7. From the CONFIG-CHAN menu of the Model 2001, select external inputs (two channels), the JN1 function for Channel 1, and the TMP function for Channel 2.
8. From the CARD-CONFIG menu of the Model 7001, select a delay of 1sec for slot one. From the SCAN-CONFIG menu, select channel spacing of IMMEDIATE. Also from the Model 7001, select a scan list of 1!1, 1!2.
9. Press STEP on the Model 7001 to start a continuous scan of Channels 1 and 2.
10. Note the reading on the Model 2001 displays when Channel 2 is closed. If the display reads other than 32.0°F, adjust trimmer R204 on the Model 7014 card until the Model 2001 reads 32.0°F, ±1 count.
11. Press OPEN ALL on the Model 7001 to stop the scan.

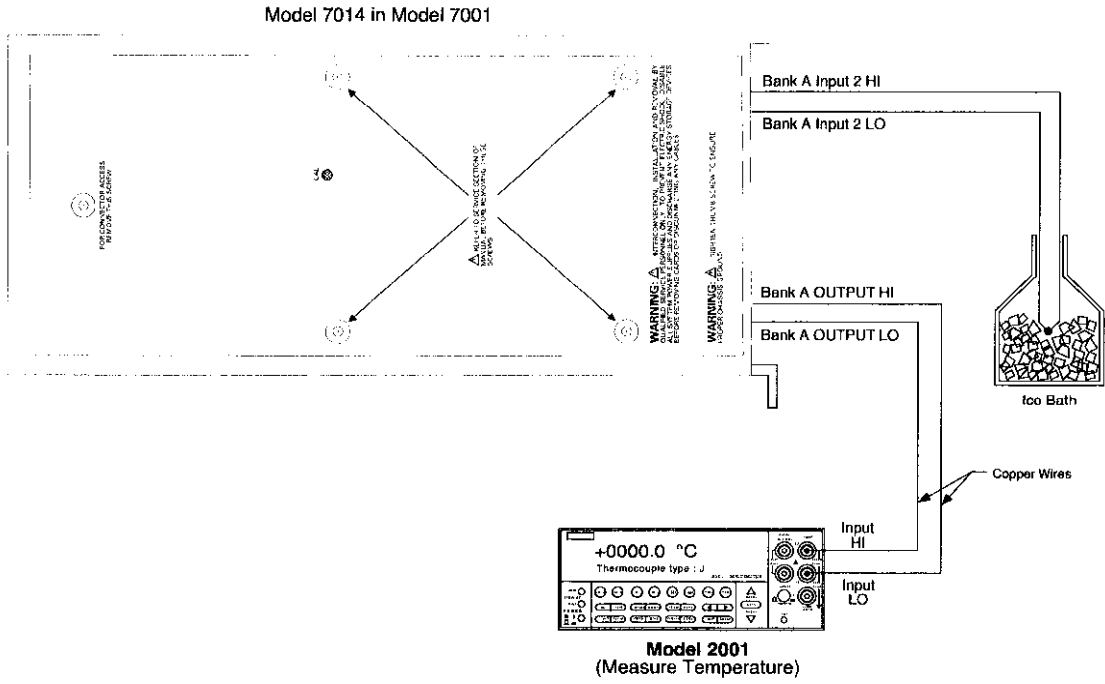


Figure 5-10
Calibration with thermocouple wire

5.5 Special handling of static-sensitive devices

CMOS and other high-impedance devices are subject to possible static discharge damage because of the high-impedance levels involved. When handling such devices, use the precautions listed below.

NOTE

In order to prevent damage, assume that all parts are static-sensitive.

1. Such devices should be transported and handled only in containers specially designed to prevent or dissipate static build-up. Typically, these devices will be received in anti-static containers made of plastic or foam. Keep these parts in their original containers until ready for installation or use.
2. Remove the devices from their protective containers only at a properly-grounded workstation. Also, ground yourself with an appropriate wrist strap while working with these devices.

3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must first be grounded to the bench or table.
5. Use only anti-static type de-soldering tools and grounded-tip soldering irons.

5.6 Principles of operation

The following paragraphs discuss the basic operating principles for the Model 7014, and can be used as an aid in troubleshooting the card. The schematic drawing of the relay card is shown on drawing number 7014-106, located at the end of Section 6.

5.6.1 Block diagram

Figure 5-11 shows a simplified block diagram of the Model 7014. Key elements include the relay drivers and relays, as well as the ROM, which contains card ID and configuration information. These various elements are discussed in the following paragraphs.

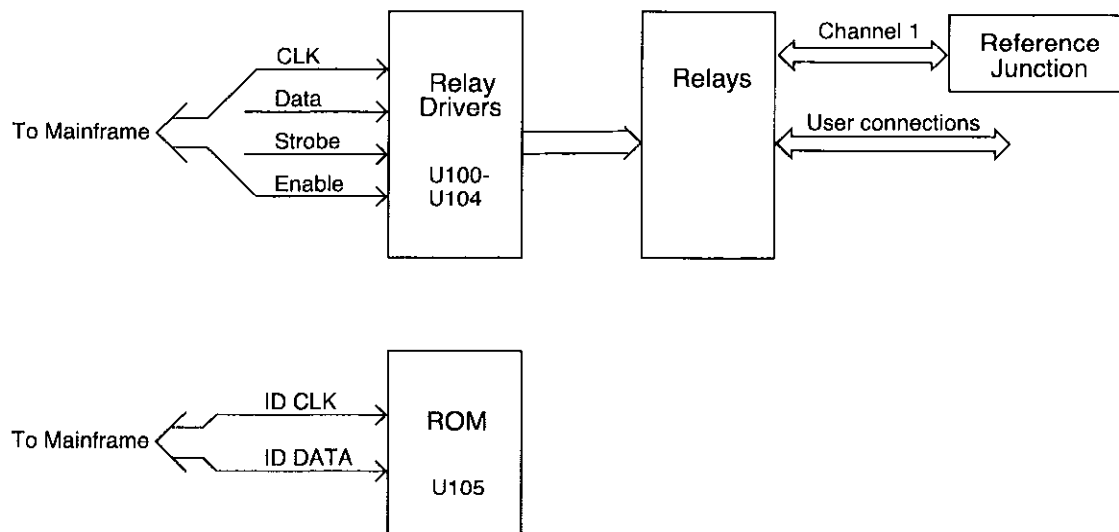


Figure 5-11
Model 7014 block diagram

5.6.2 ID data circuits

Upon power-up, card identification information from each card is read by the mainframe. This ID data includes such information as card ID, hardware settling time, and relay configuration information.

ID data is contained within an on-card EEPROM (U105). In order to read this information, the sequence described below is performed on power-up.

1. The IDDATA line (pin 6 of U105) is set from high to low while the IDCLK line (pin 5 of U105) is held high. This action initiates a start command to the

ROM to transmit data serially to the mainframe (Figure 5-12).

2. The mainframe sends the ROM address location to be read over the IDDATA line. The ROM then transmits an acknowledge signal back to the mainframe, and it then transmits data at that location back to the mainframe (Figure 5-13).
3. The mainframe then transmits an acknowledge signal, indicating that it requires more data. The ROM will then sequentially transmit data after each acknowledge signal it receives.
4. Once all data is received, the mainframe sends a stop command, which is a low-to-high transition of the IDDATA line with the IDCLK line held high (see Figure 5-12).

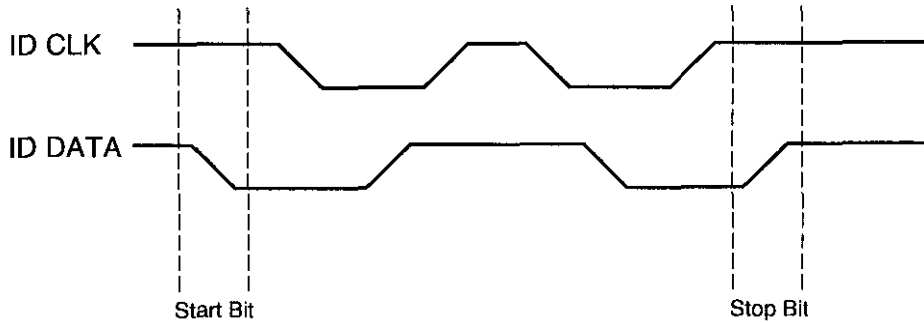


Figure 5-12
Start and stop sequences

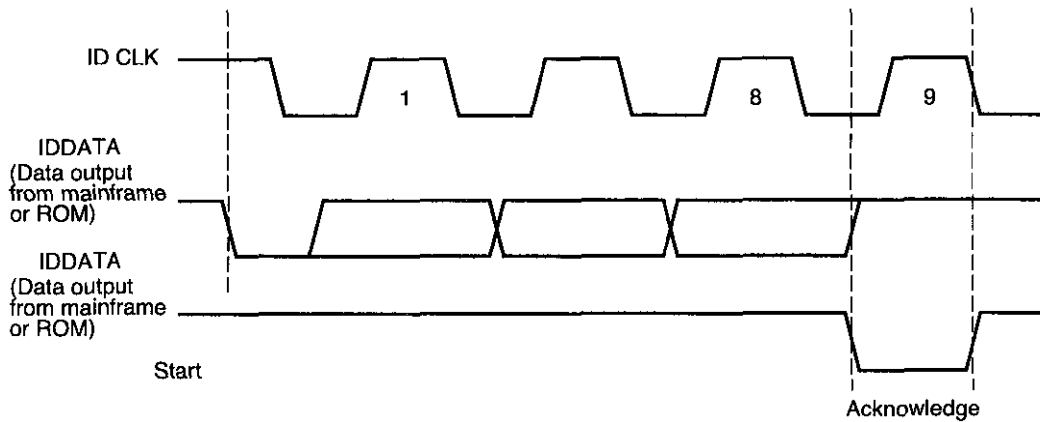


Figure 5-13
Transmit and acknowledge sequence

5.6.3 Relay control

Card relays are controlled by serial data transmitted via the relay DATA line. A total of five bytes for each card are shifted in serial fashion into latches located in the card relay driver ICs. The serial data is clocked in by the CLK line. As data overflows one register, it is fed out the Q'S line of the register down the chain.

Once all five bytes have shifted into the card, the STROBE line is set high to latch the relay information into the Q outputs of the relay drivers, and the appropriate relays are energized (assuming the driver outputs are enabled, as discussed below). Note that a relay driver output goes low to energize the corresponding relay.

5.6.4 Reference junction

NOTE

The circuit discussed below is located on the connector board of the Model 7014. See schematic diagram 7014-166 in Section 6.

The temperature of the reference junction on Channel 1 is measured by a semiconductor temperature transducer (U201). U201, R201, R203, and R204 form the isothermal measurement circuit. R204 is a calibration adjustment potentiometer that compensates for errors introduced by U201, R203, and R201.

5.6.5 Power-on safeguard

NOTE

The power-on safeguard circuit discussed below is actually located on the digital board in the Model 7001 main-frame.

A power-on safeguard circuit, made up of U114 (a D-type flip-flop) and associated components ensures that relays do not randomly energize on power-up and power-down. This circuit disables all relays (all relays are open) during power-up and power-down periods.

The PRESET line on the D-type flip-flop is controlled by the 68302 microprocessor, while the CLK line of the D-type flip-flop is controlled by a VIA port line on the 68302 processor. The Q output of the flip-flop drives each switch card relay driver IC enable pin (U100-U104, pin 8).

When the 68302 microprocessor is in the reset mode, the flip-flop PRESET line is held low, and Q out immediately goes high, disabling all relays (relay driver IC enable pins are high, disabling the relays). After the reset condition elapses (≈ 200 msec), PRESET goes high while Q out stays high. When the first valid STROBE pulse occurs, a low logic level is clocked into the D-type flip-flop, setting Q out low and enabling all relay drivers simultaneously. Note that Q out stays low, (enabling relay drivers) until the 68302 processor goes into a reset condition.

5.7 Troubleshooting

5.7.1 Troubleshooting equipment

Table 5-5 summarizes recommended equipment for troubleshooting the Model 7014.

Table 5-5
Recommended troubleshooting equipment

Description	Manufacturer and model	Application
Multimeter	Keithley 196 or 2001	Measure DC voltages
Oscilloscope	TEK 2243	View logic waveforms

5.7.2 Troubleshooting access

CAUTION

There are four screws that attach the isothermal cover to the connector board. It is only necessary to remove these screws to gain complete access to the solder side of the connector board. Removal of the cover will damage the thermal RTV seal, which will have to be replaced (Keithley Part Number CE-16).

To gain access to the relay card top surface to measure voltages under actual operation conditions, perform the following steps:

1. Disconnect the connector card from the relay card.
2. Remove the Model 7001 cover.
3. Install the relay card in the CARD 1 slot location.
4. Turn on Model 7001 power to measure voltages (see following paragraph).

NOTE

For complete access to the component side of the relay board, it is necessary to remove the copper/vinyl shield that covers the relays (Keithley P/N 7014-308).

5.7.3 Troubleshooting procedure

Table 5-6 summarizes switch card troubleshooting.

WARNING

Lethal voltages are present within the 7001 mainframe. Some of the procedures may expose you to hazardous voltages. Observe standard safety precautions for dealing with

live circuits. Failure to do so could result in personal injury or death.

CAUTION

Observe the following precautions when troubleshooting or repairing the switch card:

To avoid contamination, which could degrade card performance, always handle the card only by the handle and side edges. Do not touch edge connectors, board surfaces, or components on the card. Also, do not touch areas adjacent to electrical contacts on connectors.

Use care when removing relays from the PC board to avoid pulling traces away from the circuit board. Before attempting to remove a relay, use an appropriate de-soldering tool, such as a solder sucker, to clear each mounting hole completely free of solder. Each relay pin must be free to move in its mounting hole before removal. Also, make certain that no burrs are present on the ends of the relay pins.

Table 5-6
Troubleshooting procedure

Step	Item/component	Required condition	Comments
1	GND pad		All voltages referenced to digital ground (GND pad).
2	+6V pad	+6VDC	Relay voltage.
3	+5V pad	+5VDC	Logic voltage.
4	+14.6V pad	+14.6VDC	Relay bias voltage.
5	U201, pin 2	+59.23mV @ 23°C	Reference junction sensor output.
6	U105, pin 5	ID CLK pulses	During power-up only.
7	U105, pin 6	ID DATA pulses	During power-up only.
8	U100, pin 7	STROBE pulse	End of relay update sequence.
9	U100, pin 2	CLK pulses	During relay update sequence only.
10	U100, pin 3	DATA pulses	During relay update sequence only.
11	U100-U104, pins 10-18	Low with relay energized; high with relay de-energized.	Relay driver outputs.

6

Replaceable Parts

6.1 Introduction

This section contains replacement parts information, schematic diagrams, and component layout drawings for the Model 7014.

6.2 Parts lists

Parts lists for the various circuit boards are included in tables integrated with schematic diagrams and component layout drawings for the boards. Parts are listed alphabetically in order of circuit designation.

6.3 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:

1. Card model number 7014
2. Card serial number
3. Part description
4. Circuit description, if applicable
5. Keithley part number

6.4 Factory service

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

- Call the Test Instruments 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 card.
- Carefully pack the card in the original packing carton.
- Write ATTENTION REPAIR DEPT and the RMA number on the shipping label.

Note: It is not necessary to return the matrix main-frame with the card.

6.5 Component layouts and schematic diagrams

Component layout drawings and schematic diagrams are included on the following pages integrated with the parts lists:

Table 1 Parts List, Relay Card for 7014.

7011-100 Component Layout, Relay Card for 7011/7014.

7011-106 Schematic, Relay Card for 7014.

Table 2 Parts List, Connector Card for 7014.

7014-160 Component Layout, Connector Card for 7014.

7014-166 Schematic, Connector Card for 7014.

Table 6-1
Parts List, Relay Card (Scanner Board) for Model 7014

Circuit Desig.	Description	Keithley Part No.
	SHIELD 2-56X1/4 PHILLIPS PAN HD (FOR SCANNER SHIELD) SOCKET (FOR U105) THERMAL SHIELD (FOR RELAYS) 2-56X5/8 PHILLIPS PAN HD FASTENER (P2001 TO STANDOFF AND SHIELD) 2-56X3/16 PHILLIPS PAN HEAD SCREW (SCANNER BOARD TO SHIELD)	7011-305 2-56X1/4PPH SO-72 7014-308 FA-245-1 2-56X3/16PPH
C100-108,118,119 C111 C113,114 C115,116,117	CAP,.1UF,20%,50V,CERAMIC CAP,1UF,20%,50V, CERAMIC CAP, 10UF, 20%, 50V, ALUM ELEC CAP,150PF,10%,1000V,CERAMIC	C-365-1 C-237-1 C-489-10 C-64-150P
J1002,1003	CONN, 48-PIN, 3-ROWS	CS-736-2
K100-139	RELAY, ULTRA-SMALL POLARIZED TF2E-5V	RL-149 or RL-166 (See Note 1.)
P2001	CONNECTOR, 32-PIN, 2-ROWS	CS-775-1
R106,107	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
U100-104 U105	IC, 8-BIT SERIAL-IN LATCH DRIVER,5841A EPROM PROGRAM	IC-536 7014-800- (See Note 2.)
W100-108	JUMPER	J-15

Notes:

1. Early production runs of the Model 7014 card used RL-149 relays (Aromat TF2E-5V). Later production runs used RL-166 relays (Aromat TF2E-6V). The two relay types are pin-compatible and can be used interchangeably.
2. Order current firmware revision level (e.g., 7014-800-A01).

Table 6-2
Parts List, Connector Card (Terminal Board) for Model 7014

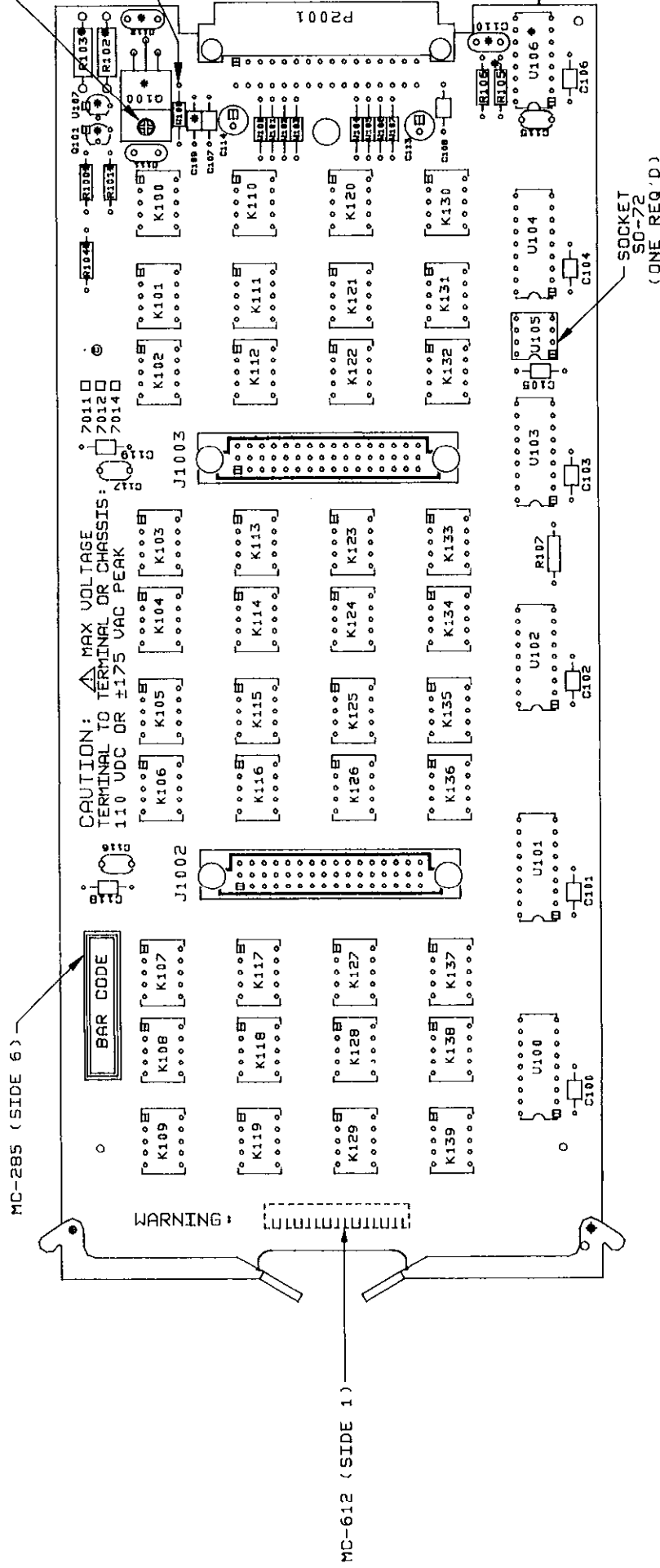
Circuit Desig.	Description	Keithley Part No.
	BRACKET SHIELD OVERLAY, SHIELD TOP CLAMP THERMAL RTV 4-40X3/16 PHILLIPS FLAT HEAD SCREW CABLE CLAMP 4-40X5/16 PHILLIPS FLAT HD (SCANNER BOARD TO TERMINAL BOARD) STRIP, POLYURETHANE (FOR BOTTOM CLAMP) CONNECTOR, JUMPER (FOR CS-339-2) CONNECTOR SHIM (FOR P1002,1003) CAPTIVE SCREW (FOR TOP CLAMP)	BR-39 7014-302 7014-304 7011-302 CE-16 4-40X3/16PFH 7011-304-4 4-40X5/16PFH 2001-345-1 CS-476 7011-309 FA-243-1
C201	CAP,1UF,20%,50V, CERAMIC	C-237-1
C202	CAP,.1UF,20%,50V,CERAMIC	C-365-.1
E201	SURGE ARRESTOR CG2-300L	SA-2
J1004-1008	CONNECTOR, 10-PIN	TE-117-10
J1009-1011	CONNECTOR, 12-PIN	TE-117-12
P1002,1003	CONNECTOR, 48-PIN, 3 ROWS	CS-748-3
R201	RES, 205, .1%, 1/10W, METAL FILM	R-263-205
R202	RES,100,5%,1/4W,COMPOSITION OR FILM	R-76-100
R203	RES,5.62K,1%,1/8W,METAL FILM	R-88-5.62K
R204	POT,10K,10%,.75W,NON-WIREWOUND	RP-89-10K
U201	IC, TEMPERATURE TRANSDUCER, AD590KH	IC-447
W201-206	CONN,BERG,2 PIN	CS-339-2

001-1102-01

LTR. EDC NO.	REVISION	ENG. DATE
B	PRELIMINARY	
C	RELEASED	MS 9-20-91
D	DELETED 2-56X3/16PPH (REQ'D) S2	8-5-92
D1	ADDED MC-612 CHART FOR 7014, AND NOTE TO INSTALL W108 TO 7014 ONLY	9-1-92

4-40X3/16 PPHSEM (ONE REQ'D)

INSTALL W108 ON 7014 ONLY



♦ FOR 7014 BUILD, DO NOT INSTALL THE FOLLOWING PARTS

R100	Q100	U106	C109
R101	Q101	U107	C110
R102			C112
R103			4-40X3/16PPHSEM
R104			
R105			

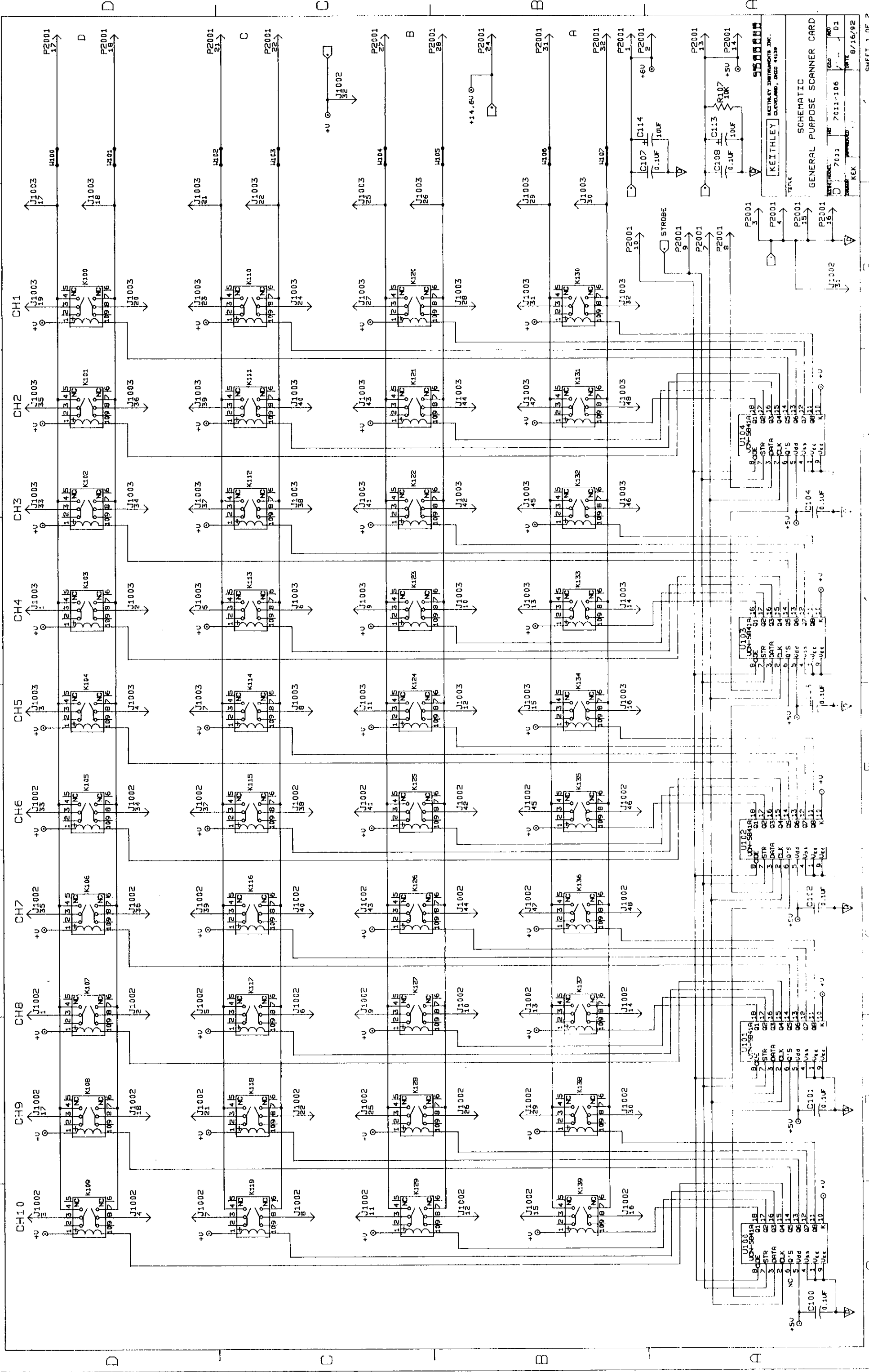
NOTE: FOR COMPONENT INFORMATION, REFER TO PRODUCT STRUCTURE FOR 7011, 7012 AND 7014

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XX-1.015	ANG. ±1°	8/12/91	5:4	COMPONENT LAYOUT
XXX-2.005	FAC. ±1/64	DRN. KEK	ENG. GPPA.	SCANNER BOARD
SURFACE MAX. 0.005				

KEITHLEY KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139

NO. 7011-100

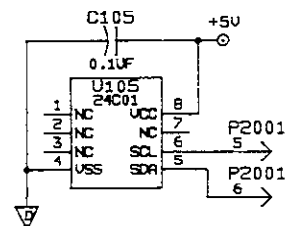
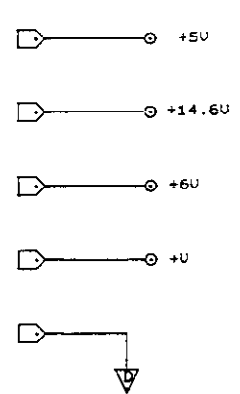
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7014	1	7011-101
7012	1	7011-101
7011	1	7011-101



SCHEMATIC
GENERAL PURPOSE SCANNER CARD
KEITHLEY
RETIRED INSTRUMENTS DIV.
CLOSURE, DEED #139
7013 7011-106
8/16/92

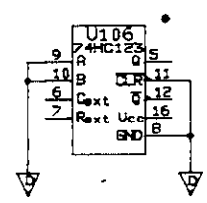
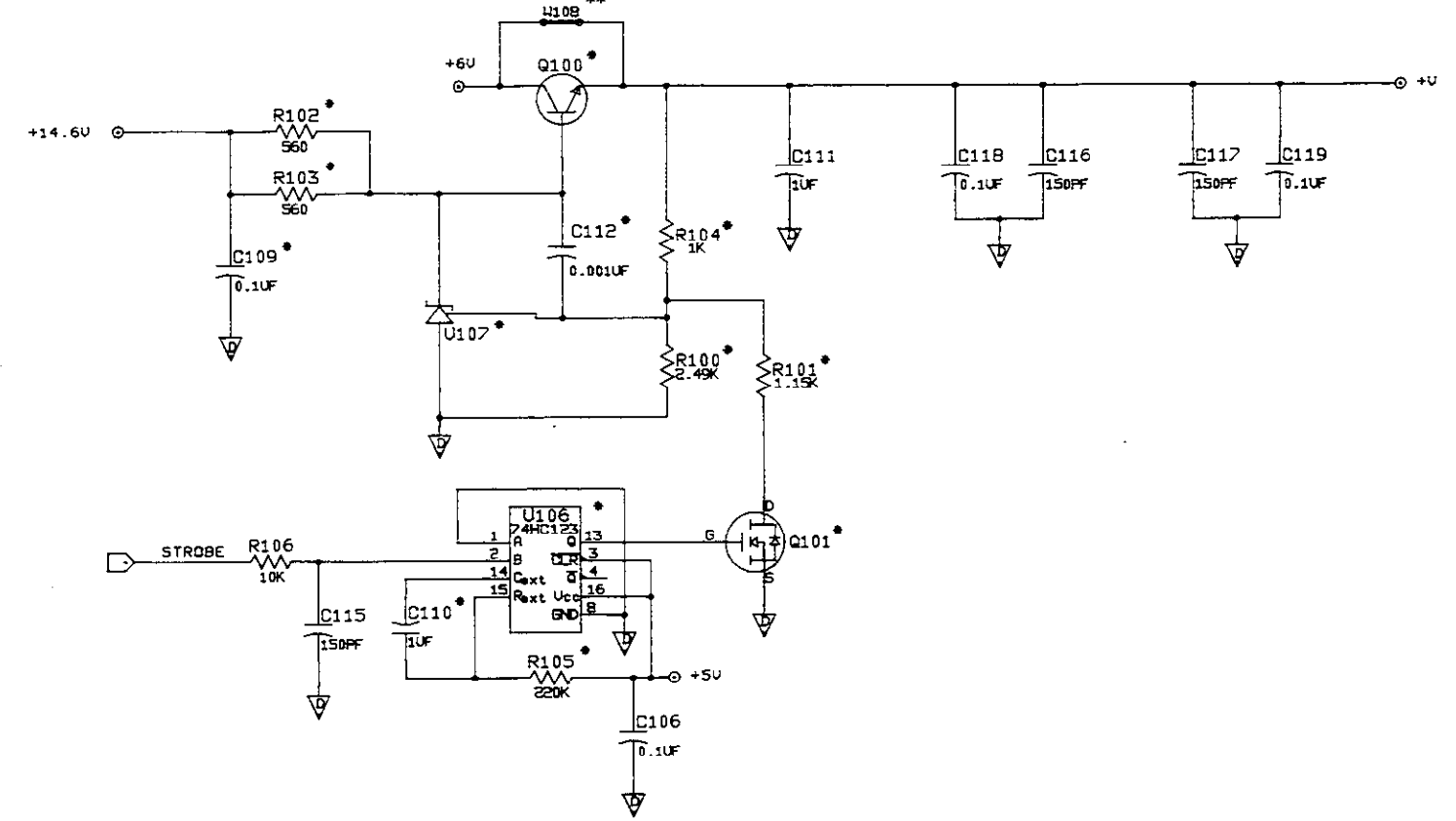
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D
C
B
A



- P2001 NC 11 →
- P2001 NC 12 →
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- P2001 NC 23 →
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- P2001 NC 26 →
- P2001 NC 29 →
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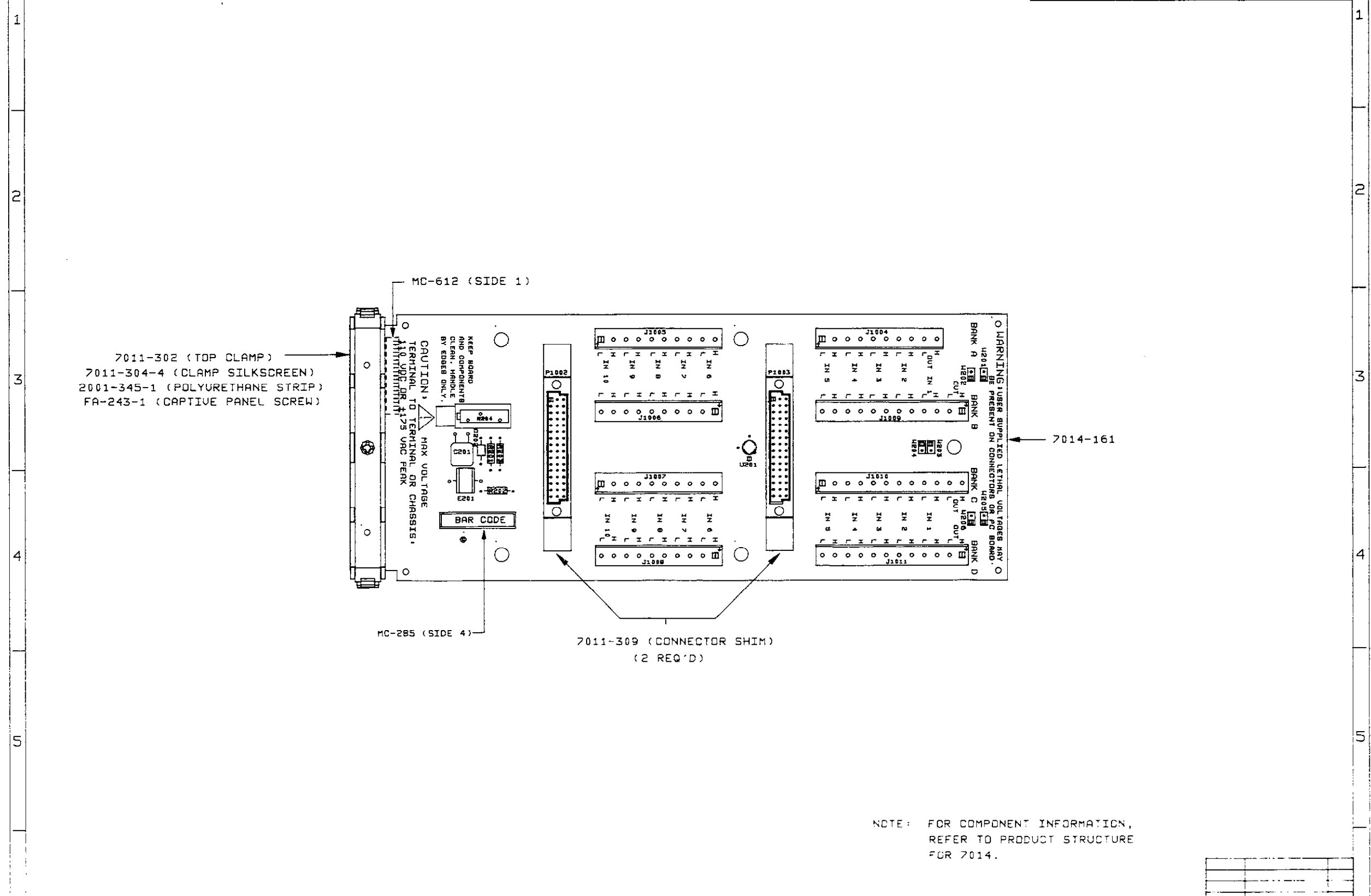
** - POPULATE W108 FOR 7014 BUILD ONLY



* - PARTS NOT USED ON 7014-102 BUILD, R100, R101, R102, R103, R104, R105, Q100, Q101, U106, U107, C110, & C112.

KEITHLEY		KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44130	
TITLE SCHEMATIC GENERAL PURPOSE SCANNER CARD			
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DESIGNER KEK	APPROVED CJM	DATE 8/16/92	

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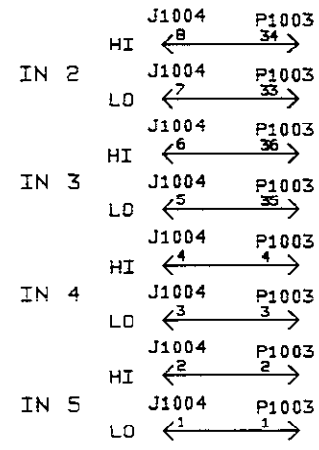


NOTE: FOR COMPONENT INFORMATION, REFER TO PRODUCT STRUCTURE FOR 7014.

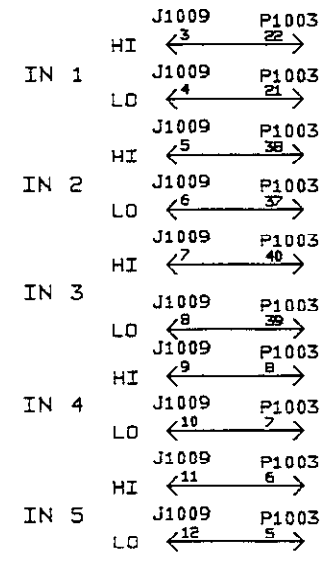
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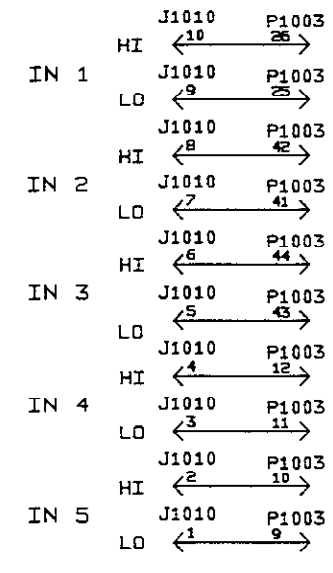
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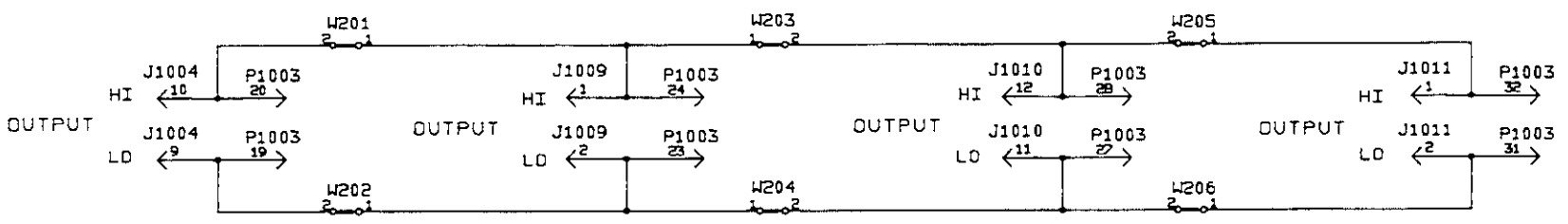
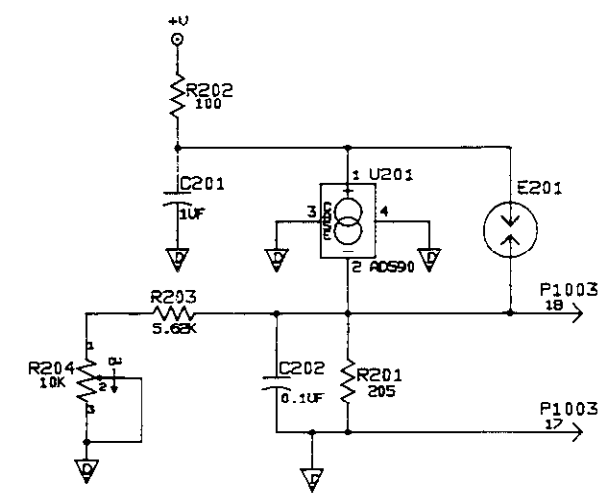
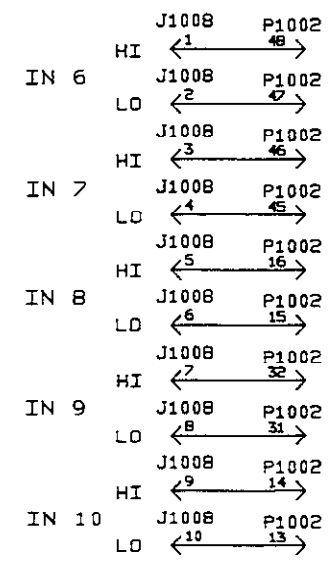
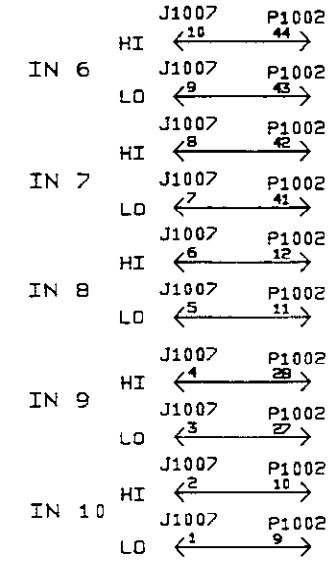
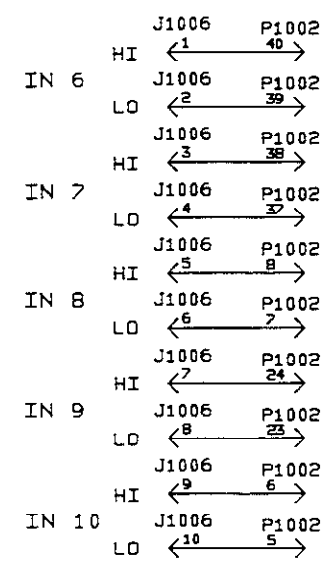
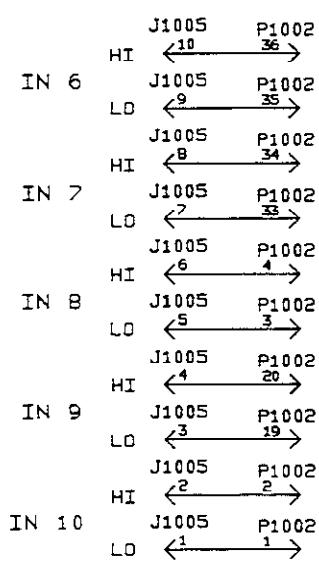
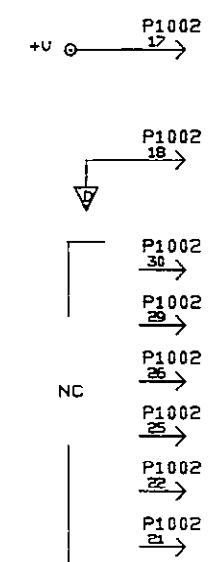
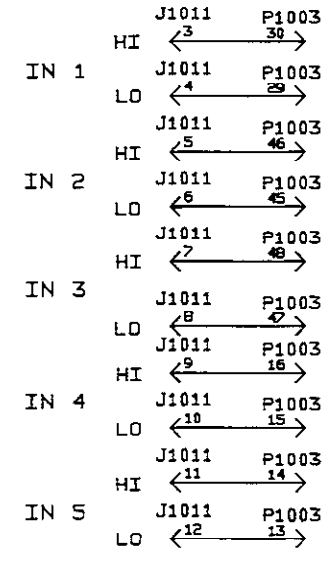
BANK B



BANK C



BANK D



KEITHLEY		KEITHLEY INSTRUMENTS INC.	
CLEVELAND, OHIO 44130			
TITLE			
SCHEMATIC,			
LOW THERMAL CARD			
REV	DATE	APP'D	CHK'D
D	7014	7014-106	5/20/67
MAH/CB			SAVE
			8/17/92

8 7 6 5 4 3 2 1

A

Thermocouple Conversion Tables

Table A-1
NIST Quartic Coefficients for Types S, R, B, E, J, K and T

Type S Thermocouples ¹ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (µV)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
-50 to 900			5.5439639	+0	1.0103667	-2	-1.0944499	-5	4.9628963	-9	-7 to 14	
0 to 1100			5.8791282	+0	7.9098118	-3	-6.7450002	-6	2.5247577	-9	-16 to 12	
0 to 1400			6.2516859	+0	5.8347856	-3	-3.4351369	-6	9.4022202	-10	-35 to 25	
0 to 1650			6.5554932	+0	4.4519908	-3	-1.6378513	-6	2.4140360	-10	-55 to 35	
0 to 1768			6.6834421	+0	3.9334084	-3	-1.0384046	-6	3.4244511	-11	-60 to 35	
400 to 1100	-3.8051591	+2	8.7228147	+0	6.2984807	-4	9.0526670	-7	-2.9241601	-10	-.7 to .5	
400 to 1400	-5.2412524	+2	9.5827994	+0	-1.2077351	-3	2.5723104	-6	-8.3681057	-10	-1.6 to 1.5	
400 to 1650	-5.0061921	+2	9.4591354	+0	-9.7986687	-4	2.3967559	-6	-7.8837971	-10	-1.8 to 1.9	
1050 to 1400	1.4352322	+3	2.9873073	+0	6.9951678	-3	-1.8986036	-6	6.5006637	-11	-.05 to .05	
1050 to 1650	1.3054176	+3	3.4129348	+0	6.4741403	-3	-1.6163524	-6	7.9103746	-12	-.05 to .05	
1400 to 1550	1.8695088	+2	6.4091373	+0	3.4664812	-3	-2.7553724	-7	-2.1606150	-10	-.05 to .05	
1400 to 1650	1.0863331	+3	3.9952876	+0	5.8939317	-3	-1.3595782	-6	-3.4675031	-11	-.05 to .05	
1400 to 1768	-7.4180405	+4	2.0043202	+2	-1.8607781	-1	8.1899566	-5	-1.3556030	-8	-1.0 to 1.3	
1666 to 1768	8.2703440	+4	-1.3532278	+2	8.0243878	-2	-1.0633404	-5	1.7212343	9	.05 to .05	
Reference Junction Correction	0 to 50		5.3994446	+0	1.2467754	-2	1.9934168	-5			-0.01 to +0.01	

¹Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $E = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$ where E is in microvolts and T is in degrees Celsius.

Type S Thermocouples ² Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (°C)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
-50 to 900			1.6414048	-1	-2.0241757	-5	2.7849728	-9	-1.4172102	-13	-11 to 3	
0 to 1100			1.5445376	-1	-1.3349067	-5	1.3626587	-9	-5.3270847	-14	-3 to 6	
0 to 1400			1.4713897	-1	-9.0783455	-6	6.5660913	-10	-1.8499175	-14	-5 to 9	
0 to 1650			1.4260554	-1	-7.0073775	-6	3.8981279	-10	-8.3047780	-15	-6 to 11	
0 to 1768			1.4087955	-1	-6.3195007	-6	3.1267454	-10	-5.7422562	15	-6 to 12	
400 to 1100	4.1137317	+1	1.1599785	-1	-1.8642979	-6	1.2643267	-11	8.4828836	-16	-.05 to .07	
400 to 1400	4.4507790	+1	1.1373998	-1	-1.3349811	-6	-3.9224680	-11	2.6563405	15	-.08 to .08	
400 to 1650	4.1670535	+1	1.1543356	-1	-1.6782780	-6	-1.0845801	-11	1.8379726	-15	-.2 to .2	
1050 to 1400	-3.0938374	+1	1.4106560	-1	-4.9794442	-6	1.7334256	-10	-1.9262160	15	-.003 to .003	
1050 to 1650	1.2226507	+1	1.2706383	-1	-3.2873314	-6	8.3038098	-11	-1.3019379	-16	-.010 to .010	
1400 to 1550	1.3866867	+2	9.3486676	-2	4.8592708	-8	-6.3885209	-11	2.2896541	-15	-.0005 to .0005	
1400 to 1650	1.3923740	+2	9.3267401	-2	7.7266682	-8	-6.5458208	-11	2.3208160	-15	-.0005 to .0005	
1400 to 1768	4.5133695	+3	-1.0046437	+0	1.0322002	-4	-4.3637046	-9	6.9361610	-14	-.13 to .10	
1666 to 1768	2.3131446	+4	-5.4122671	+0	4.9347196	-4	-1.9681943	-8	2.9430179	-13	-.0005 to .0005	

²Quartic approximations to the data as a function of voltage in selected temperature ranges (°C). The expansion is of the form $T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$ where E is in microvolts and T is in degrees Celsius.

Type R Thermocouples ³ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (µV)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact- Approx.	
-50 to 900			5.4295008	+0	1.1446885	-2	-1.1295306	-5	5.0020496	-9	-7 to 15	
0 to 1100			5.7622558	+0	9.2715271	3	-7.1346883	6	2.5877458	-9	-16 to 12	
0 to 1400			6.1429772	+0	7.1515857	-3	-3.7539447	-6	9.6963832	-10	-35 to 25	
0 to 1650			6.4615269	+0	5.7010917	-3	-1.8683292	-6	2.3636365	-10	-55 to 35	
0 to 1768			6.5962120	+0	5.1559203	-3	-1.2385309	-6	1.8827643	-11	-65 to 35	
400 to 1100	-4.0674108	+2	8.7490294	+0	1.7115155	-3	7.5039035	-7	-3.0096280	-10	-.4 to .5	
400 to 1400	-5.6047484	+2	9.6731111	+0	-2.6994046	-4	2.5536988	-6	-8.9155491	-10	-1.7 to 1.6	
400 to 1650	-5.4505828	+2	9.5942872	+0	-1.2813352	-4	2.4468512	-6	-8.6286756	-10	-2.1 to 1.8	
1050 to 1400	1.6618159	+3	2.3048526	+0	8.7635426	-3	-2.3016819	-6	7.4284923	-11	-.05 to .05	
1050 to 1650	1.5132838	+3	2.7958847	+0	8.1571403	-3	-1.9701159	-6	6.5568964	-12	-.05 to .05	
1400 to 1550	2.4008703	+3	4.1604579	-1	1.0549178	-2	-3.0383621	-6	1.8540516	-10	-.05 to .05	
1400 to 1650	1.5787334	+3	2.6321144	+0	8.3100314	-3	-2.0332036	-6	1.6260416	-11	-.05 to .05	
1400 to 1768	-7.1904948	+4	1.9442383	+2	-1.7913090	-1	7.9264764	-5	-1.3187245	-8	-1.0 to 1.3	
1666 to 1768	8.8532076	+4	-1.5014129	+2	9.5376167	-2	-1.6644901	-5	-8.3062870	-10	-.05 to .05	
Reference Junction Correction 0 to 50			5.2891411	+0	1.3844426	-2	-2.0889531	-5			-0.01 to +0.01	

³ Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $E = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$ where E is in microvolts and T is in degrees Celsius.

Type R Thermocouples ⁴ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (°C)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact- Approx.	
-50 to 900			1.6251434	-1	-2.0454379	-5	2.5404935	-9	-1.1767904	-13	-13 to 3	
0 to 1100			1.5239494	-1	-1.3755675	-5	1.2610922	-9	-4.4281251	-14	-.4 to 7	
0 to 1400			1.4441607	-1	-9.5014952	-6	6.2073358	-10	-1.5622497	-14	-6 to 10	
0 to 1650			1.3944190	-1	-7.4485484	-6	3.8266182	-10	-7.4517277	-15	-7 to 13	
0 to 1768			1.3752883	-1	-6.7651171	-6	3.1420473	-10	-5.4254872	-15	-7 to 14	
400 to 1100	4.5509556	+1	1.1284875	-1	-2.8603978	-6	8.5173702	-11	-1.1440038	-15	-.04 to .04	
400 to 1400	4.9160016	+1	1.1054589	-1	-2.3559046	-6	3.9276248	-11	3.3369324	-16	-.08 to .09	
400 to 1650	4.8343651	+1	1.1098270	-1	-2.4353890	-6	4.5164488	-11	1.8172612	-16	-.10 to .12	
1050 to 1400	-4.1134459	+0	1.2738464	-1	-4.3132296	-6	1.3863582	-10	-1.5283798	-15	-.002 to .002	
1050 to 1650	3.7487318	+1	1.1519304	-1	-2.9827002	-6	7.4538667	-11	-3.7809957	-16	-.011 to .011	
1400 to 1550	8.0559850	+1	1.0442877	-1	-1.9827500	-6	3.3603790	-11	2.4513433	-16	-.0005 to .0005	
1400 to 1650	1.4180146	+2	9.0181346	-2	-7.4068329	-7	-1.4487255	-11	9.4290495	-16	-.0005 to .0005	
1400 to 1768	3.1758093	+3	-5.8922431	-1	5.6190639	-5	-2.1303241	-9	3.0369250	-14	-.11 to .08	
1666 to 1768	1.2883437	+4	-2.6747958	+0	2.2334214	-4	-8.0565860	-9	1.0882779	-13	-.0007 to .0007	

⁴ Quartic approximations to the data as a function of voltage in selected temperature ranges (°C). The expansion is of the form $T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$ where E is in microvolts and T is in degrees Celsius.

Type B Thermocouples ⁵ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (µV)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
0 to 900			-2.3614224	-1	5.7496551	-3	-5.6339756	-7	-1.1808558	-10	-22 to .14	
0 to 1100			-2.3893338	-1	5.7684447	-3	-5.9963692	-7	-9.7041131	-11	-18 to .20	
0 to 1400			-2.3476301	-1	5.7480761	-3	-5.7165679	-7	-1.0838193	-10	-.7 to 1.0	
0 to 1650			-1.9185893	-1	5.5578879	-3	-3.3057924	-7	-2.0018428	-10	-4 to 5	
0 to 1820			-1.3749133	-1	5.3446673	-3	-9.1094186	-8	-2.8098361	-10	-8 to 9	
400 to 1100	1.3740347	+1	-3.2914888	-1	5.9766638	-3	-8.0141311	-7	-2.7203972	-11	-.05 to .05	
400 to 1400	-2.5321108	+1	-9.9736579	-2	5.4976533	-3	-3.7806912	-7	-1.6156824	-10	-.5 to .5	
400 to 1650	-1.1708354	+2	3.9860894	-1	4.5539656	-3	3.6623964	-7	-3.6969100	-10	-2.0 to 1.8	
1050 to 1400	-9.8446259	+2	3.3670688	+0	8.2282215	-4	2.4061224	-6	-7.7901142	-10	-.05 to .05	
1050 to 1650	-1.3702395	+3	4.6252371	+0	-7.0976836	-4	3.2325686	-6	-9.4548852	-10	-.05 to .05	
1400 to 1550	-4.7644591	+2	2.2890832	+0	1.5749253	-3	2.2417410	-6	-7.8471224	-10	-.05 to .05	
1400 to 1650	-6.4878929	+2	2.7380621	+0	1.1375302	-3	2.4305578	-6	-8.1518033	-10	-.05 to .05	
Reference Junction Correction												
0 to 50			-2.4673839	-1	5.9050303	-3	-1.2267180	-6			-0.01 to +0.01	

⁵ Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $E = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$ where E is in microvolts and T is in degrees Celsius.

Type B Thermocouples ⁶ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (°C)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
0 to 900			8.9244743	-1	-5.7447033	-4	1.8053618	-7	-1.9719121	-11	-30 to 75	
0 to 1100			7.2874066	-1	-3.1771931	-4	6.8254996	-8	-5.1002233	-12	-35 to 90	
0 to 1400			5.7822214	-1	-1.6039309	-4	2.2187592	-8	-1.0678514	-12	-45 to 110	
0 to 1650			4.9929130	-1	-1.0349686	-4	1.0792281	-8	-3.9111456	-13	-50 to 120	
0 to 1820			4.6255054	-1	-8.2176262	-5	7.3717195	-9	-2.2913665	-13	-50 to 130	
400 to 1100	1.8946288	+2	3.0966136	-1	-5.8100680	-5	8.2483967	-9	-4.7591774	-13	-.09 to 1.0	
400 to 1400	2.0949015	+2	2.7222162	-1	-3.6930932	-5	3.6830239	-9	-1.4483702	-13	-3 to 3	
400 to 1650	2.2354664	+2	2.4988761	-1	-2.7160312	-5	2.1299660	-9	-6.4220755	-14	-5 to 5	
1050 to 1400	3.2188156	+2	1.8282378	-1	-1.1561743	-5	6.4320083	-10	-1.4544375	-14	-.003 to .003	
1050 to 1650	3.4418084	+2	1.7031473	-1	-8.9696912	-6	4.0789445	-10	-6.6410259	-15	-.025 to .020	
1400 to 1550	3.7140306	+2	1.5828913	-1	-7.0050689	-6	2.6714849	-10	-2.9082072	-15	-.001 to .001	
1400 to 1650	3.9253848	+2	1.4979551	-1	-5.7276293	-6	1.8192801	-10	-7.8042686	-16	-.001 to .001	

⁶ Quartic approximations to the data as a function of voltage in selected temperature ranges (°C). The expansion is of the form $T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$ where E is in microvolts and T is in degrees Celsius.

Type E Thermocouples ⁷ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (μV)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact- Approx.	
-270 to 0			5.9287179	+1	7.0983783	-2	5.2421843	-5	3.8137875	-7	-5 to 5	
-200 to 0			5.8754764	+1	5.7443085	-2	-5.0637772	-5	1.3960921	-7	-.5 to .4	
-200 to 800			5.8043714	+1	5.6118501	-2	-5.9506584	-5	2.2327737	-8	-60 to 30	
-20 to -500			5.8318735	+1	5.4292960	-2	-5.6288941	-5	2.0825828	-8	-8 to 4	
0 to 400			5.8327591	+1	5.3761106	-2	-5.2870656	-5	1.5352840	-8	-.3 to 4	
0 to 1000			5.8734597	+1	5.0789891	-2	-4.7821793	-5	1.4659118	-8	-18 to 17	
400 to 1000	-8.5384268	+2	6.5022632	+1	3.4354900	-2	-2.9769494	-5	7.6039401	-9	-2 to 2.5	
600 to 800	-1.3839633	+3	6.7211126	+1	3.1669230	-2	-2.9237913	-5	8.1514671	-9	-.03 to .03	
850 to 1000	-5.1503130	+4	-1.6691278	+2	4.1877018	-1	-3.1228607	-4	8.5283044	-8	-.06 to .06	
Reference Junction Correction 0 to 50			5.8637565	+1	4.6720025	-2	-1.4438022	-5			-12 to +.24	

⁷ Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $E = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$ where E is in microvolts and T is in degrees Celsius.

Type E Thermocouples ⁸ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (°C)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact- Approx.	
-270 to 0			2.8168878	-3	-8.5940057	-6	-1.4930918	-9	-8.7987588	-14	-9 to 6	
-200 to 0			1.5726646	-2	-1.2102152	-6	-1.9577799	-10	-1.6696298	-14	-.3 to .3	
-200 to 800			1.8432856	-2	-3.2311582	-7	6.9795810	-12	-5.1106852	-17	-8 to 7	
-20 to 500			1.6970287	-2	-2.0830603	-7	4.6512717	-12	-4.1805785	-17	-.18 to .12	
0 to 400			1.7022525	-2	-2.2097240	-7	5.4809314	-12	-5.7669892	-17	-.05 to .04	
0 to 1000			1.6410783	-2	-1.3560189	-7	1.8600342	-12	-8.5537337	-18	-.9 to 1.4	
400 to 1000	1.9669452	+1	1.4207735	-2	-5.1844510	-8	5.6361365	-13	-1.5646343	-18	-.03 to .03	
600 to 800	2.5192188	+1	1.3909529	-2	-4.7201133	-8	5.5638718	-13	-1.7775228	-18	-.0005 to .0005	
850 to 1000	-7.1102114	+2	5.6554599	-2	-9.7013068	-7	9.3938146	-12	-3.3333675	-17	-.001 to .001	

⁸ Quartic approximations to the data as a function of voltage in selected temperature ranges (°C). The expansion is of the form $T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$ where E is in microvolts and T is in degrees Celsius.

Type J Thermocouples ⁹ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (μV)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
-200 to 0			5.0408743	+1	3.2009063	-2	-6.3493968	-5	2.5174022	-7	-2 to .3	
-200 to 760			4.9502533	+1	3.2898022	-2	-6.9936031	-5	5.1112729	-8	-100 to 80	
-200 to 1200			4.7062907	+1	2.5522650	-2	-2.2198295	-5	7.1373907	-9	-500 to 600	
-20 to 500			5.0465304	+1	2.8062596	-2	-6.5666305	-5	5.3587106	-8	-1.5 to 3.0	
0 to 400			5.0452399	+1	2.8409137	-2	-6.7556436	-5	5.6382040	-8	-.8 to .5	
0 to 760			5.1258213	+1	2.0040854	-2	-4.2235982	-5	3.2819408	-8	-24 to 36	
0 to 1200			5.5861877	+1	-1.4207954	-2	3.1325181	-5	-1.5023710	-8	-210 to 160	
400 to 760	-5.7931005	+3	9.7718575	+1	-1.1658430	-1	1.3184454	-4	-4.8218788	-8	-2.5 to 2.8	
400 to 1200	7.1127371	+3	1.8969007	+1	5.3862730	-2	-2.2171472	-5	1.8445398	-10	-110 to 100	
600 to 760	-2.5724435	+4	2.2157898	+2	-4.0418097	-1	4.2749984	-4	1.6174242	-7	-.1 to .1	
760 to 1200	3.9064962	+4	-1.4765017	+2	3.6470921	-1	-2.7029005	-4	7.2113090	-8	-11 to 11	
Reference Junction Correction												
0 to 50			5.0373743	+1	3.0167011	-2	-7.4293513	-5			-.06 to +.06	

⁹ Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $E = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$ where E is in microvolts and T is in degrees Celsius.

Type J Thermocouples ¹⁰ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (°C)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
-200 to 0			1.8843850	-2	-1.2029733	-6	-2.5278593	-10	-2.5849263	-14	-.4 to .5	
-200 to 760			2.1155170	-2	-3.3513149	-7	1.2443997	-11	-1.5227150	-16	-6 to 7	
-200 to 1200			2.1676850	-2	-2.1844464	-7	3.9094347	-12	-2.4303017	-17	-14 to 10	
-20 to 500			1.9745056	-2	-1.8094256	-7	7.8777919	-12	-1.1897222	-16	-.07 to .06	
0 to 400			1.9750953	-2	-1.8542600	-7	8.3683958	-12	-1.3280568	-16	-.03 to .05	
0 to 760			1.9323799	-2	-1.0306020	-7	3.7084018	-12	-5.1031937	-17	-.9 to .7	
0 to 1200			1.8134974	-2	-5.6495930	-8	-2.4644023	-12	2.1141718	-17	-3 to 4	
400 to 760	9.2808351	+1	5.4463817	-3	6.5254537	-7	-1.3987013	-11	9.9364476	-17	-.03 to .03	
400 to 1200	-1.1075293	+2	2.8651303	-2	-2.9758175	-7	2.5945419	-12	-4.9012035	-18	-1.3 to 1.6	
600 to 760	1.8020713	+2	-4.5284199	-3	1.0769294	-6	-2.1962321	-11	1.5521511	-16	-.001 to .001	
760 to 1200	-6.3828680	+2	7.4068749	-2	-1.7177773	-6	2.1771293	-11	-9.9502571	-17	-.15 to .11	

¹⁰ Quartic approximations to the data as a function of voltage in selected temperature (°C). The expansion is of the form $T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$ where E is in microvolts and T is in degrees Celsius.

Type K Thermocouples ¹¹ Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (µV)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact- Approx.	
-270 to 0			3.9575518	+1	3.1063355	-2	-9.1607995	-5	3.0006628	-8	-1.1 to 1.2	
-200 to 0			3.9478446	+1	2.8256412	-2	-1.1488433	-4	-2.8153447	-8	-.08 to .05	
-200 to 800			3.6762217	+1	2.4544587	-2	-4.3081993	-5	2.5127588	-8	-180 to 200	
-20 to 500			4.0999640	+1	-3.2619221	-3	8.5714137	-6	-1.6912373	-9	-25 to 45	
0 to 400			4.0981103	+1	-1.5992510	-4	-1.2525700	-5	3.2784725	-8	-25 to 20	
0 to 1370			3.9443859	+1	5.8953822	-3	-4.2015132	-6	1.3917059	-10	-60 to 110	
400 to 1000	1.3223524	+3	3.0191663	+1	2.7508912	-2	-2.4734437	-5	6.9799332	-9	-.9 to 1.4	
400 to 1370	-3.5456236	+1	3.8349319	+1	9.9993329	-3	-8.7444446	-6	1.7108618	-9	-12 to 11	
600 to 800	2.1326086	+3	2.5608012	+1	3.7091744	-2	-3.3517324	-5	9.9607405	-9	-.05 to .07	
850 to 1000	-9.0373549	+2	4.0577145	+1	9.5092149	-3	-1.0989249	-5	3.0753213	-9	-.05 to .03	
1050 to 1150	-2.5972816	+3	5.2075276	+1	-1.4576419	-2	9.4854151	-6	-3.1178779	-9	-.05 to .05	
Reference Junction Correction 0 to 50			3.9448872	+1	2.4548362	-2	-9.0918433	-5			-.06 to +.14	

¹¹ Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $E = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$ where E is in microvolts and T is in degrees Celsius.

Type K Thermocouples ¹² Temperature Range (°C)		a ₀		a ₁		a ₂		a ₃		a ₄		Error Range (°C)
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact- Approx.	
-270 to 0			1.2329875	-2	-1.4434305	-5	-4.2824995	-9	-4.2028679	-13	-11 to 8	
-200 to 0			2.3783697	-2	-2.4382217	-6	-6.8203073	-10	-9.4854031	-14	-.5 to .5	
-200 to 800			2.8346886	-2	-5.8008526	-7	2.5720615	-11	-3.6813679	-16	-8 to 10	
-20 to 500			2.4363851	-2	5.6206931	-8	-3.8825620	-12	3.9120208	-17	-1.2 to .6	
0 to 400			2.4383248	-2	9.7830251	-9	3.6276965	-12	-2.5756438	-16	-.5 to .6	
0 to 1370			2.5132785	-2	-6.0883423	-8	5.5358209	-13	9.3720918	-18	-2.4 to 1.2	
400 to 1000	-2.4707112	+1	2.9465633	-2	-3.1332620	-7	6.5075717	-12	-3.9663834	-17	-.02 to .02	
400 to 1370	6.2300671	+0	2.4955374	-2	-7.8788333	-8	1.3269743	-12	1.5580541	-18	-.3 to .3	
600 to 800	-3.9480992	+1	3.1425797	-2	-4.0905633	-7	8.5482602	-12	-5.5696636	-17	-.001 to .001	
850 to 1000	-3.1617495	+0	2.7115517	-2	-2.1941995	-7	4.8782826	-12	-2.9316611	-17	-.0012 to .0012	
1050 to 1150	2.3615582	+2	1.1066277	-3	8.2516607	-7	-1.3558849	-11	9.1638500	-17	-.001 to .001	

¹² Quartic approximations to the data as a function of voltage in selected temperature ranges (°C). The expansion is of the form $T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$ where E is in microvolts and T is in degrees Celsius.

Type T Thermocouples ¹³		Temperature Range (°C)										Error Range (µV)
		a ₀		a ₁		a ₂		a ₃		a ₄		
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
-270 to 0			3.9439919	+1	6.2407452	-2	8.0773568	-5	2.6845647	-7	-9 to 7	
-200 to 0			3.8749056	+1	4.5149809	-2	4.7759448	-5	-2.5773959	-8	-.14 to .13	
-200 to 400			3.8621703	+1	4.5433050	-2	-3.4731838	-5	1.4661300	-8	-7 to 3.5	
0 to 400			3.8468407	+1	4.6651731	-2	-3.7375793	-5	1.5999833	-8	-.9 to .9	
Reference Junction Correction												
0 to 50			3.8709457	+1	3.7085566	-2	5.6495520	-5			-1 to .1	

¹³ Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $E = a_0 + a_1T + a_2T^2 + a_3T^3 + a_4T^4$ where E is in microvolts and T is in degrees Celsius.

Type T Thermocouples ¹⁴		Temperature Range (°C)										Error Range (°C)
		a ₀		a ₁		a ₂		a ₃		a ₄		
Quartic Equation	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Argument	Exp.	Exact-Approx.	
-270 to 0			4.3553379	-3	-2.0325426	-5	-5.4720813	-9	-5.0865527	-13	-8 to 6	
-200 to 0			2.3837090	-2	-2.9878839	-6	-7.1945810	-10	-1.0041943	-13	-.3 to .3	
-200 to 400			2.6792411	-2	-1.0370271	-6	6.1330327	-11	-1.3988385	-15	-6 to 5	
0 to 400			2.5661297	-2	-6.1954869	-7	2.2181644	-11	-3.5500900	-16	-.15 to .17	

¹⁴ Quartic approximations to the data as a function of temperature (°C) in selected temperature ranges. The expansion is of the form $T = a_0 + a_1E + a_2E^2 + a_3E^3 + a_4E^4$ where E is in microvolts and T is in degrees Celsius.

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Service Form

Model No. _____ Serial No. _____ Date _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

- Intermittent
- IEEE failure
- Front panel operational
- Analog output follows display
- Obvious problem on power-up
- All ranges or functions are bad
- Particular range or function bad; specify _____
- Batteries and fuses are OK
- Checked all cables

Display or output (check one)

- Drifts
- Unstable
- Overload
- Unable to zero
- Will not read applied input

- Calibration only
- Certificate of calibration required

- Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

Be sure to include your name and phone number on this service form.



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