
Instruction Manual

Models 7012-S and 7012-C 4 × 10 Matrix Cards

Contains Operating and Servicing Information

KEITHLEY

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

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

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

LIMITATION OF WARRANTY

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

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Models 7012-S and 7012-C 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.

Many product updates and revisions do not require manual changes and, conversely, manual corrections may be done without accompanying product changes. Therefore, it is recommended that you review the Manual Update History.

Revision A (Document Number 7012-901-01)November 1991
Addendum A (Document Number 7012-901-02)January 1992

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.

7012 SPECIFICATIONS

MODEL 7012-S 4x10 Matrix with Screw Terminals.

MODEL 7012-C 4x10 Matrix with Mass Terminated Connector.

MATRIX CONFIGURATION: 4 rows by 10 columns. Jumpers can be removed to isolate any row from the backplane.

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

CONNECTOR TYPE:

7012-S: Screw terminal, #16AWG maximum wire size, with .092 inch O.D. 28 Conductors maximum. #22AWG typical wire size with .062 inch O.D. 88 Conductor maximum.

7012-C: 96-Pin male Euro card connector. Mates to female twisted wire cable, crimp or solder connector.

MAXIMUM SIGNAL LEVEL:

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

AC Signals: 125V RMS or 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: 10^8 closures.

At Maximum Signal Levels: 10^5 closures.

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

CONTACT POTENTIAL:

7012-S: < 500 nV per contact pair (Hi, Lo).
 < 1.5 μ V per single contact.

7012-C: < 1 μ V per contact pair (Hi, Lo).
 < 3 μ V per single contact.

OFFSET CURRENT: < 100 pA.

ACTUATION TIME: 3 ms.

ISOLATION:

Path: $> 10^9\Omega$, < 50 pF.

Differential: $> 10^9\Omega$, < 200 pF.

Common Mode: $> 10^9\Omega$, < 400 pF.

CROSS TALK (1MHz, 50 Ω Load): < -40 dB.

INSERTION LOSS (50 Ω Source, 50 Load): < 0.1 dB below 1MHz, < 3 dB below 2MHz.

RELAY DRIVE CURRENT (per relay): 16mA.

ENVIRONMENT:

Operation: 0°C to 50°C , up to 35°C $< 80\%$ RH.

Storage: -25°C to 65°C .

Specifications subject to change without notice.

7012 4x10 Matrix

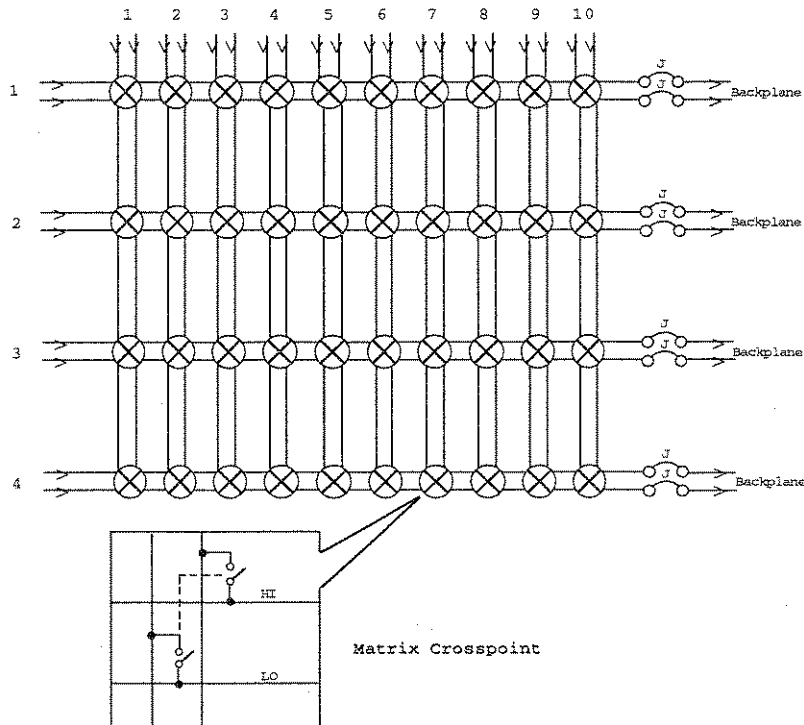


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1

General Information

1.1 Introduction

This section contains general information about the Model 7012 4 × 10 Matrix card.

There are two basic versions of this matrix card; the Model 7012-S and the Model 7012-C. The Model 7012-S assembly consists of a screw terminal connector card and the relay card. External test circuits are wired directly to the screw terminals of the connector card. Also available from Keithley is the Model 7012-ST. This is an extra screw terminal connector card. With an extra connector card, you can wire a second test system without disturbing the wiring configuration of the first test system.

The Model 7012-C assembly consists of a multi-pin (mass termination) connector card and the relay card. External test circuit connections to the matrix are made via the 96-pin male DIN connector on the connector card. Keithley offers a variety of optional accessories that can be used to make connections to the connector card (see paragraph 1.9).

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 7012 is a two-pole, dual, 4 × 10 (four rows by 10 columns) matrix 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 (Model 7012-S) and backplane row jumpers.
- Backplane row jumpers. Cutting jumpers disconnects matrix rows 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 7012 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the matrix 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 matrix 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 matrix card. Such damage may invalidate the warranty.

1.6 Specifications

Model 7012 specifications are found at the front of this manual. These specifications are exclusive of the matrix mainframe specifications.

1.7 Unpacking and inspection

1.7.1 Inspection for damage

The Model 7012 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 7012 order:

- Model 7012 4 × 10 Matrix Card
- Model 7012 Instruction Manual
- Additional accessories as ordered

1.7.3 Instruction manual

The Model 7012 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 matrix card instruction manual.

If an additional instruction manual is required, order the manual package, Keithley part number 7012-901-00. The manual package includes an instruction manual and any pertinent addenda.

1.8 Repacking for shipment

Should it become necessary to return the Model 7012 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 matrix card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.9 Optional accessories

The following accessories are available for use with the Model 7012:

Model 7012-ST — This screw terminal connector card is identical to the one provided with the Model 7012-S assembly. An extra screw terminal connector card allows you to wire a second test system without disturbing the wiring configuration of the first connector card.

Model 7011-KIT-R — This connection kit includes a 96-pin female DIN connector that will mate directly to the connector on the Model 7012-C or to a standard 96-pin male DIN bulkhead connector (see Model 7011-MTR). This connector uses solder cups for connections to external circuitry. It includes an adapter for a round cable and the housing.

Model 7011-MTC-2 — This two-meter round cable assembly is terminated with a 96-pin female DIN connector on each end. It will mate directly to the connector on the Model 7012-C and to a standard 96-pin male DIN bulkhead connector (see Model 7011-MTR).

Model 7011-MTR — This 96-pin male DIN bulkhead connector uses solder cups for connections to external circuitry. It will mate to the Model 7011-KIT-R connector and Model 7011-MTC-2 cable assembly.

2

Matrix Switching Basics

2.1 Introduction

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

- 2.2 **Basic matrix configuration:** Covers the basic 4×10 matrix configuration. The significance of the backplane jumpers is also covered here.
- 2.3 **Typical matrix switching schemes:** Explains some of the basic ways a matrix can be used to source or measure. Covers single-ended switching, differential (floating) switching, and sensing.
- 2.4 **Matrix expansion:** Discusses the various matrix configurations that are possible by using multiple cards.

2.2 Basic matrix configuration (4×10)

A simplified schematic of the Model 7012 matrix card is shown in Figure 2-1. The card is configured as a 4×10 matrix. Each of the 40 crosspoints is made up of a two-pole switch. By closing the appropriate crosspoint switch, any matrix row can be connected to any column in the matrix.

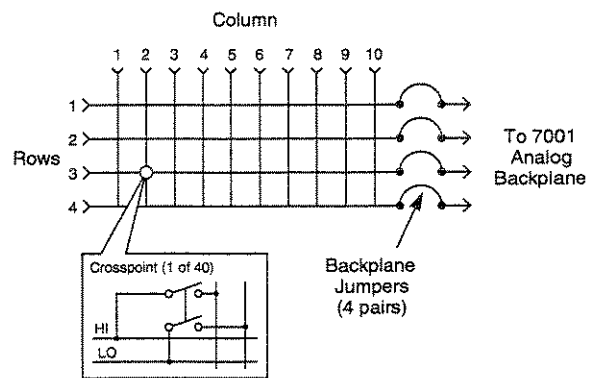


Figure 2-1
Model 7012 simplified schematic

Backplane jumpers

Notice in Figure 2-1 there are four pairs of backplane jumpers located on the relay card. With the jumpers installed, the matrix card is connected to the analog backplane of the Model 7001 allowing matrix expansion with a second 7001 card installed in the mainframe. With the jumpers removed (cut), the matrix card is isolated from another card installed in the mainframe.

The three-pole analog backplane of the mainframe is shown in Figure 2-2. It is through this analog backplane where the rows of a Model 7012 matrix card installed in one slot can be connected to the rows (or banks) of a compatible card installed in the other slot of the mainframe.

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 paragraph 3.3.1.

NOTE

The Model 7001 does not provide an analog backplane for the non-701X series cards. As a result, anyone of these cards installed in one slot in the mainframe is electrically isolated from any card installed in the other slot. The only way to connect a Model 7012 to one of these cards is to wire them together.

Figure 2-3 shows how each row of the Model 7012 is connected to the backplane. Notice that, since the Model 7012 is a two-pole card, there is no connection made to the Guard terminal of the backplane. The Model 7012 is shipped from the factory with the backplane row jumpers installed.

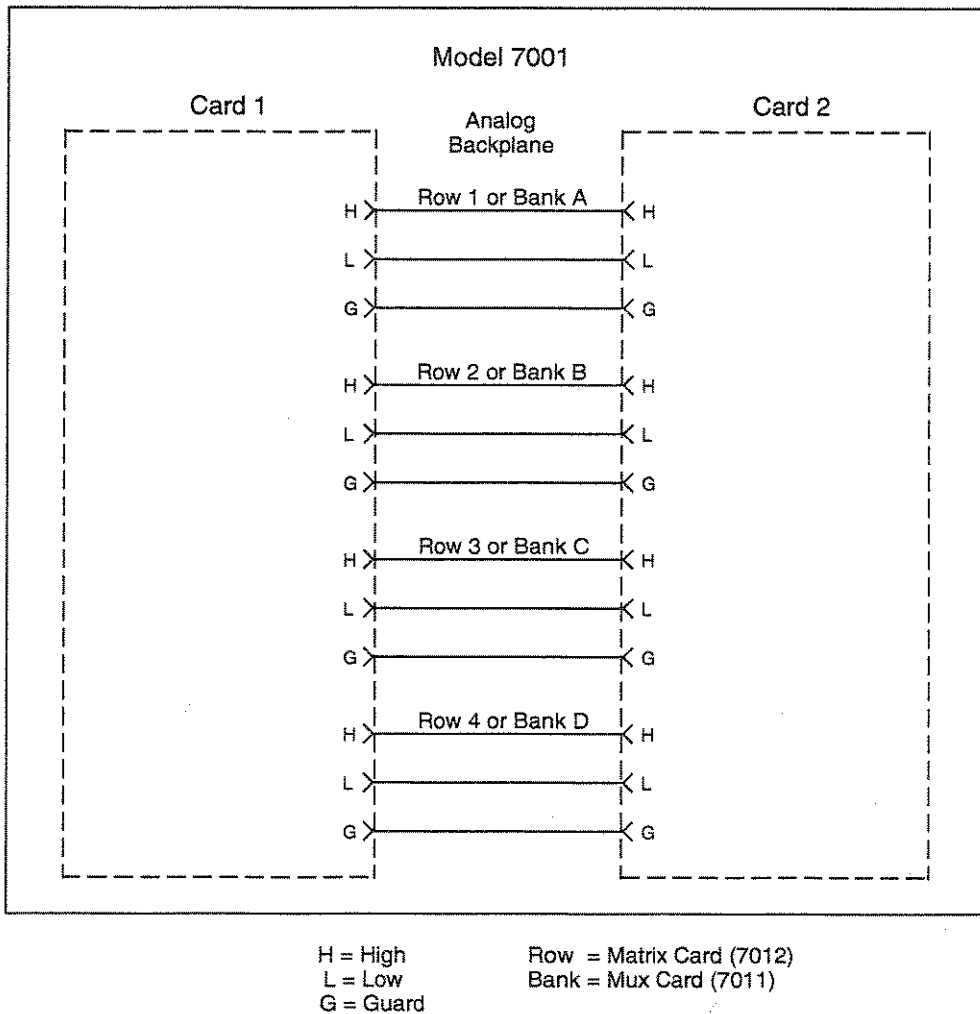


Figure 2-2
Model 7001 analog backplane

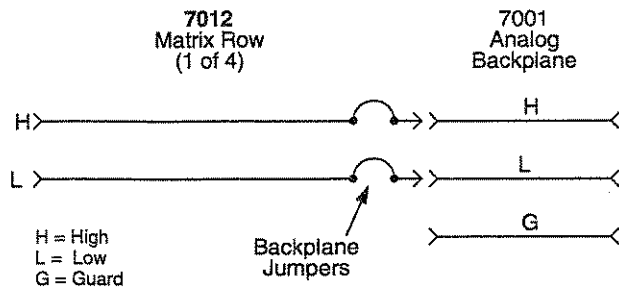


Figure 2-3
Matrix row connections to backplane

2.3 Typical matrix switching schemes

The following paragraphs describe some basic switching schemes that are possible with a two-pole switching matrix. 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.

2.3.1 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 2-4.

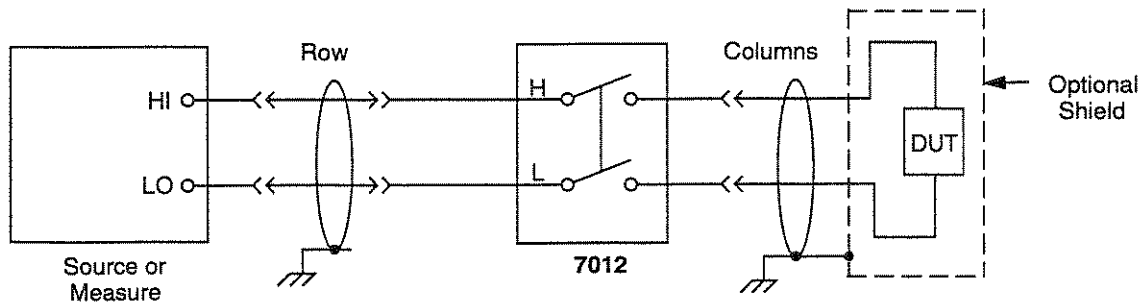


Figure 2-4
Single-ended switching example

2.3.2 Differential switching

The differential or floating switching configuration is shown in Figure 2-5. The advantage of using this configuration is that the terminals of the source or measure instrument are not confined to the same matrix crosspoint. Each terminal of the instrument can be connected to any matrix crosspoint.

2.3.3 Sensing

Figure 2-6 shows how the matrix card can be configured to use instruments that have sensing capability. The main advantage of using sensing is to cancel the effects of matrix card path resistance ($<1\Omega$) and the resistance of external cabling. Whenever path resistance is a consideration, sensing should be used.

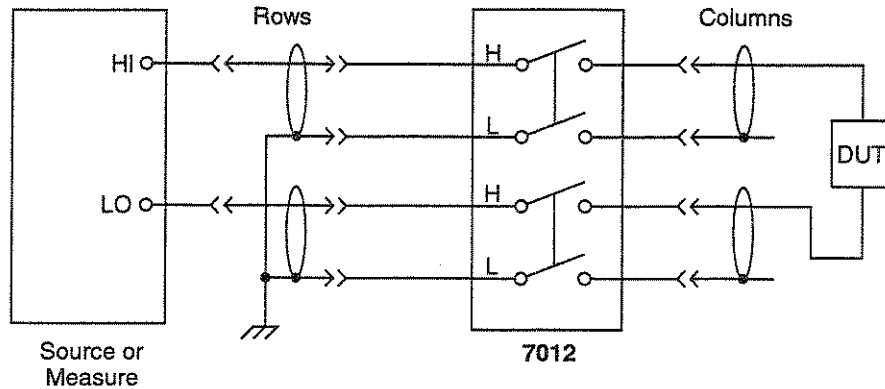


Figure 2-5
Differential switching example

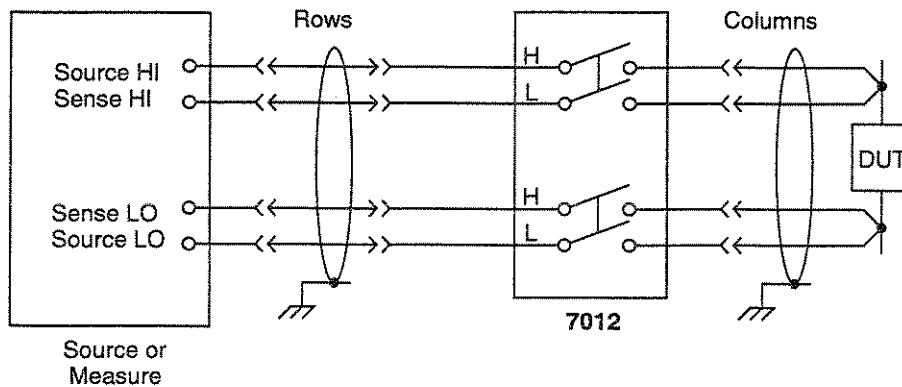


Figure 2-6
Sensing example

2.3.4 SMU connections

Figure 2-7 shows how a Keithley Model 236, 237 or 238 Source Measure Unit could be connected to the matrix 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.

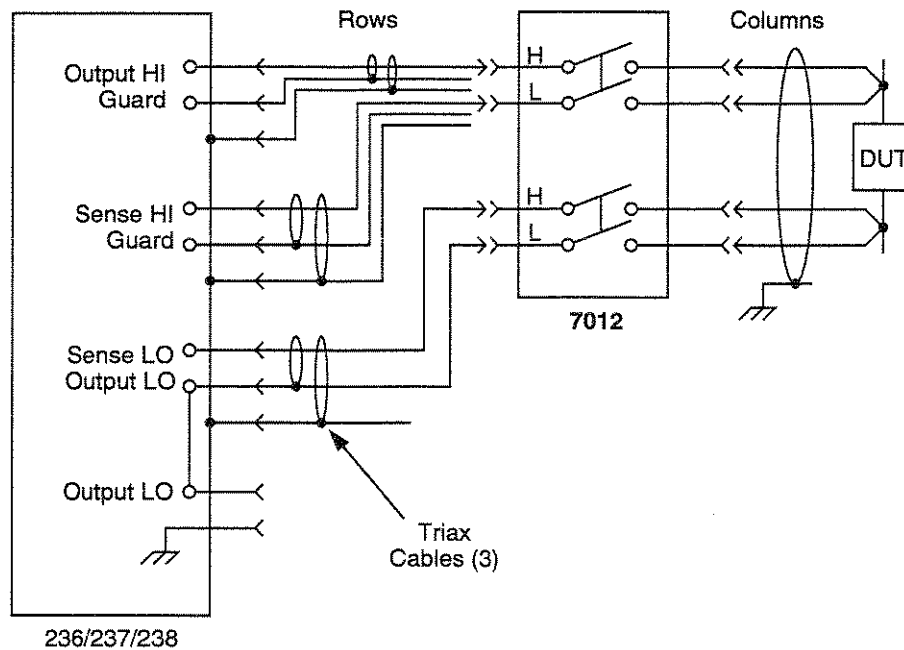
2.4 Matrix expansion

With the use of additional matrix cards and mainframes, larger matrices 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 in six mainframes can be configured.

2.4.1 Two-card switching systems

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



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

Figure 2-7
SMU connections

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 2-8 shows an example using two Model 7012 matrix cards.

Narrow matrix expansion (4 × 20 matrix)

A narrow 4 row × 20 column matrix is configured by simply installing two "as shipped" Model 7012s in the Model 7001 mainframe. By leaving the backplane jumpers installed, the rows of the matrix card installed in slot 1 (CARD 1) are automatically connected to the rows of the matrix card installed in slot 2 (CARD 2) through the analog backplane. The 4 × 20 matrix is shown in Figure 2-9.

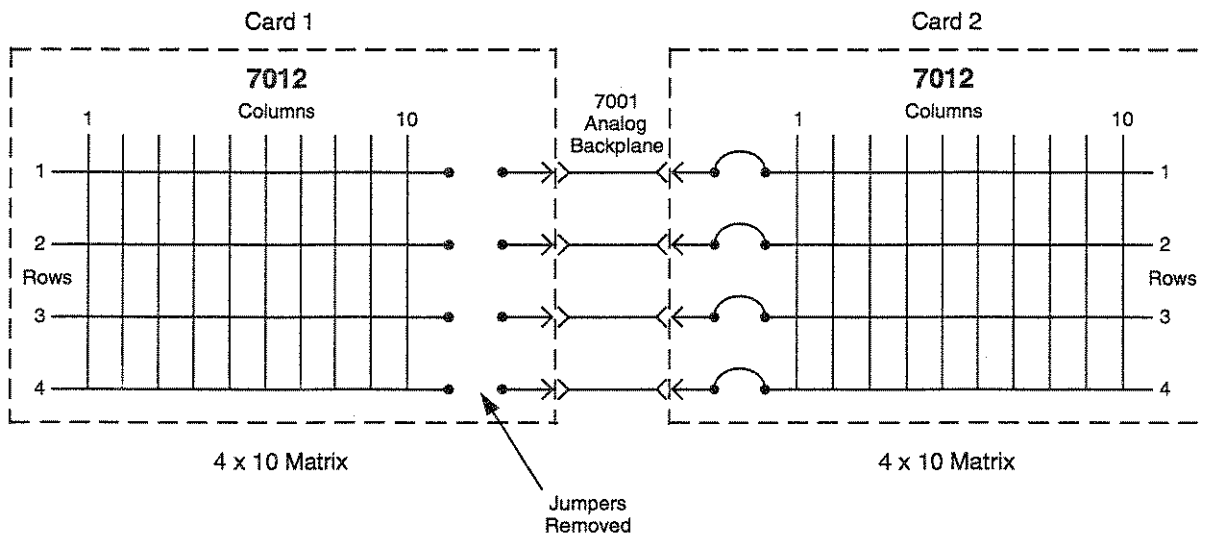


Figure 2-8
Two separate 4 × 10 matrices

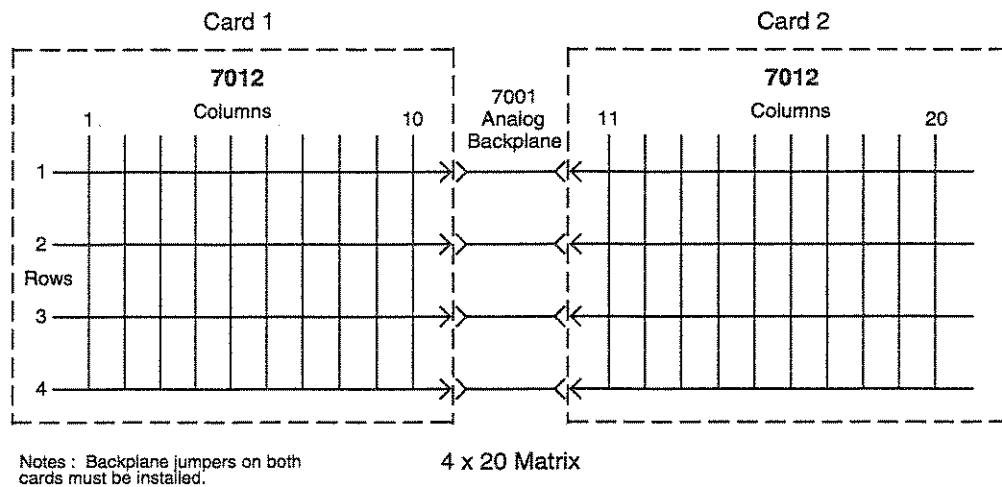


Figure 2-9
Narrow matrix example (4 x 20)

Wide matrix expansion (8 x 10 matrix)

A wide 8 row x 10 column matrix is shown in Figure 2-10. For this configuration, the 10 columns of the two matrix cards must be physically hard-wired together. Also note that the backplane jumpers on one of the cards must be removed in order to isolate the rows of the two cards from each other.

Mixing card types

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

could have a Model 7012 matrix card installed in one slot and a Model 7011 multiplexer card installed in the other slot.

Figure 2-11 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 7011 for complete information on the multiplexer card.

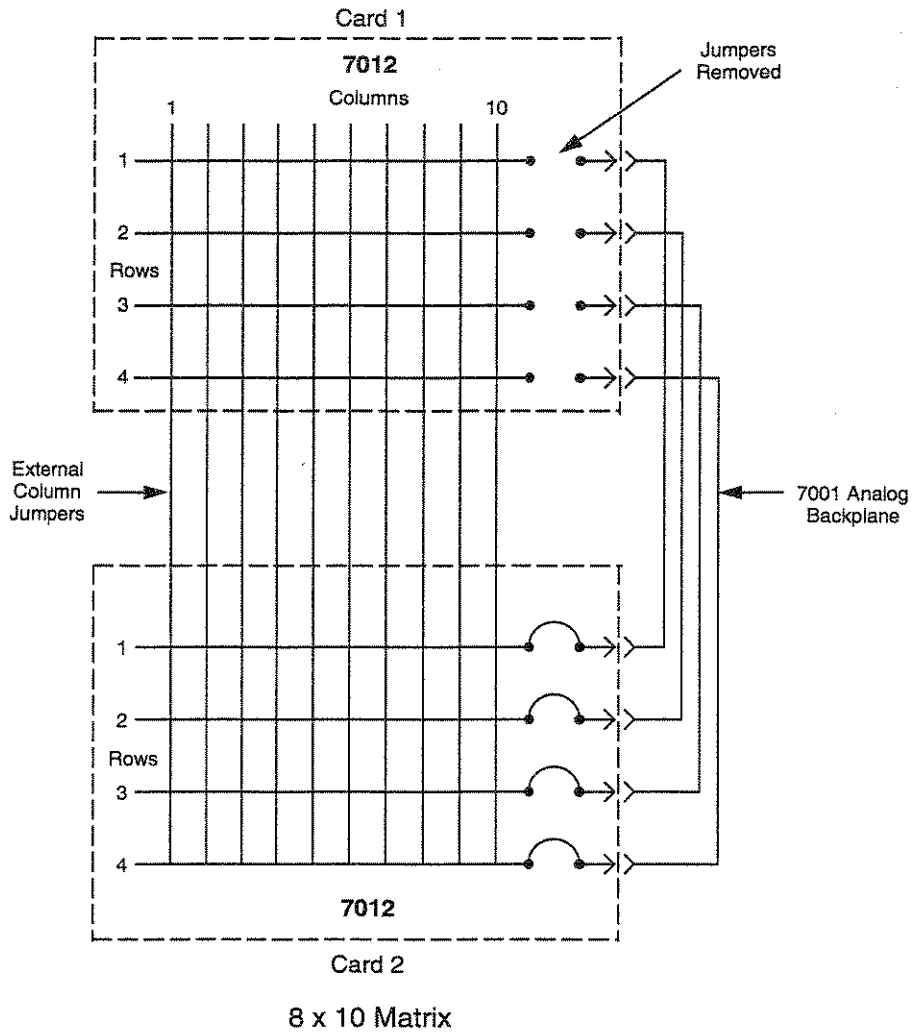
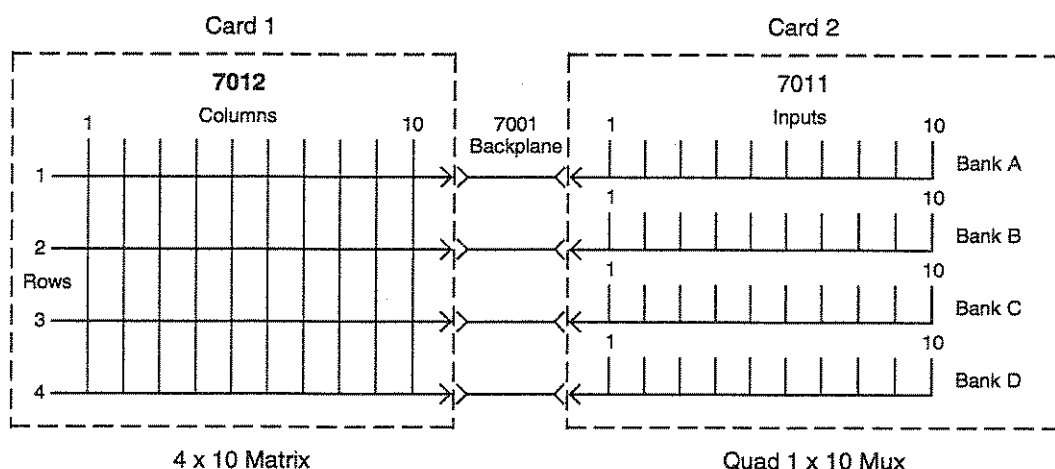


Figure 2-10
Wide matrix example (8 x 10)



- Notes :**
1. Models 7011 and 7012 backplane jumpers must be installed.
 2. Model 7011 bank-to-bank jumpers must be removed.

Figure 2-11
Mixed card type example

2.4.2 Mainframe matrix expansion

Matrices using up to 12 matrix cards are possible by using six Model 7001 mainframes together. Using 12 Model 7012 matrix cards provides 480 cross-points.

In general, connecting the rows of a card in one mainframe to the rows of a card in a second mainframe increases the column numbers of the matrix. For example, if the rows of a 4×20 matrix in one mainframe are connected to the rows of a 4×20 matrix in a second mainframe, the resulting matrix would be 4×40 . Paragraph 3.4.3 explains how to connect a test system using two mainframes.

Partial matrix implementation

A fully implemented matrix provides a relay at each potential crosspoint. For example, a fully implemented 8×20 matrix utilizing four 4×10 matrix cards contains 160 crosspoints. A partially implemented 8×20 matrix would contain fewer crosspoints.

An example of a partially implemented 8×20 matrix is shown in Figure 2-12. The partial matrix is still considered 8×20 , but contains only 120 crosspoints using three Model 7012 matrix cards installed in two Model 7001 mainframes.

Matrix card #1 (7012 #1) installed in one of the slots of the first mainframe (7001 #1) provides a 4×10 matrix. The other slot of the first mainframe should be left empty. If another switching card is left in that slot, make sure it is isolated from the analog backplane (i.e. backplane jumpers removed). The two matrix cards (7012 #2 and #3) installed in the second mainframe (7001 #2) are configured as an 8×10 matrix as explained in paragraph 2.4.2 (Wide Matrix Expansion). Keep in mind that the rows of card #2 must be isolated from the rows of card #3. This is accomplished by removing the jumpers on one of the two cards. Finally, the partially implemented 8×20 matrix is realized by externally hard-wiring the rows of card #1 to the rows of card #2.

An obvious advantage of a partial matrix is that fewer matrix cards are needed. Another reason to use a partial matrix is to keep specific devices from being connected directly to other devices. For example, a source connected to rows 5, 6, 7 or 8 (Figure 2-12) cannot be

connected to a column of Model 7012 #1 with one "accidental" crosspoint closure. Three specific crosspoints must be closed in order to route the source signal to a column of card #1.

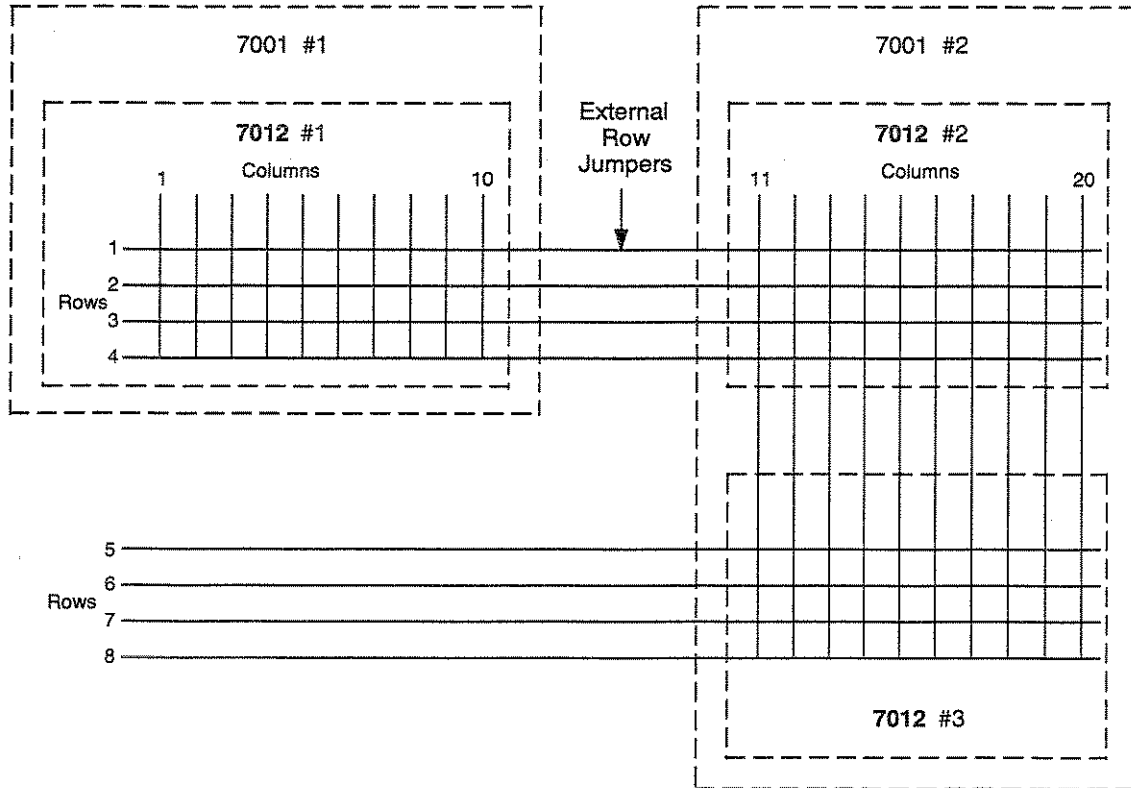


Figure 2-12
Partial matrix expansion (8 x 20)

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 precaution:** Explains precautions that must be followed to prevent contamination to the matrix card assembly. Contamination could degrade the performance of the matrix card.
- 3.3 **Connection:** Covers the basics for connecting external circuitry to the two available connector cards for the matrix; the screw terminal connector card and the multi-pin connector card.
- 3.4 **Typical connection scheme:** Provides some typical connection schemes for single card, two-card and two-mainframe system configurations.
- 3.5 **Model 7012 installation:** Provides a procedure to install the matrix 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 matrix 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 matrix. It includes the removal/installation of the backplane row jumpers on the relay card, and detailed information on the two available connector cards.

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 Backplane row jumpers

The Model 7001 mainframe has an analog backplane that allows the rows of a Model 7012 matrix to be internally connected to a compatible switching card installed in the other slot (see paragraph 2.4.1 for details).

The backplane row jumpers for the matrix card assembly are located on the relay card as shown in Figure 3-1. The card is shipped from the factory with the jumpers installed.

Jumper removal

Perform the following steps to remove backplane row jumpers:

1. If mated together, separate the relay card from the connector card by removing the mounting screw and then pulling the two cards away from each other. Remember to only handle the cards by the edges and shields to avoid contamination.
2. Use Figure 3-1 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 3-1 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 then pulling the two cards away from each other. 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.

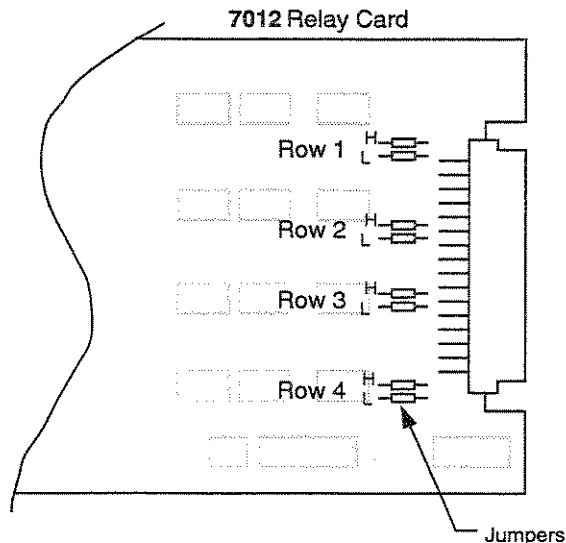


Figure 3-1
Backplane row jumpers

3.3.2 Screw terminal connector card

The screw terminal connector card is shown in Figure 3-2. Connections are made directly to the screw terminals of the four 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.

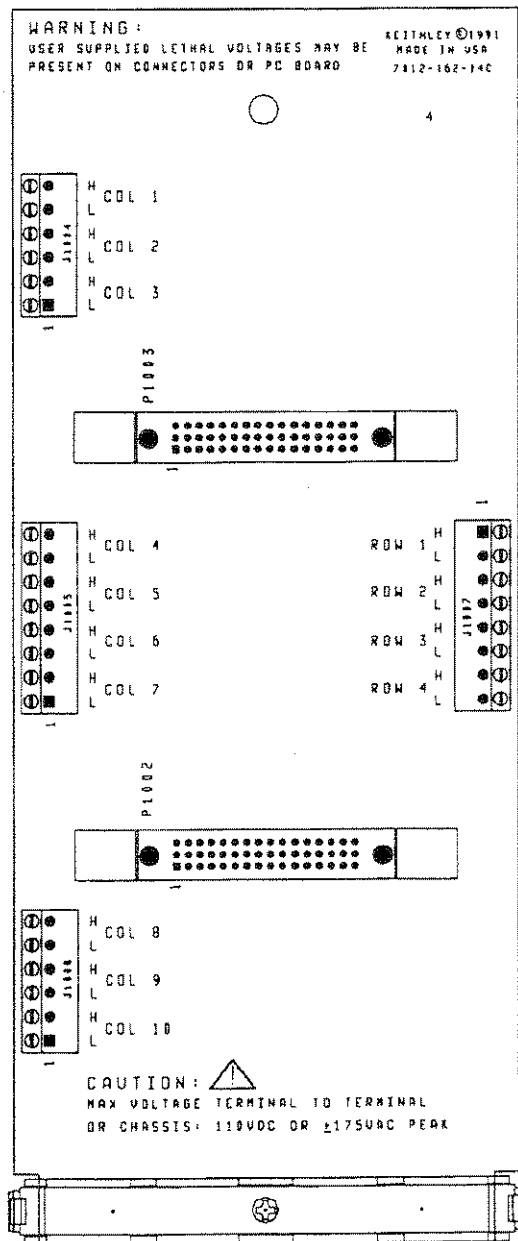


Figure 3-2
Screw terminal connector card

1. If mated together, separate the connector card from the relay card by removing the mounting screw and then pulling the two cards away from each other. 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 3-3 shows how Column 1 of the matrix would be connected to a DUT.
3. Referring to Figure 3-4, 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.
4. Route wires under wire guide/connector shim.
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. The Model 7012 is now ready to be installed in the Model 7001 mainframe. See paragraph 3.5 for details.

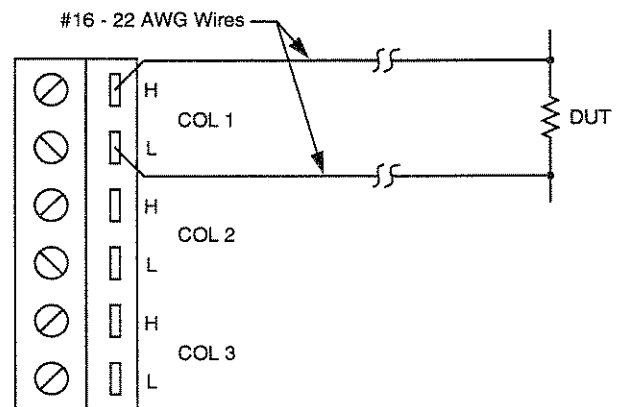


Figure 3-3
Typical terminal block connections

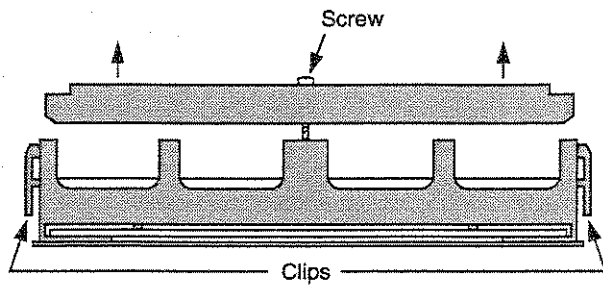


Figure 3-4
Cable clamp for screw terminal connector card

3.3.3 Multi-pin (mass termination) connector card

Since connections to external circuitry are made at the 96-pin male DIN bulkhead connector, there is no need to separate the connector card from the relay card. If the connector card is separated from the relay card, carefully mate them together. Make sure to handle the cards by the edges and shields to avoid contamination.

Terminal identification for the DIN connector of the multi-pin connector card is provided by Figure 3-5. This connector will mate to a 96-pin female DIN connector.

Keithley has a variety of cable and connector accessories available to accommodate connections from the connector card to test instrumentation and DUT (devices under test). In general, these accessories, which are summarized in Table 3-1, utilize a round cable assembly for connections.

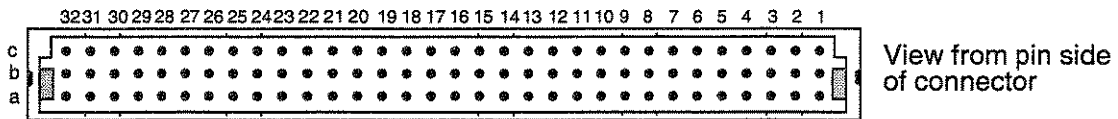
Table 3-1
Mass termination accessories

Model	Description
7011-KIT-R	96-pin female DIN connector and housing for round cable.
7011-MTC-2	Two-meter round cable assembly terminated with a 96-pin female DIN connector on each end.
7011-MTR	96-pin male DIN bulkhead connector.

Pins of the Model 7012-C mass termination connector can be identified in one of three ways:

1. Matrix row (1-4) or column (1-10).
2. Connector designation, consisting of rows a-c and columns 1-32.
3. Schematic and component layout designation (1-96).

The following pinout diagrams show the correspondence between these arrangements:



Matrix Terminal	Connector Desig. 1a-32c	Schematic Desig. 1-96	Matrix Terminal	Connector Desig. 1a-32c	Schematic Desig. 1-96
Row 1	HI	72	Col 1	HI	96
	LO	40		LO	64
Row 2	HI	70	Col 2	HI	94
	LO	38		LO	62
Row 3	HI	68	Col 3	HI	92
	LO	36		LO	60
Row 4	HI	66	Col 4	HI	90
	LO	34		LO	58
			Col 5	HI	88
				LO	56
			Col 6	HI	86
				LO	54
			Col 7	HI	84
				LO	52
			Col 8	HI	82
				LO	50
			Col 9	HI	80
				LO	48
			Col 10	HI	78
				LO	46

Notes:

1. Refer to the schematic for shield pins.
2. Short pins 1a to 1b on the mating connector (pins 1 and 33 on schematic) to allow the output relays on the connector card to close.

Figure 3-5
Multi-pin connector card terminal identification

Typical connection techniques

All external circuitry, such as instrumentation and DUTs, that you wish to connect to the matrix card must be terminated with a single 96-pin female DIN connector. The following connection techniques provide some guidelines and suggestions for wiring your circuitry.

WARNING

Before beginning any wiring procedures, make sure all power is off and any stored energy in external circuitry is discharged.

NOTE

It is recommended that external circuitry be connected (plugged in) after the Model 7012 assembly is installed in the Model 7001 mainframe and with the 7001 power off. Installation is covered in paragraph 3.5.

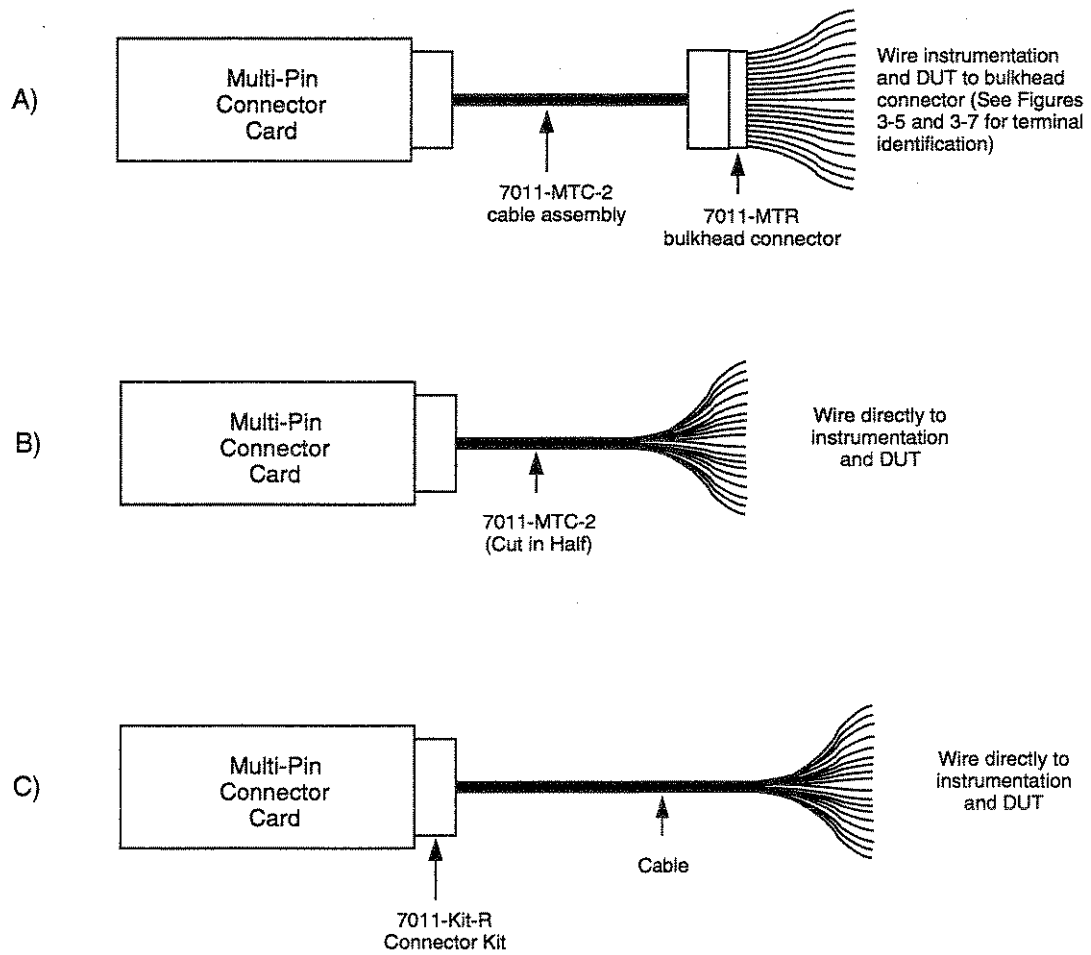
Output relays— The multi-pin connector card uses a relay for each of the four output banks. These output relays are normally open to prevent any hazardous voltages (via the mainframe backplane) from appearing on the pins of the male DIN connector. The output relays will only close when the Model 7011-MTC-2 cable assembly is connected to card. If building your own cable assembly, you must make sure that it shorts pins 1a to 1b of the card connector (Figure 3-8) when it is mated to the card. Shorting pins 1a to 1b allows the output relays to close.

Round cable assemblies — Figure 3-6 shows typical round cable connection techniques using accessories available from Keithley.

In Figure 3-6A, connections are accomplished using a Model 7011-MTC-2 cable and a Model 7011-MTR bulkhead connector. The two-meter round cable is terminated with a 96-pin female DIN connector at each end. This cable mates directly to the multi-pin connector card and to the bulkhead connector. The bulkhead connector has solder cups to allow direct connection to instrumentation and DUT. Figure 3-7 provides pinout for the bulkhead connector. The view shown is from the solder cup end of the connector.

In Figure 3-6B, connections are accomplished using a Model 7011-MTC-2 cable assembly that is cut in half. The 96-pin female DIN connector on one end of the cable mates directly to the multi-pin connector card. The unterminated end of the cable is wired directly to instrumentation and DUT. The other half of the cable assembly could be used for a second switching card.

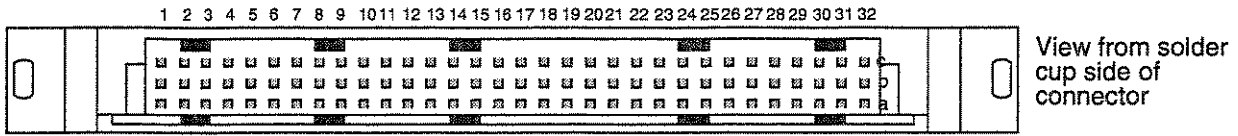
In Figure 3-6C, connections are accomplished using a custom-built cable assembly that consists of a Model 7011-KIT-R connector and a suitable round cable. Hitachi cable p/n N2807-P/D-50TAB is a 50-conductor round cable. Two of these cables can be used to provide 100 conductors. The connector has solder cups to accommodate the individual wires of the unterminated cable. Figure 3-8 provides an exploded view of the connector assembly and shows how the cable is connected. The connector end of the resultant cable assembly mates directly to the multi-pin connector card. The unterminated end of the cable assembly is wired directly to instrumentation and DUT.



Notes : Figure 3-8 provides an exploded view showing how the connector (with cable) is assembled.

Cable Hitachi p/n N2807-P/D-50TAB is a 50-conductor cable. Two of these cables can be used to supply 100 conductors.

Figure 3-6
Typical round cable connection techniques



View from solder
cup side of
connector

Note : See Figure 3-5 for terminal identification.

Figure 3-7
Model 7011-MTR connector pinout

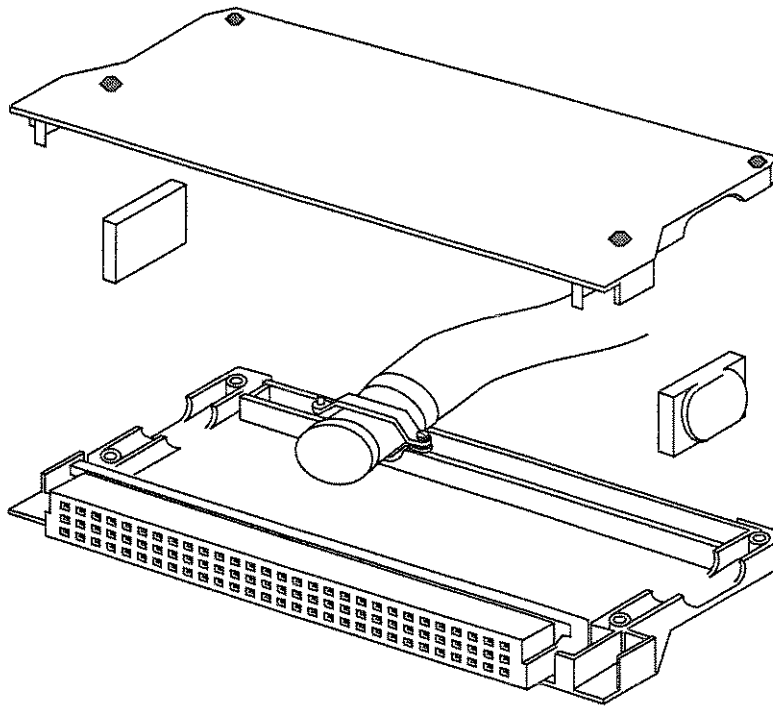


Figure 3-8
Model 7011-KIT-R (with cable) assembly

3.4 Typical connection schemes

The following information provides some typical connection schemes for single card, two-card, and two-mainframe system configurations. Connection schemes for the multi-pin connector card use some of the techniques presented in paragraph 3.3.2. Keep in mind that these are only examples to demonstrate various ways to wire a test system. Connection details for both connector cards (multi-pin and screw terminal connector cards) are provided in paragraph 3.3.

3.4.1 Single card system

Figure 3-9 shows how external connections can be made to a single card system that uses the multi-pin connector card. Instrumentation and DUT are hard-wired to the Model 7011-MTR male bulkhead connector. This connector has solder cups that will accept wire size up to #24 AWG. The test system is connected to the matrix using the Model 7011-MTC-2 round cable assembly. This cable mates directly to both the external bulkhead connector and the Model 7012-C matrix card assembly. Notice that the bulkhead connector is shown mounted to a fixture to help keep the cabling stable during the test.

The single card system in Figure 3-10 is identical to the system in the previous illustration, except for the connection scheme. The system in Figure 3-10 uses the terminal block connector card. With this card, single conductor connections are made directly from the terminal blocks of the connector card to instrumentation and DUT.

When using a single card system, 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:

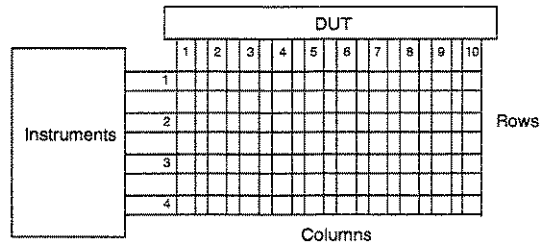
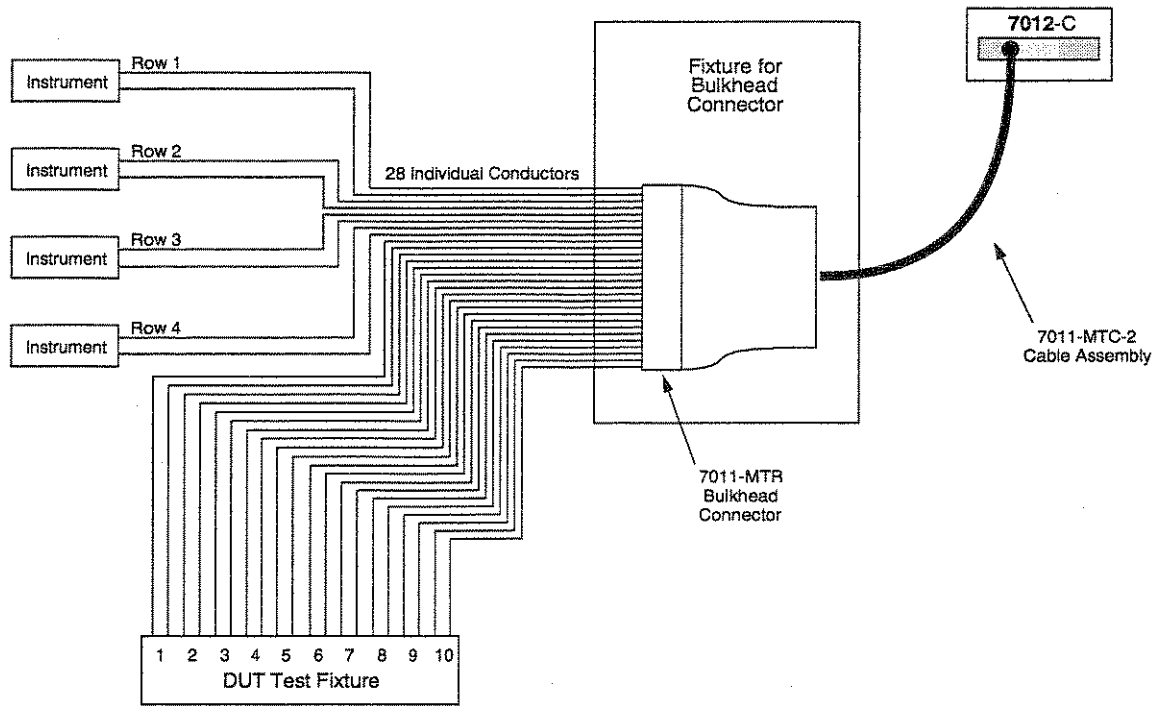
1. Vacate the other mainframe slot. If there is a Model 701X card installed in the other slot, remove it.
2. Remove the backplane jumpers on the matrix card. This will disconnect the card from the analog backplane of the mainframe.
3. Remove the backplane jumpers from the switching card installed in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

3.4.2 Two-card system

Both Figure 3-11 and Figure 3-12 show a system using two matrix cards installed in one Model 7001 mainframe to configure a 4×20 test matrix. In both these connection schemes, row connections of the two matrix cards are accomplished internally through the backplane of the Model 7001 mainframe. To connect rows internally, the backplane row jumpers of both matrix cards must be installed.

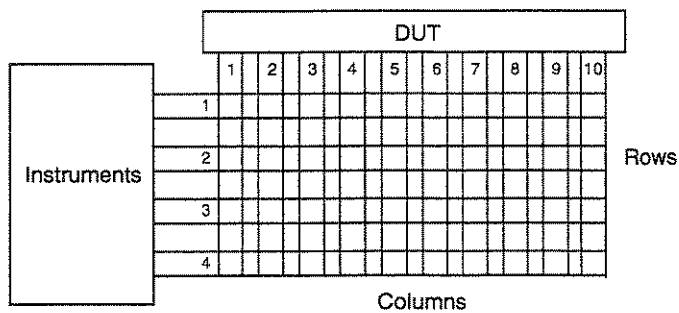
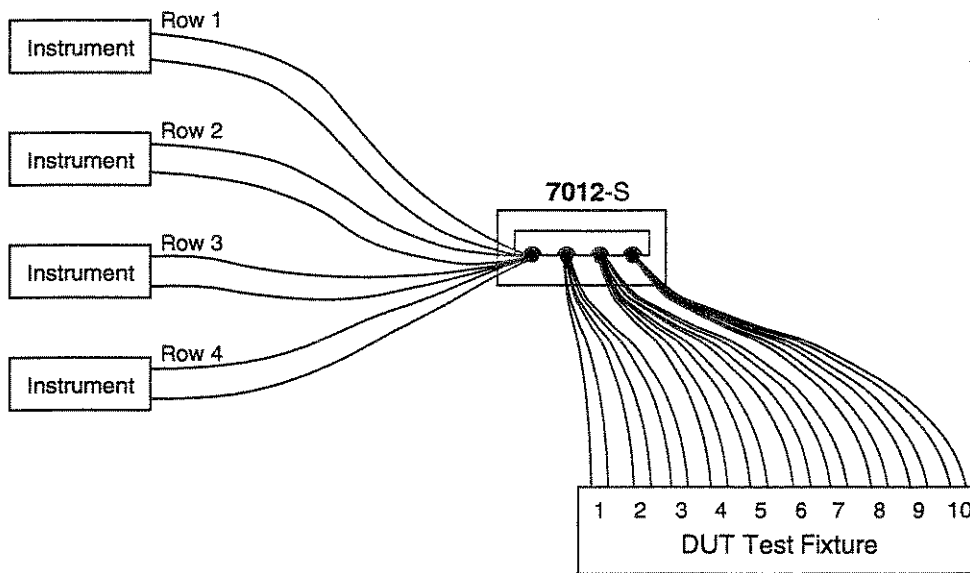
Figure 3-11 shows how external connections can be made for the multi-pin connector cards. In this example, a single Model 7011-MTC-2 round cable assembly is cut in half to provide two cables, each of which is unterminated at one end. The unterminated ends of the two cables are hard-wired to instrumentation and DUT as shown in the drawing. The other ends of these cables mate directly to the Model 7012-C matrix card assemblies.

Figure 3-12 shows how external connections can be made for the screw terminal connector card. Single conductor connections are made directly from the screw terminals of the connector card to instrumentation and DUT.



Equivalent Circuit

Figure 3-9
Single card system example (multi-pin connector card)



Equivalent Circuit

Figure 3-10
Single card system example (screw terminal connector card)

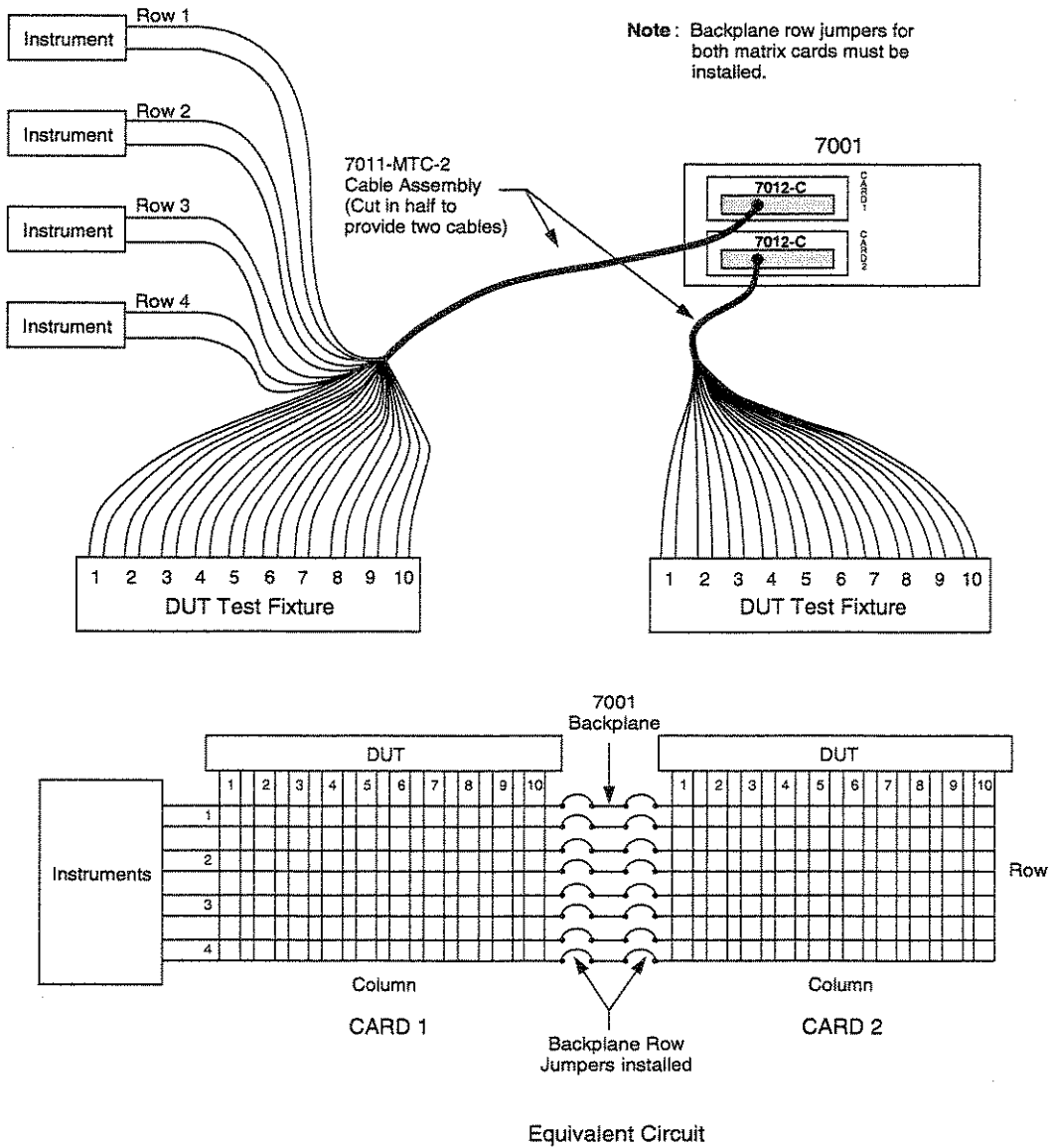


Figure 3-11
Two-card system example (multi-pin connector card)

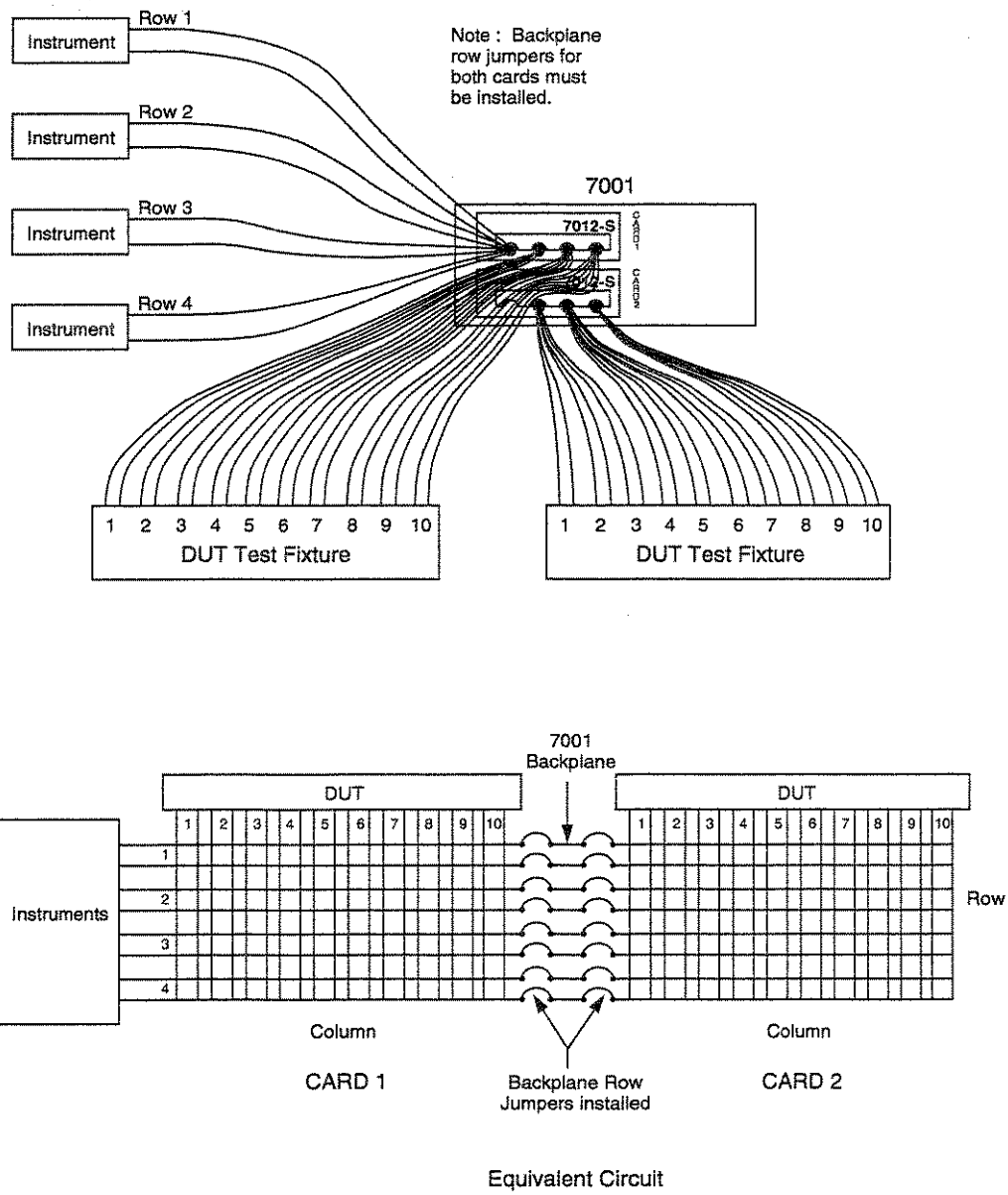


Figure 3-12
Two-card system example (screw terminal connector card)

3.4.3 Two-mainframe system

Figure 3-13 and Figure 3-14 show a system using three matrix cards in two Model 7001 mainframes to configure a 4×30 test matrix. This system is similar to the Two-card System (see previous paragraph), except that a third matrix card (installed in a second mainframe) is added.

Figure 3-13 shows the connection scheme for the multi-pin connector cards. External circuit connections to the Model 7001 #1 mainframe are identical to the ones used for the Two-card System. The third matrix card (installed in Model 7001 #2 mainframe) shows how a custom-built cable can be used to make connections to external circuitry. A suitable round cable can be terminated with a 96-pin female DIN connector (Model 7011-KIT-R) that will mate to the Model 7012-C matrix card assembly. The unterminated end of the cable is connected directly to instrumentation and DUT. Notice that the row connections for the third matrix card are made at the instruments.

Figure 3-14 shows connections for the screw terminal connector card. Single conductor connections are made directly from the screw terminals of the connector card to instrumentation and DUT

3.5 Model 7012 installation and removal

This paragraph explains how to install and remove the Model 7012 matrix card assembly from the Model 7001 mainframe.

WARNING

Installation or removal of the Model 7012 is to be performed by qualified service personnel. Failure to recognize and observe standard safety precautions could result in personal injury or death.

NOTE

If using the screw terminal connector card, 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 matrix card that could degrade performance, only handle the card assembly by the edges and shields.

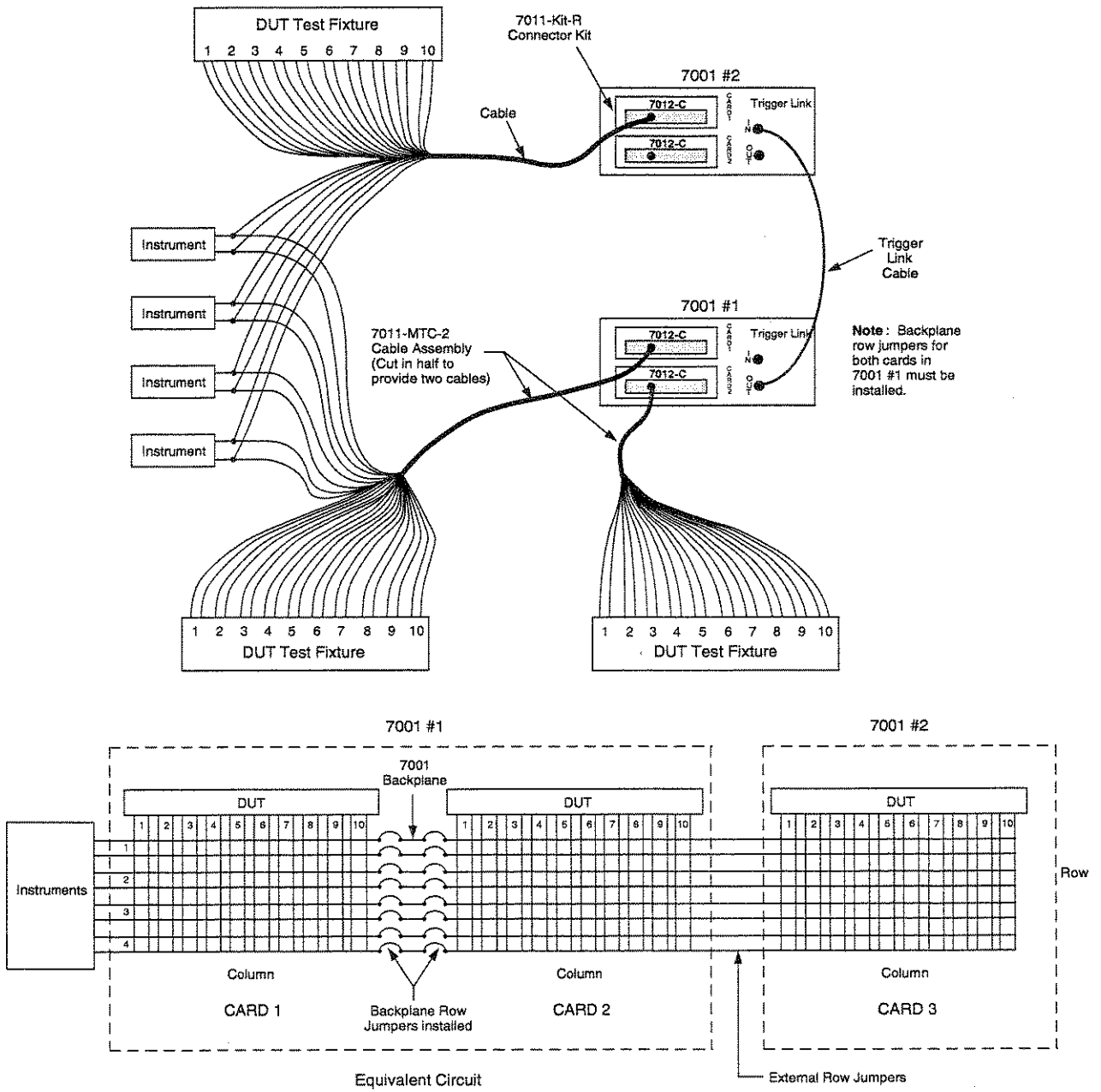


Figure 3-13
Two-mainframe system example (multi-pin connector card)

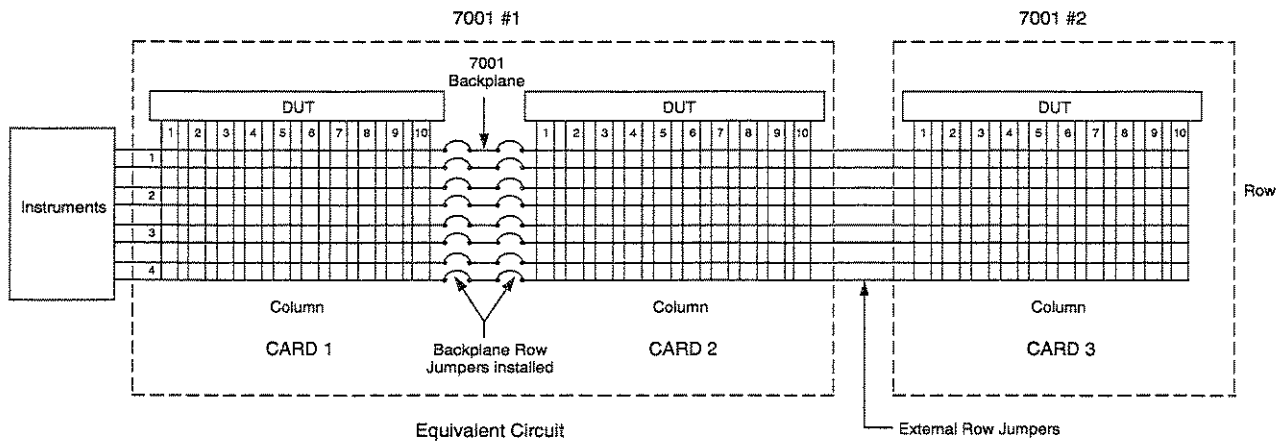
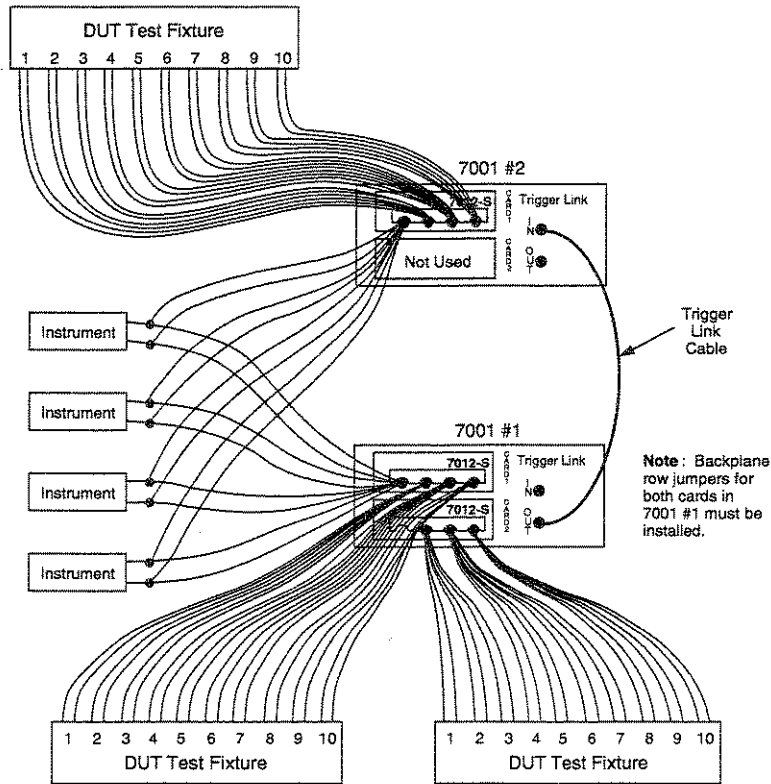


Figure 3-14
Two-mainframe system example (screw terminal connector card)

Matrix card installation

Perform the following steps to install the matrix 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 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. 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 3-15 for Model 7012-S installation, or Figure 3-16 for Model 7012-C installation, feed the matrix 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. For the 7012-C, also install the screw shown in Figure 3-16.

Matrix card removal

To remove the matrix card assembly, first unlock it by pulling the latches outward, then 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.

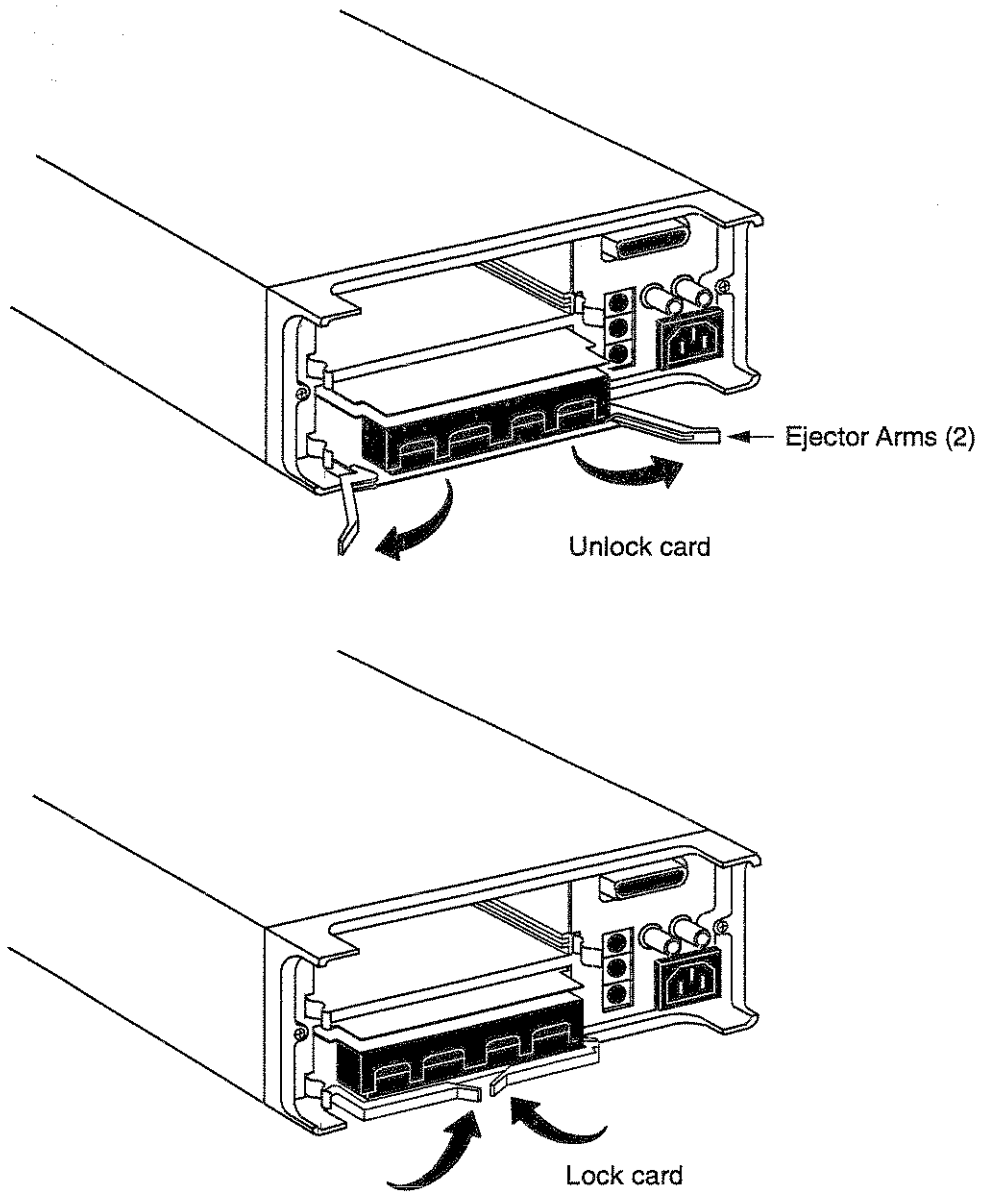


Figure 3-15
Model 7012-S card installation in Model 7001

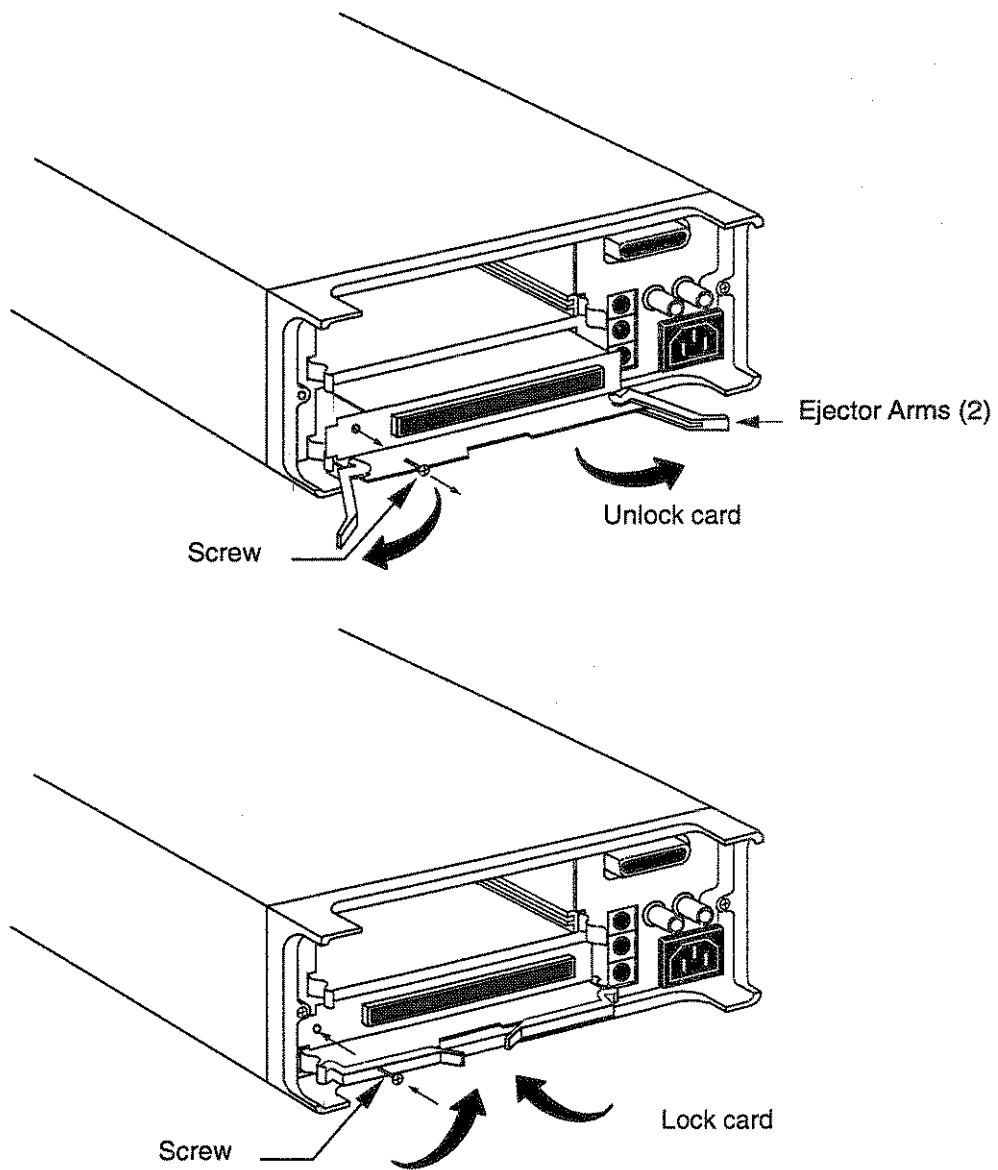


Figure 3-16
Model 7012-C card installation in Model 7001

4

Operation

4.1 Introduction

The information in this section is arranged as follows:

- 4.2 **Power limits:** Summarizes the maximum power limits of the Model 7012 matrix card assembly.
- 4.3 **Mainframe control of matrix card:** Summarizes programming steps to control the matrix card from the Model 7001 Switch System mainframe.
- 4.4 **Multiplexer switching examples:** Provides some typical applications for using the Model 7012.
- 4.5 **Measurement considerations:** Reviews a number of considerations when using the Model 7012 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 matrix card

The following information pertains to the Model 7012 matrix 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) in 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).

Notice that the matrix organization of the channel status display corresponds directly to the 4 × 10 organization of the matrix card. With a matrix card installed, the top row of the display corresponds to Row 1 of the matrix card. The 10 columns of the matrix are labeled 1 through 10 on the display. The next rows down correspond to Rows 2, 3, and 4 respectively.

Matrix organization of the channel status display corresponds to the 4 × 10 organization of the matrix card

as shown in Figure 4-2. Each channel is designated as a row/column crosspoint.

To control the matrix card from the mainframe, each matrix crosspoint must have a unique CHANNEL assignment. The CHANNEL assignments for the matrix card are provided in Figure 4-3. Each CHANNEL assignment is made up of the slot designator (1 or 2) and the matrix crosspoint. To be consistent with Model 7001 operation, the slot designator, row and column are separated by exclamation points (!). Some examples of CHANNEL assignments:

- CHANNEL 1!1!1 = Slot 1, Row 1, Column 1
- CHANNEL 1!4!10 = Slot 1, Row 4, Column 10
- CHANNEL 2!2!9 = Slot 2, Row 2, Column 9
- CHANNEL 2!3!4 = Slot 2, Row 3, Column 4

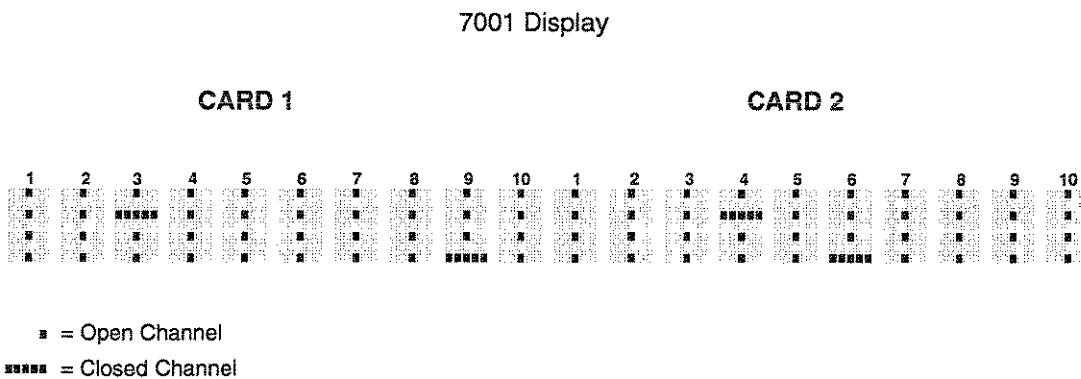


Figure 4-1
Channel status display

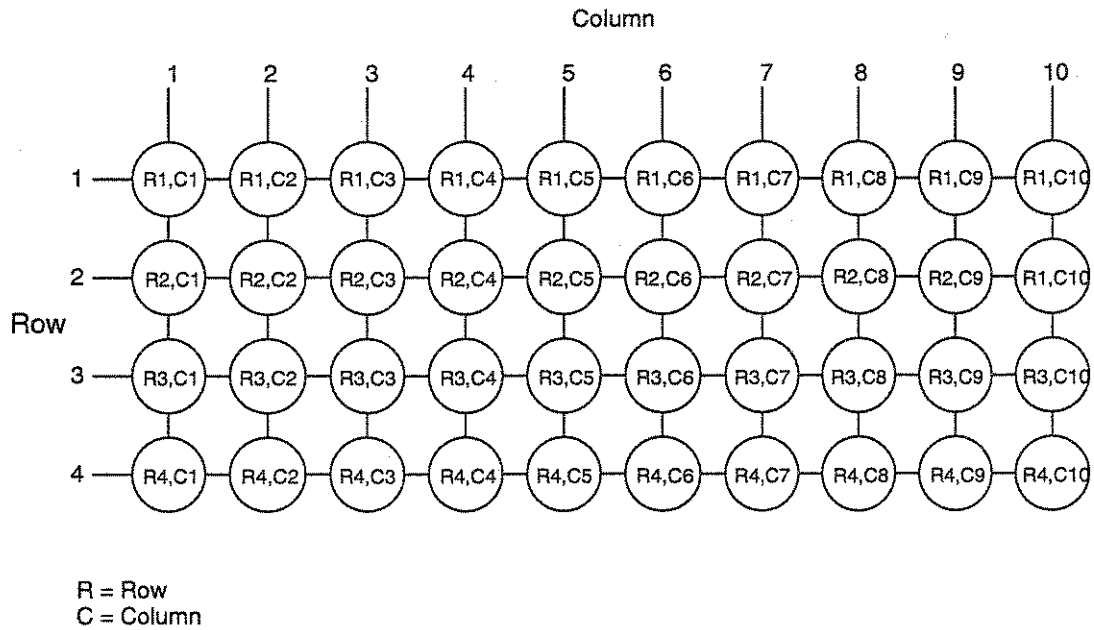
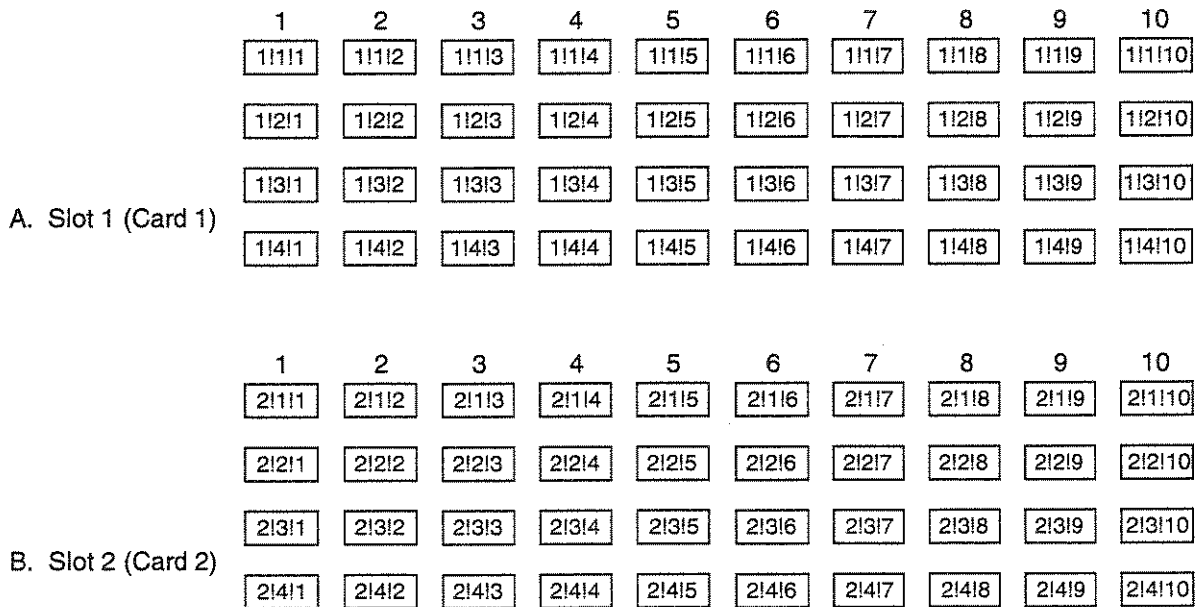


Figure 4-2
Display organization for multiplexer channels



Examples : 11214 = Slot 1, Row 2, Column 4
21316 = Slot 2, Row 3, Column 6

Figure 4-3
Model 7012 programming channel assignments

4.3.2 Front panel control

Closing and opening channels

A matrix crosspoint is closed from the front panel by simply keying in the channel assignment and pressing CLOSE. For example, to close Row 3, Column 4 crosspoint of a matrix card installed in slot 2, key in the following channel list and press CLOSE:

```
SELECT CHANNELS 2!3!4
```

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!1, 2!1!3, 2!2!1-2!2!5
```

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

Matrix crosspoints 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 scan list.) The following shows an example of a scan list:

```
SCAN CHANNELS 2!1!1, 2!1!3, 2!2!1-2!2!5
```

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!1, and 1!1!3 through 1!1!6:

```
OUTPUT 707; ":clos (@ 1!1!1, 1!1!3:1!1!6)"
```

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

Either of the following statements will open channels 1!1!1, and 1!1!3 through 1!1!6:

```
OUTPUT 707; ":open (@ 1!1!1, 1!1!3:1!1!6)"
OUTPUT 707; ":open all"
```

Scanning channels

There are many commands associated with scanning. However, it is possible to configure a scan using as little as four commands. These commands are listed as follows:

```
*RST
:TRIGger:SEQuence:COUNt:AUTO ON"
: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!1:1!4!10)"
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 240msec (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!1:1!4!10)"
40 OUTPUT 707; ":INIT"
50 END
```

Line 5 Opens all channels.

Line 25 Sets a 1/4 second delay after each channel closes.

4.4 Matrix switching examples

Some applications to test thick film resistor networks and transistors are provided in the following paragraphs. These applications are intended to demonstrate the versatility of using the matrix card in test systems.

4.4.1 Thick film resistor network testing

A dedicated matrix system for testing thick film resistor networks is shown in Figure 4-4. This particular system provides two different methods to check thick films; four-wire resistance measurements, and voltage measurements using an applied voltage.

The system shown in Figure 4-4 tests two 4-element thick films, but can be expanded to test more by simply using additional Model 7012 matrix cards. The Model 7001 will accommodate two matrix cards. Daisy-chain in six Model 7001s expands the system to 12 matrix cards allowing 24 four-element thick films to be tested.

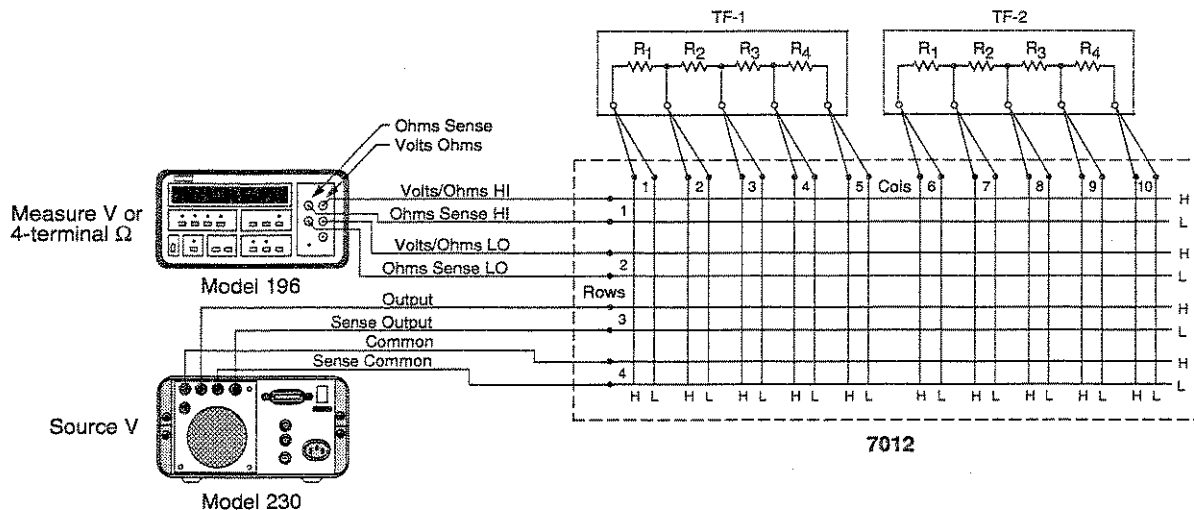


Figure 4-4
Thick film resistor network testing

Four-terminal ohms measurements

For general purpose testing, the Keithley Model 196 can be used to make four-terminal resistance measurements of each thick film. As shown in Figure 4-5, OHMS HI and OHMS SENSE HI are connected to one matrix row, and OHMS LO and OHMS SENSE LO are connected to another matrix row. With this configuration, the resistance of each resistor element and/or combined elements can be measured by closing the appropriate crosspoints. In Figure 4-5, crosspoints 1!1 (Row 1, Column 1) and 2!3 (Row 2, Column 3) are closed to measure the combined resistance of R1 and R2.

The effects of thermal EMFs generated by relay contacts and connections can be cancelled by using the offset compensated ohms feature of the Model 196. (The Model 7012 has been designed to keep relay EMF at a minimal level.) To compensate for thermal EMFs, close two crosspoints (such as 1!1!1 and 1!2!1), this will short the input of the Model 196, enable zero to cancel internal offset, and then enable offset compensated ohms.

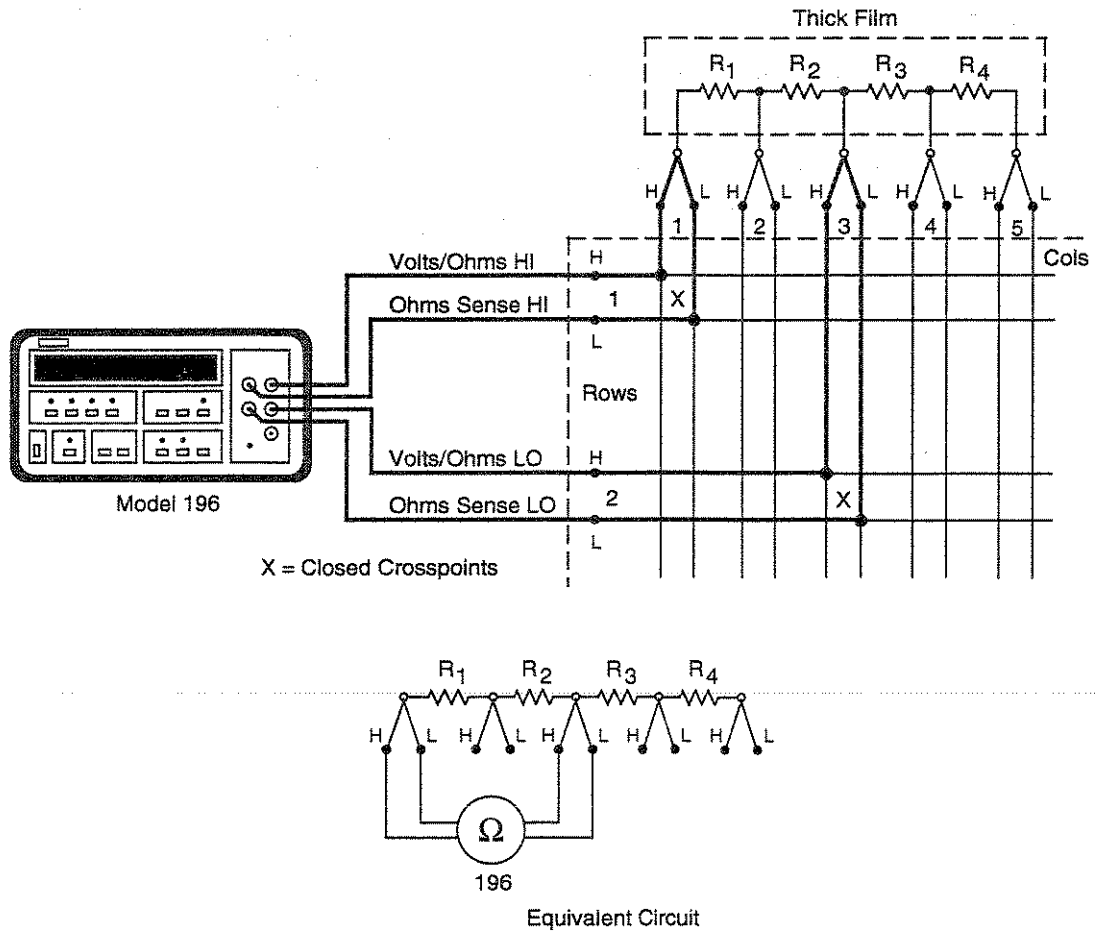


Figure 4-5
Four-terminal ohms measurements

Voltage divider checks

For thick film resistor networks that are to be used as voltage dividers, it may be desirable to test them using voltages that simulate actual operating conditions. This is a particularly useful test for resistor networks that have a voltage coefficient specification. The test system in Figure 4-4 uses a Keithley Model 230 to source voltage and the Model 196 to measure voltage.

A consideration in these checks is the effect of the Model 196 input impedance on voltage measurements. The input impedance is shunted across the resistor being measured. The resultant divider resistance is the parallel combination of the resistor under test and the input impedance. As long as the input impedance is much larger than the resistor being tested, the error introduced into the measurement will be minimal. Minimum input impedance requirements are, of course, determined by the accuracy needed in the measurement. The input impedances of the Model 196 are as follows: 300mV and 3V ranges, 1G Ω ; 30V range, 11M Ω ; 300V range, 10.1M Ω . For better input impedance requirements, the Keithley Model 617 Electrometer can be incorporated into the test system to measure voltage.

Another factor to be considered when checking low voltage dividers is thermal EMFs generated by the matrix card. (The Model 7012 has been designed to keep relay EMF at a minimal level.) A matrix card crosspoint can generate up to 5 μ V of thermal EMF. Thus, when making low voltage measurements be sure to account for this additional error.

Even though four-terminal connections are made at the Model 196 and the resistor networks, the sense leads are internally disconnected from the input of the DMM when the volts function is selected. The simplified test system is shown in Figure 4-6.

The thick film is tested by applying a voltage across the resistor network and measuring the voltage across each resistor element and/or across combined elements. In Figure 4-6, crosspoints 1!3!1 and 1!4!4 are closed to apply voltage across the network, and crosspoints 1!1!3 and 1!2!4 are closed to measure the voltage drop across R3.

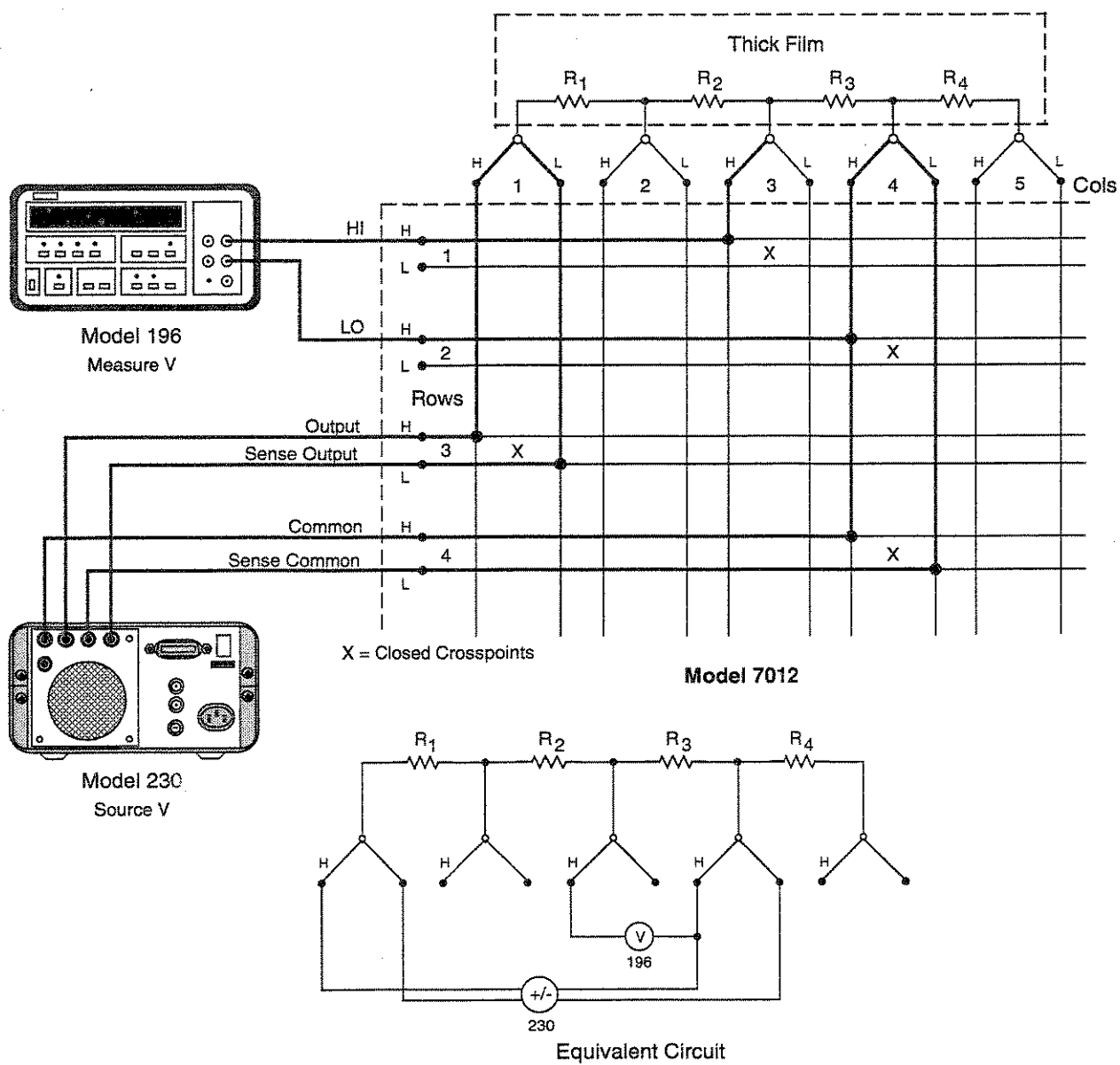


Figure 4-6
Voltage divider checks

4.4.2 Transistor testing

A matrix system for testing DC parameters of transistors is shown in Figure 4-7. This system uses two Source Measure Units (SMU). There are three SMUs available from Keithley; the Model 236 Source Measure Unit, Model 237 High Voltage Source Measure Unit and Model 238 High Current Source Measure Unit. Keep in mind that if using the Models 237 (high voltage capability) or 238 (high current capability), do not exceed the maximum signal levels of the matrix card. Maximum allowable DC signals are 110V and 1A, 30W with resistive load.

This system tests three transistors, but can be expanded to test more by simply using additional Model 7012 matrix cards. The Model 7001 will accommodate two matrix cards. Daisy-chaining six Model 7001s expands the system to 12 matrix cards allowing 36 or more transistors to be tested.

NOTE

The Model 7012 is a general purpose matrix card and cannot be used to check FETs or transistors that have high gain or low power. To test these devices, a matrix card with low offset current and high isolation characteristics must be used.

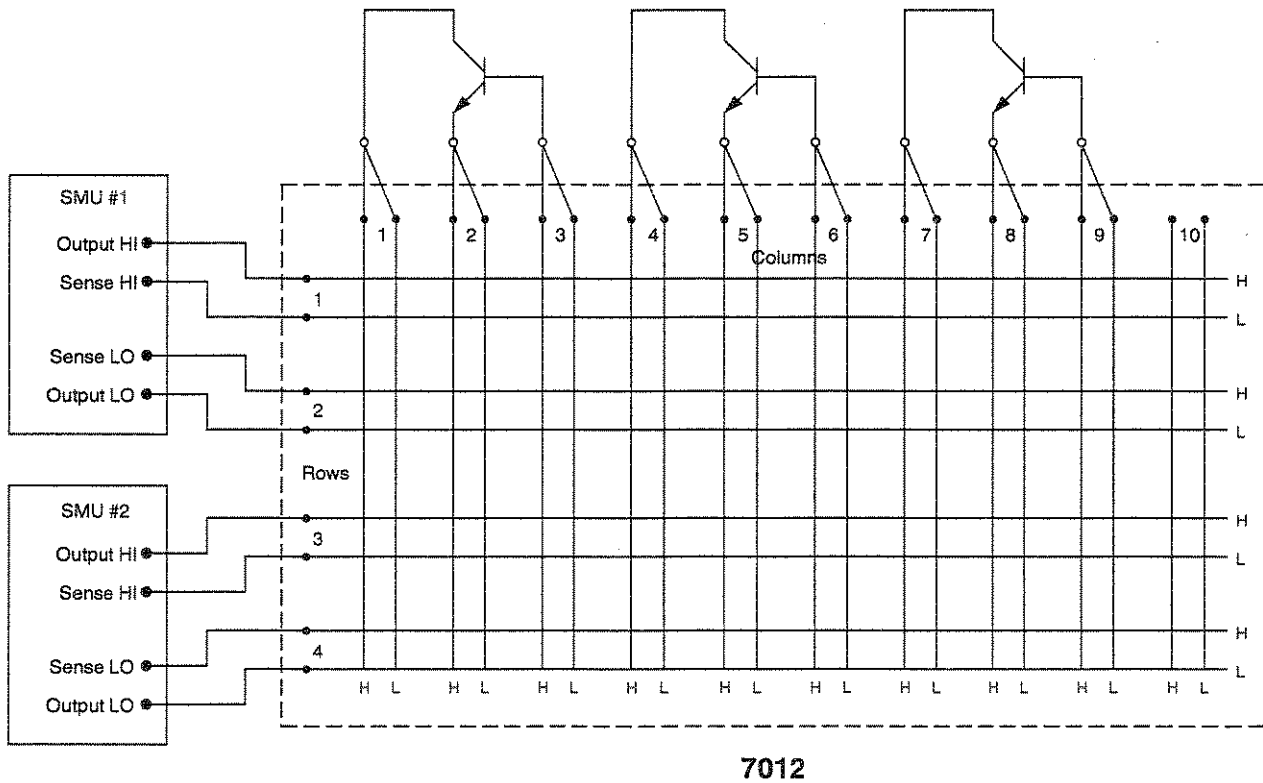


Figure 4-7
Transistor testing

DC parameter checks

With a transistor configured as a common-emitter amplifier, the test system shown in Figure 4-8 can be used to determine the following DC parameters: Collector current (I_C), base current (I_B), current gain, emitter current (I_E) and base-to-emitter voltage (V_{BE}).

Figure 4-8 shows which crosspoints to close to configure the amplifier circuit. SMU #1 is configured to source voltage and measure current. It is used to power the collector circuit (V_{CE}) and measure the collector current (I_C). SMU #2 is configured to source current and measure voltage. It is used to provide the base current (I_B) for the transistor, and will also measure the base-to-emitter voltage (V_{BE}). With collector current (I_C) and base current (I_B) known, the current gain can be calculated as follows:

$$\text{Gain} = \frac{I_C}{I_B}$$

The emitter current (I_E) can be determined by using Kirchoff's Current Law as follows:

$$I_E = I_C + I_B$$

Common-emitter characteristic curves

A profile of the transistor operating characteristics can be obtained by measuring the collector current over a specified voltage range (V_{CE}) for different base bias currents (I_B). For example, Figure 4-9 shows the characteristics of a typical NPN silicon transistor at base bias currents (I_B) of 20 μ A, 40 μ A, 60 μ A, and 80 μ A.

Extensive trigger capabilities facilitate synchronization of the Keithley Source Measure Unit operations. By performing a subordinate sweep, SMU #1 will perform a staircase sweep at every base bias current level set by SMU #2. On every step of each staircase sweep, SMU #1 will source a voltage level (V_{CE}) and measure the subsequent collector current (I_C). For the characteristics shown in Figure 4-9, four staircase sweeps were performed; one staircase sweep at each base bias level.

Refer to a Keithley Source Measure Unit instruction manual for details on performing sweeps.

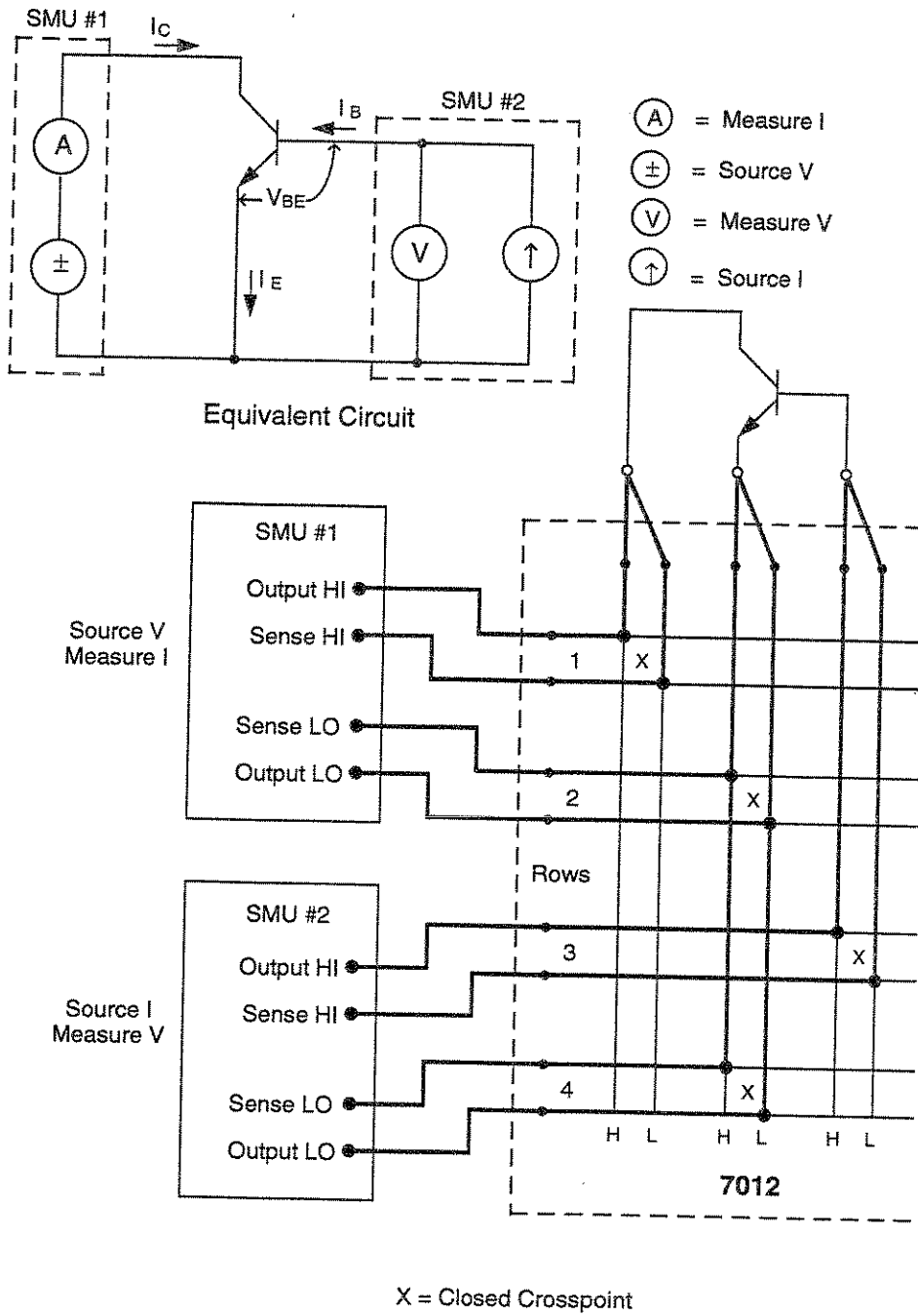


Figure 4-8
DC parameter checks

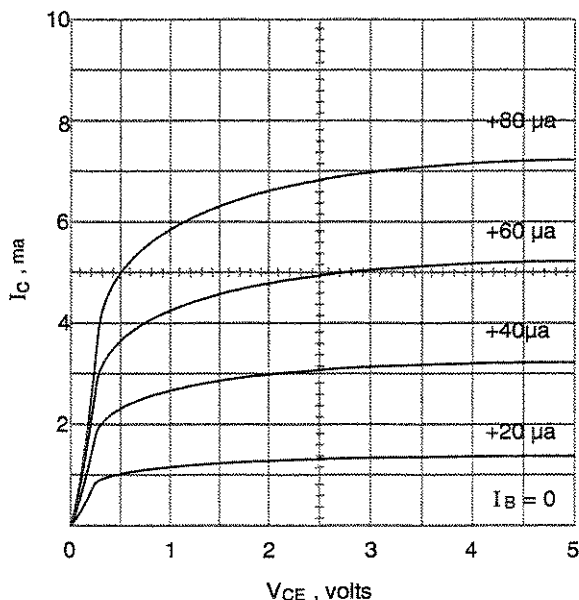


Figure 4-9
Common-emitter characteristics of an NPN silicon Transistor

4.5 Measurement considerations

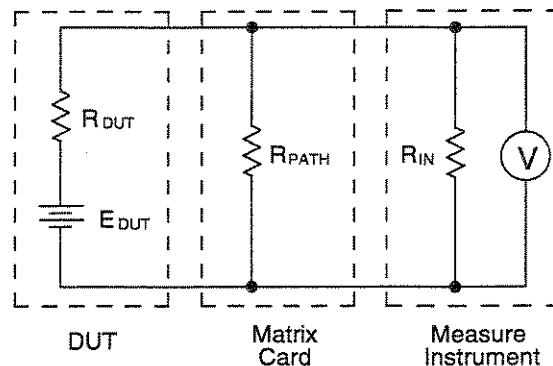
Many measurements made with the Model 7012 are subject to various effects that can seriously affect low-level measurement accuracy. The following paragraphs discuss these effects and ways to minimize them.

4.5.1 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.

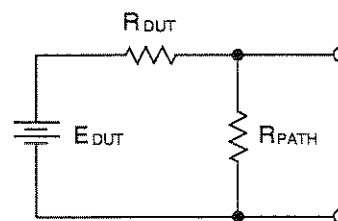
Path isolation resistance forms a signal path that is in parallel with the equivalent resistance of the DUT, as shown in Figure 4-10. For low-to-medium device resistance values, path isolation resistance is seldom a con-

sideration; 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 4-11. 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 4-10
Path isolation resistance



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

Figure 4-11
Voltage attenuation by 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 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.

4.5.2 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.

4.5.3 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 matrix 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.

4.5.4 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 4-12, 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.

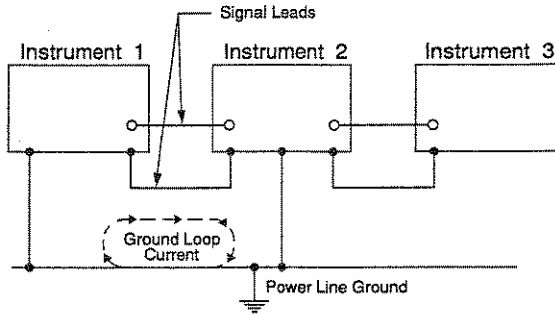


Figure 4-12
Power line ground loops

Figure 4-13 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.

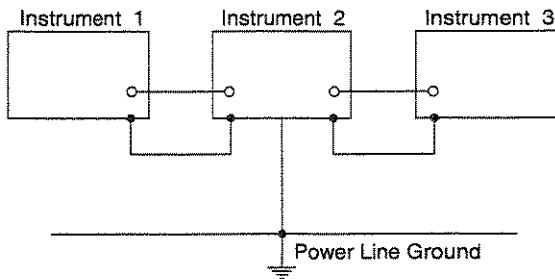


Figure 4-13
Eliminating ground loops

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.

4.5.5 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.

4.5.6 AC frequency response

The AC frequency response of the Model 7012 is important in test systems that switch AC signals. Refer to the specifications at the front of this manual.

