Instruction Manual

Model 7021
Multiplexer-Digital I/O Card

Contains Operating and Servicing Information

KEITHLEY

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

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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Model 7021 Multiplexer-Digital I/O Card
Instruction Manual

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Manual Print History

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

Revision A (Document Number 7021-901-01)..... May 1997

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, 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) measuring circuits 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.

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 the 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.

ANALOG MULTIPLEXER SPECIFICATIONS

MULTPLEXER CONFIGURATION: Independent 1 × 12 and 1 × 18 multiplex banks. Adjacent banks can be connected together. Jumpers can be removed to isolate any bank from the backplane.

CONTACT CONFIGURATION: 2-pole Form A (HI, LO).

MAXIMUM SIGNAL: 110V DC, 110V rms, 155V peak between any two inputs or chassis, 1A switched, 30VA (resistive load).

CONTACT LIFE: **Cold Switching:** 10^8 closures.
Maximum Signal Levels: 10^5 closures.

CHANNEL RESISTANCE (per conductor): <1.25Ω.

CONTACT POTENTIAL: <3µV per channel contact pair
<9µV per single contact

OFFSET CURRENT: <100pA.

ACTUATION TIME: <3ms.

ISOLATION:[1]

Bank:	>10^9Ω, <25pF.
Channel to Channel:	>10^9Ω, <50pF.
Differential:	Configured as 1×12: >10^9Ω, <100pF. Configured as 1×18: >10^9Ω, <150pF. Configured as 1×30: >10^9Ω, <200pF.
Common Mode:	Configured as 1×12: >10^9Ω, <200pF. Configured as 1×18: >10^9Ω, <250pF. Configured as 1×30: >10^9Ω, <350pF.

CROSSTALK[1] (1MHz, 50Ω Load): <–40dB.

INSERTION LOSS[1] (50Ω Source, 50Ω Load): <0.25dB below 1MHz, <3dB below 10MHz.

RELAY DRIVE CURRENT (per relay): 16mA.

[1] Specifications apply with no more than one channel closed.

DIGITAL I/O SPECIFICATIONS

DIGITAL I/O CAPABILITY: 10 independent inputs.
10 independent outputs.

OUTPUT:

Configuration: 10 open collector drivers with factory installed 10kΩ pull-up resistors. Each driver has an internal flyback diode.

Pull-Up Voltage: 5V internally supplied, external connection provided for user supplied voltage up to 42V max. Outputs short circuit protected up to 25V.

Maximum Sink Current: **Per Channel:** 250mA.
Per Card: 1A.

Logic: Hardware user configurable for negative or positive true logic levels.

INPUT:

Configuration: 10 inputs with internal 10kΩ pull-up resistors provided. Input resistors can be set for pull-up or pull-down configuration.

MAXIMUM VOLTAGE LEVEL: 42V peak.

LOGIC: Positive true.

GENERAL

CONNECTOR TYPE: 96-pin male DIN connector.

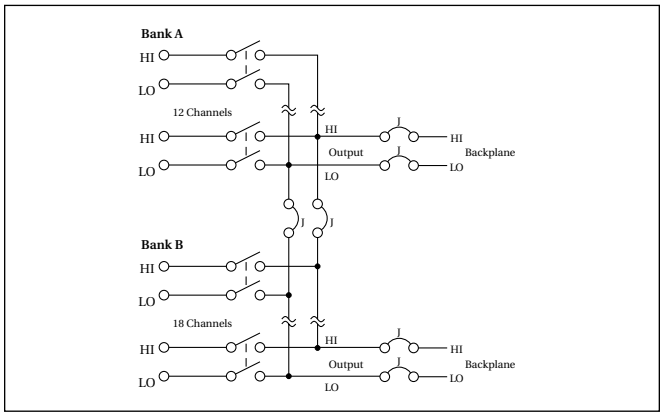
ENVIRONMENT: **Operating:** 0° to 50°C, up to 35°C <80% RH.
Storage: –25° to 65°C.

EMC: Conforms with European Union Directive 89/336/EEC EN 55011, EN 50082-1, EN 61000-3-2 and 61000-3-3, FCC part 15 class B.

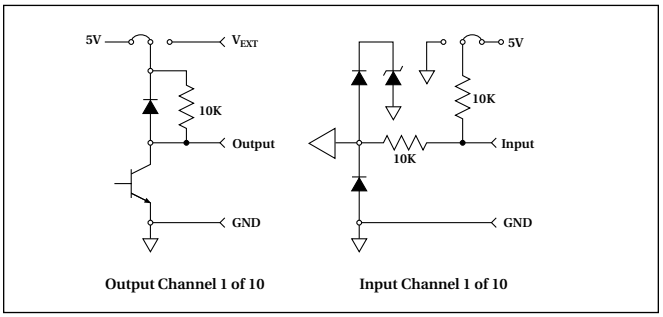
SAFETY: Conforms with European Union Directive 73/23/EEC EN 61010-1, UL 3111-1.

Specifications subject to change without notice.

Multiplexer Configuration



Digital I/O Configuration



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List of Tables

4 Card Connections and Installation

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1
General Information

Introduction

This section contains general information about the Model 7021 multiplexer-digital I/O card.

The Model 7021 consists of a multi-pin (mass termination) connector card and a relay card. Any external test circuit connections are made via the 96-pin male DIN connector on the connector card. Keithley offers a variety of optional accessories at the end of this section that can be used to make connections to the connector card.

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

- **Features**
- **Warranty information**
- **Manual addenda**
- **Safety symbols and terms**
- **Specifications**
- **Unpacking and inspection**
- **Optional accessories**

Features

The Model 7021 has two-pole, independent 1×12 and 1×18 multiplex banks and ten independent inputs and outputs for both multiplexer and digital I/O capabilities. Some of the key features include:

- Low contact potential and offset current for minimal effects on low-level signals.
- Easy jumper configuration for one or two multiplex banks.
- Backplane jumpers. Cutting jumpers disconnects multiplexer bank outputs from the Model 7001/7002 analog backplane.
- Model 7011-KIT-R connector assembly kit that includes a 96-pin female DIN connector that will mate directly to the connector on the Model 7021 or to a standard 96-pin male DIN bulkhead connector (see Model 7011-MTR). This connector uses solder cups for connections to external circuitry and includes an adapter for a round cable and the housing.

Warranty information

Warranty information is located on the inside front cover of this instruction manual. Should your Model 7021 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the 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.

Manual addenda

Any improvements or changes concerning the multiplexer-digital I/O 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.

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 card. Such damage may invalidate the warranty.

Specifications

Model 7021 specifications are found at the front of this manual. These specifications are exclusive of the mainframe specifications.

Unpacking and inspection

Inspection for damage

The Model 7021 is packaged in a resealable, 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 7001/7002 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.

Shipping contents

The following items are included with every Model 7021 order:

- Model 7021 Multiplexer-Digital I/O Card
- Model 7011-KIT-R 96-Pin Female DIN Connector Kit
- Model 7021 Instruction Manual
- Additional accessories as ordered

Instruction manual

The Model 7021 Instruction Manual is three-hole drilled so it can be added to the three-ring binder of the Model 7001 or Model 7002 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 Model 7021 instruction manual.

If an additional instruction manual is required, order the manual package, Keithley part number 7021-901-01. The manual package includes an instruction manual and any pertinent addenda.

Repacking for shipment

Should it become necessary to return the Model 7021 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 card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

Optional accessories

The following accessories are available for use with the Model 7021:

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.

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 7021 and to a standard 96-pin male DIN bulkhead connector (see Model 7011-MTR).

2
Multiplexer Configuration

Introduction

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

- **Basic multiplexer configurations —** Covers the basic multiplexer configurations: dual 1 × 12 and 1 × 18 configuration and single 1 × 30 configuration. The significance of the backplane jumpers is also covered here.
- **Typical multiplex switching schemes —** Explains some of the basic ways a multiplexer can be used to source or measure. Covers single-ended switching, differential (floating) switching, sensing, and SMU connections.
- **Multiplexer expansion —** Discusses the various configurations that are possible by using multiple cards.

Basic multiplexer configurations

A simplified schematic of the Model 7021 multiplex banks is shown in Figure 2-1. It is organized as two multiplex banks: 1 × 12 and 1 × 18. Bank A has 12 inputs and one output, and bank B has 18 inputs and one output. Two-pole switching is provided for each multiplexer input, with HI and LO switched. The two banks can be jumpered together to expand multiplexer inputs, and backplane jumpers provide bank connections to an adjacent card installed in a Model 7001/7002 mainframe.

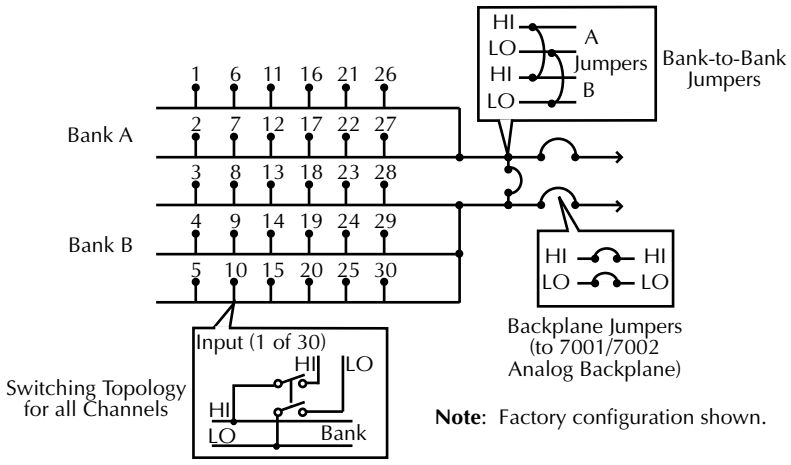


Figure 2-1
Model 7021 simplified schematic

Multiplexer bank-to-bank jumpers

Jumpers are installed on the connector card to connect multiplex banks together to form a 1 × 30 multiplexer. Each jumper set connects two adjacent banks together. These jumper sets are included with the Model 7021.

The bank-to-bank jumpers allow you to configure the multiplexer in a variety of ways. Typical multiplexer configurations include:

- Dual 1 × 12 and 1 × 18 multiplex banks; no jumpers installed (Figure 2-2).
- One 1 × 30 multiplex bank; all bank-to-bank jumpers installed (Figure 2-3).

Refer to Section 4 for information on installing bank-to-bank jumpers.

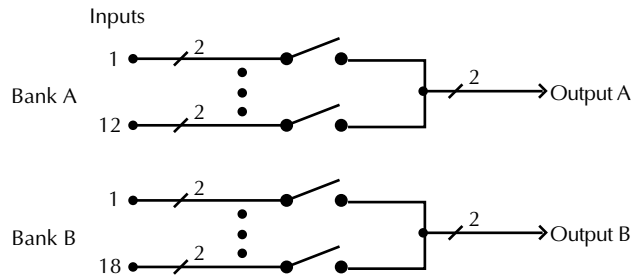


Figure 2-2
Dual 1 × 12 and 1 × 18 multiplexer configuration (jumpers not installed)

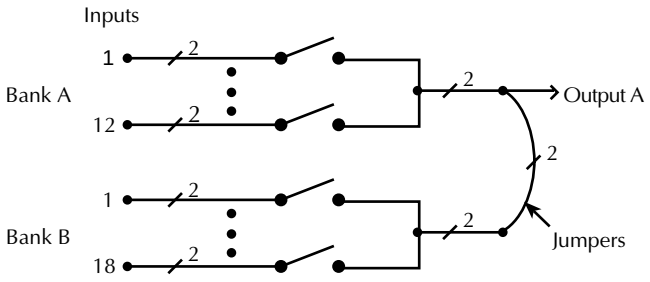


Figure 2-3
One 1 × 30 multiplexer configuration (jumpers installed)

Backplane jumpers

There are four pairs of backplane jumpers located on the relay card. With the jumpers installed, the multiplex banks of one card connect to the multiplex banks of a second card through the analog backplane of the Model 7001/7002 mainframe, which expands the number of inputs. With the jumpers removed (cut), the multiplexer is isolated from another card installed in the mainframe.

The three-pole analog backplane of the Model 7001/7002 mainframe is shown in Figure 2-4. The GUARD connection of the analog backplane is found only on the mainframe and is not used with the Model 7021 or Model 7022 card. Through this analog backplane, the banks of a Model 7021 installed in one slot can be connected to the banks (or rows) of a compatible card installed in an adjacent slot.

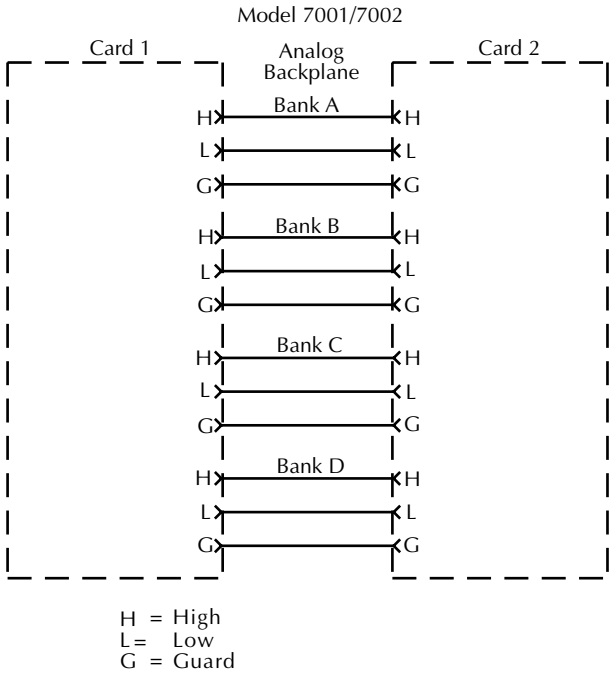


Figure 2-4
Model 7001/7002 analog backplane

Figure 2-5 shows how each bank of the Model 7021 is connected to the backplane. Notice that since the Model 7021 is a two-pole card, there is no connection made to the GUARD terminal of the backplane. The Model 7021 is shipped from the factory with the backplane jumpers installed.

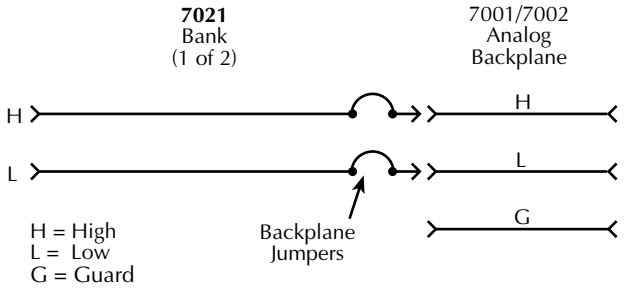


Figure 2-5
Bank connections to backplane

Removing (cutting) the backplane jumpers isolates the card from the backplane, and subsequently, any card installed in an adjacent slot. For information on removing the jumpers, refer to Section 4.

NOTE

The Model 7001/7002 does not provide an analog backplane for the non-701X/702X/703X series cards. As a result, any 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 7021 to one of these cards is to wire them together.

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 pickup 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 7001/7002 mainframe.

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 2-6. 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.

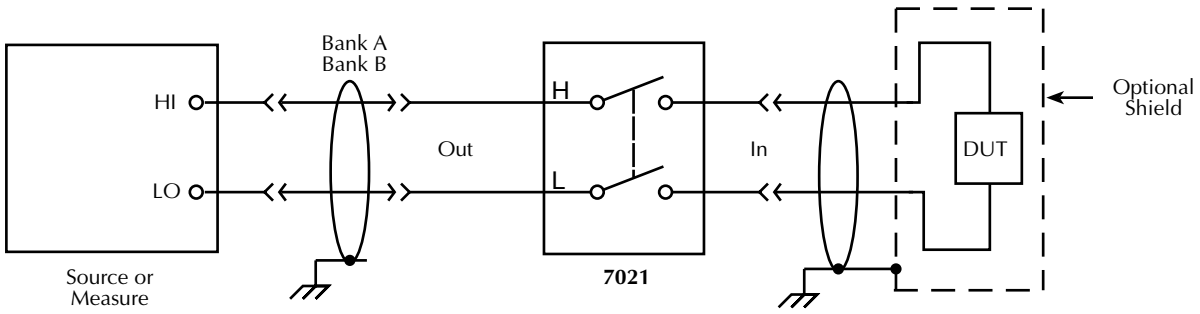


Figure 2-6
Single-ended switching example

Differential switching

The differential or floating switching configuration is shown in Figure 2-7. 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.

Sensing

Figure 2-8 shows how the multiplexer 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 (<1.25Ω) and the resistance of external cabling. Whenever path resistance is a consideration, sensing should be used.

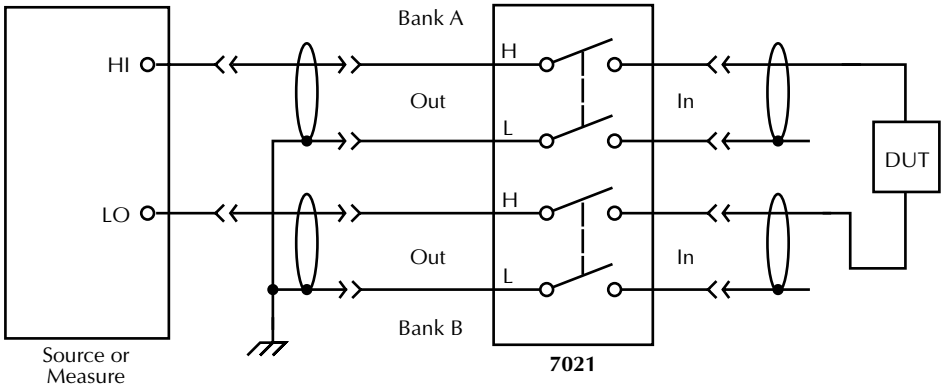


Figure 2-7
Differential switching example

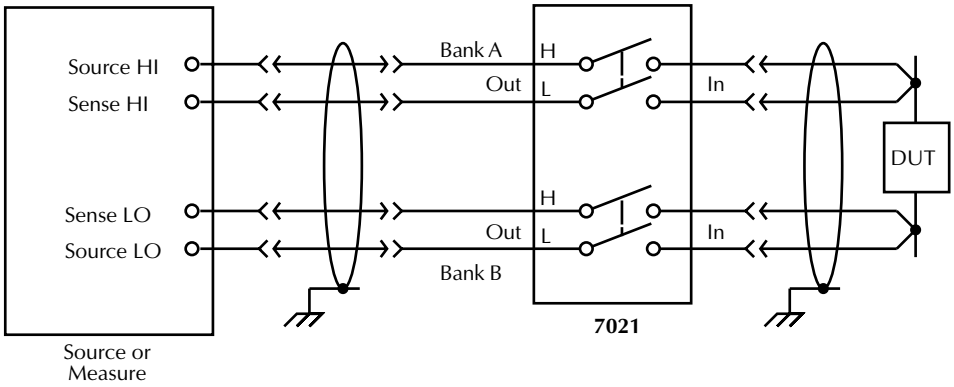


Figure 2-8
Sensing example

SMU connections

Figure 2-9 shows how to connect a Keithley Model 236, 237, or 238 Source Measure Unit to the multiplexer. 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.

Multiplexer expansion

With the use of additional switching cards and mainframes, larger systems can be configured. Each Model 7001 switch system mainframe can accommodate up to two cards, and up to six mainframes can be connected together. With this switch system, up to 12 cards can be configured. Each Model 7002 switch system mainframe can accommodate up to ten cards. And, by connecting up to six Model 7002 mainframes, 60 cards can be configured. The limits on the number of cards in the Model 7001/7002 are due to triggering.

Multiple-card switching systems

The Model 7001/7002 switch system mainframes can accommodate two and ten cards, respectively. The following paragraphs use a two-card system to illustrate multiple-card switching configurations.

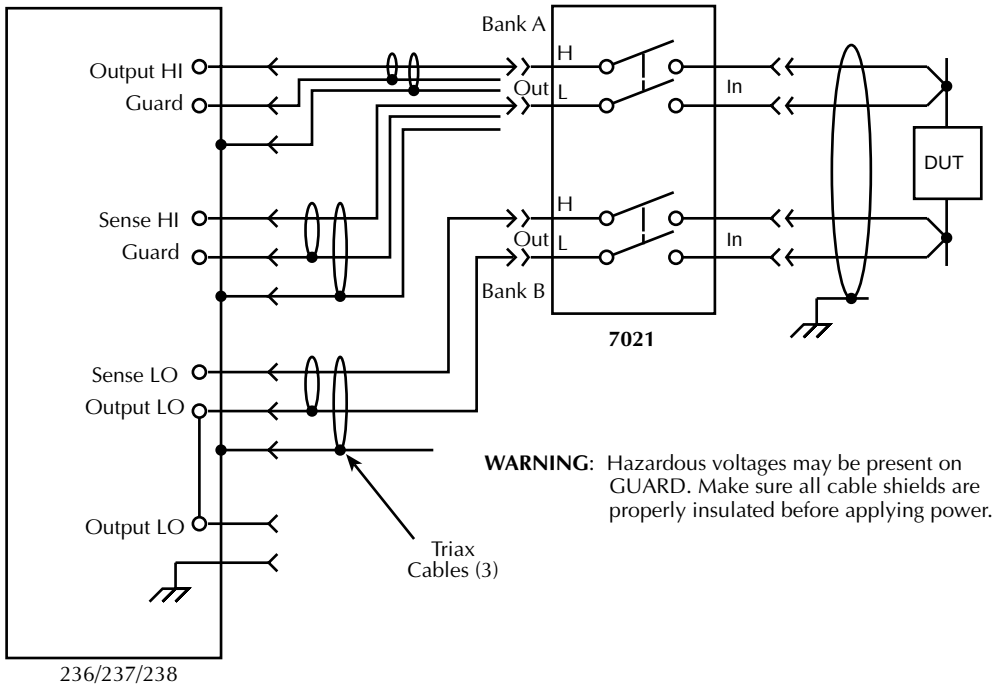


Figure 2-9
SMU connections

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 2-10 shows an example using two Model 7021 cards.

Multiplexer input expansion

You can double the number of multiplexer inputs by installing two "as shipped" Model 7021s in the Model 7001/7002 mainframe. By leaving the backplane jumpers installed, the multiplex banks of the card installed in slot 1 (CARD 1) are automatically connected to the multiplex banks of the card installed in slot 2 (CARD 2) through the analog backplane.

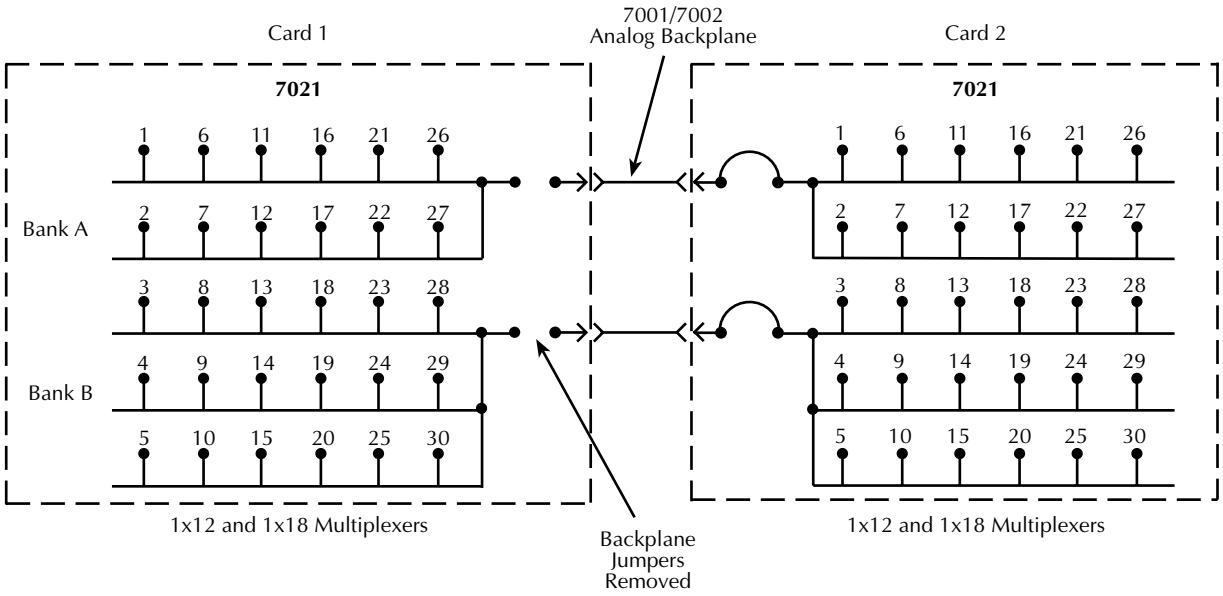


Figure 2-10
Two separate multiplexer systems

Figure 2-11 shows an example of input expansion. Each Model 7021 card is configured with dual 1 × 12 and 1 × 18 multiplex banks. By connecting the banks together (via the Model 7001/7002 analog backplane), the resultant multiplexer system has 24 inputs for bank A and 36 inputs for bank B. Notice that if all the bank-to-bank jumpers (for both cards) were installed, the result would be a single 1 × 60 multiplexer.

Figure 2-12 shows a possible switching system using a matrix and a multiplexer. The backplane jumpers for both the matrix and multiplexer must be installed. This allows matrix rows to be connected to multiplex banks. On the multiplex banks, the bank-to-bank jumpers must be removed to maintain isolation between the matrix rows. See the instruction manual for the Model 7022 for complete information on the matrix.

Mixing card types

Different types of cards can be used together to create some unique switching systems. For example, you could have a Model 7021 multiplexer-digital I/O card installed in one slot and a Model 7022 matrix-digital I/O card installed in an adjacent slot.

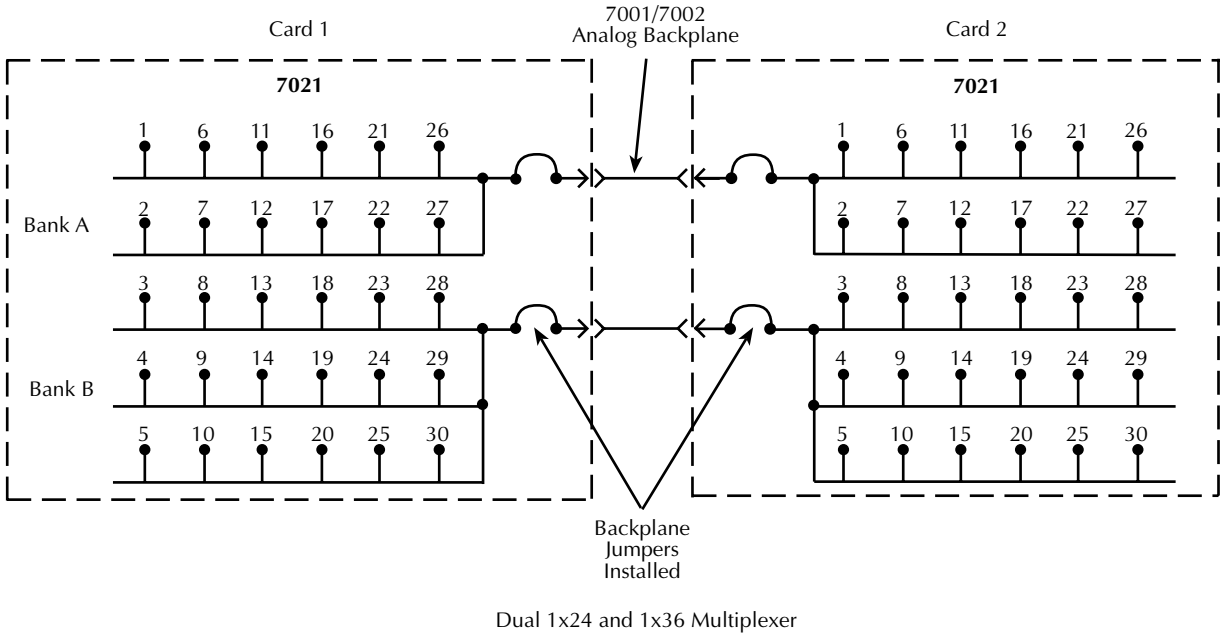
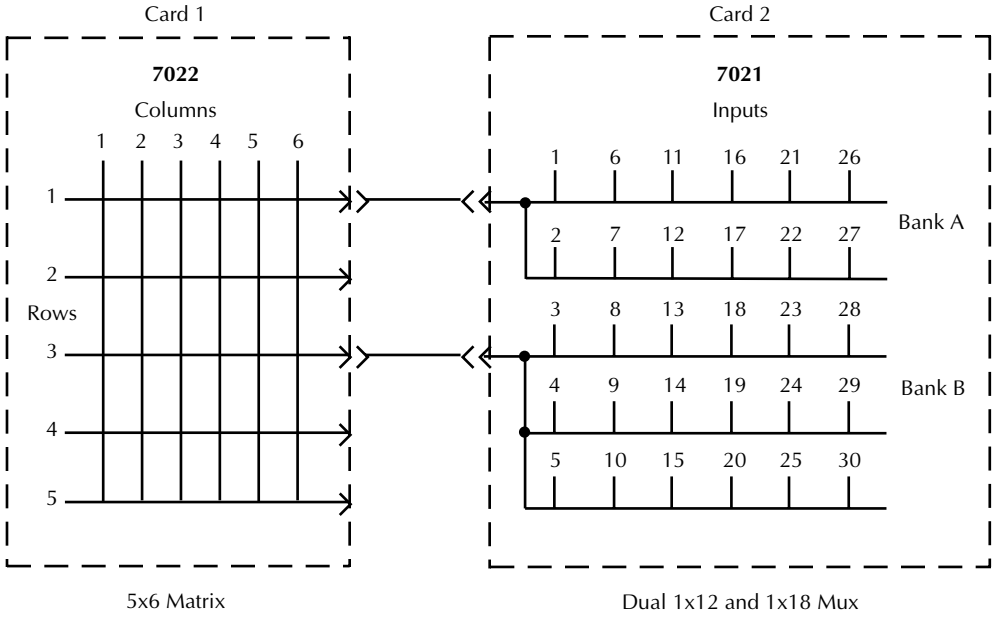


Figure 2-11
Multiplexer input expansion example



Notes: 1. Models 7021 and 7022 backplane jumpers must be removed from rows 2 and 4.

2. Model 7021 bank-to-bank jumpers must be removed.

Figure 2-12
Mixed card type example

Mainframe multiplexer expansion

Twelve- or 60-card multiplexer systems are possible by connecting six Model 7001 or six Model 7002 mainframes, respectively. Each Model 7021 added to the system provides 30 additional inputs. The limits on the number of cards in the Model 7001/7002 switch system are due to triggering. Section 4 explains how to connect a test system using two mainframes.

3

Digital I/O Configuration

Introduction

This section covers the basic digital input and output configurations for the Model 7021. Connection information for these configurations is provided in Section 4 of this manual, while operation (front panel and IEEE-488 bus) is explained in Section 5.

Digital outputs

Output channels are user configurable for negative (low) or positive (high) true logic. That is, the output can be high or low when the channel is turned on (closed) depending upon user configuration. Conversely, the output can be high or low when the channel is turned off (open). Refer to Section 4 to configure the logic to your requirement.

Controlling pull-up devices

Typically, the digital outputs are used to provide drive for relatively high current devices such as solenoids, relays, and small motors. The configurations for these applications are shown in Figure 3-1. Figure 3-1 allows you to use an external voltage source (V) for devices that require a higher voltage (42V maximum). An internal jumper is used to select the internal pull-up voltage. At the factory, the internal 5V source is selected.

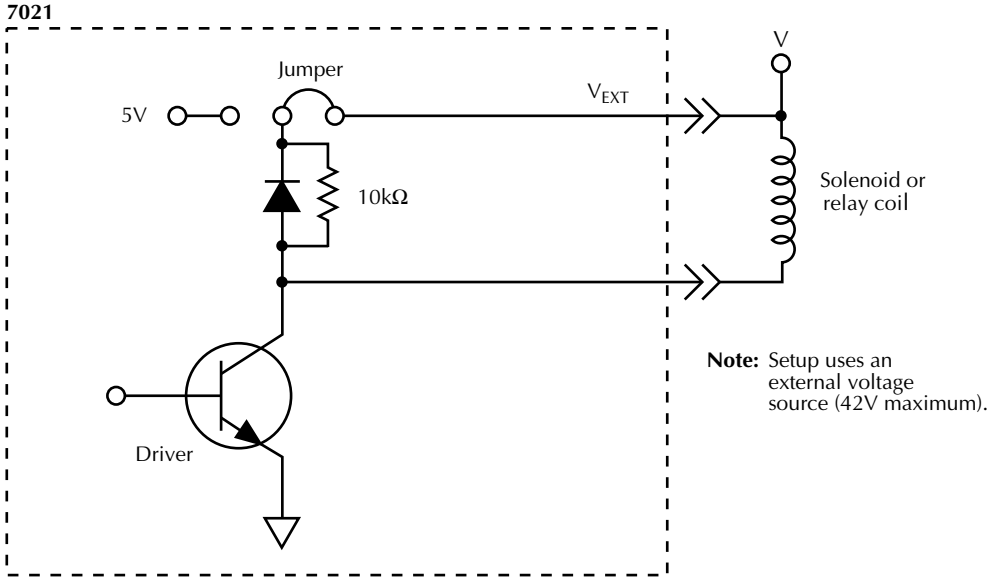


Figure 3-1
Output configuration for pull-up devices

Each output channel uses a fly-back diode for protection when switching an inductive device, such as a solenoid coil. This diode diverts the potentially damaging fly-back voltage away from the driver.

CAUTION

Failure to set J201 to the V_{ext} position when using external pull-up voltages may result in damage to the output drivers.

Controlling devices using pull-up resistors

When interfacing outputs to high-impedance devices (i.e. logic devices), internal pull-up resistors are used to achieve the appropriate logic level. Figure 3-2 shows the output configuration using the 10kΩ pull-up resistor (R_P).

The configuration in Figure 3-2 uses the internal 5V source as the high logic level. If you need a higher logic level, you can place the jumper in the alternate position and apply an external voltage (via V_{EXT}).

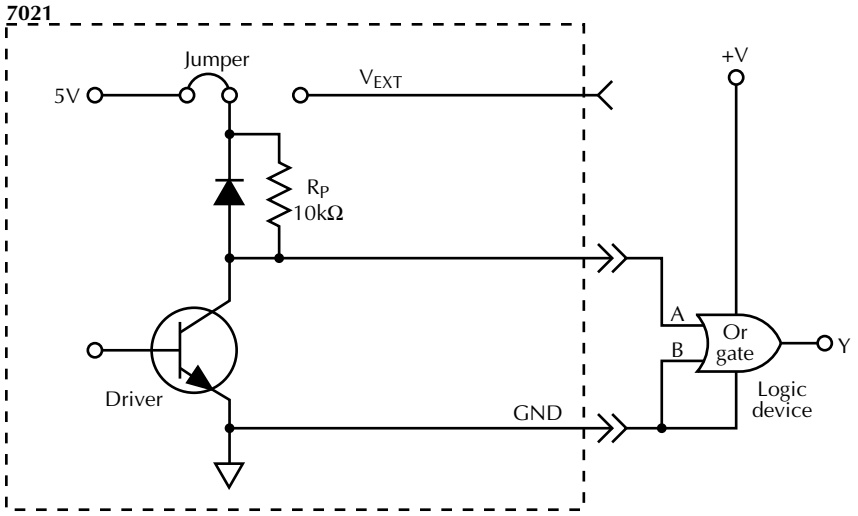


Figure 3-2
Output configuration using pull-up resistance

Digital inputs

Input channels use positive true logic but can be pulled up or pulled down based on the configuration of the pull-up resistor. Each channel uses a 10kΩ pull-up resistor (R_1). The pull-up resistors can be pulled up to 5V or pulled down to ground depending on the positioning of the jumper on the input logic bank. Refer to Section 4 for more information. Figure 3-3 shows the resistor being pulled up to 5V.

When the resistor is connected to 5V, the channel is pulled high. Thus, with nothing connected to the channel, the input is pulled high to 5V which displays the channel as on.

When the resistor is connected to ground, the channel is pulled low. Thus, with nothing connected to the channel, the input is pulled low to ground which displays the channel as off.

The digital input is compatible with external TTL logic. Each built-in pull-up resistor provides level shifting so devices such as micro-switches can be monitored. Each input has a protection network that clamps the input at 5.7V. This allows logic levels up to 42V peak to be monitored.

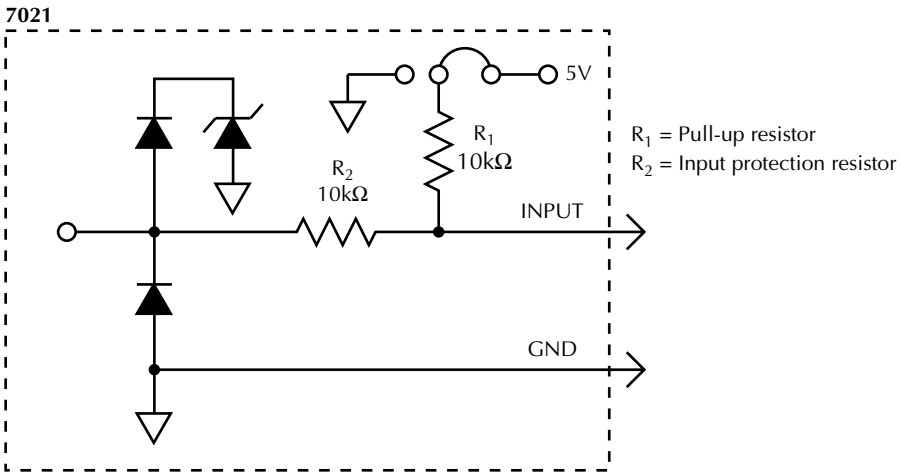


Figure 3-3
Input configuration

4

Card Connections and Installation

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:

- **Handling precautions —** Explains precautions that must be followed to prevent contamination to the card. Contamination could degrade the performance of the card.
- **Multiplexer connections —** Covers the basics for connecting external circuitry to the connector card.
- **Digital I/O connections —** Explains the voltage source jumpers, pull-up resistors, output logic, and input resistance and how to configure them.
- **Multi-pin (mass termination) connector card —** Covers the basic connections to the 96-pin DIN male connector and identifies each terminal.
- **Typical multiplexer connection schemes —** Provides some typical connection schemes for single card, two-card and two-mainframe system configurations.
- **Typical digital I/O connection schemes —** Provides some typical connection schemes for output solenoid, relay, motor, and logic device control and for input micro-switch monitoring.
- **Model 7021 installation and removal —** Provides the procedures to install and remove the Model 7021 card from the Model 7001/7002 mainframe.

Handling precautions

To maintain high impedance isolation, care should be taken when handling the relay and connector cards 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 buildup over a period of time is another possible source of contamination. To avoid this problem, operate the mainframe and card in a clean environment.

If a card becomes contaminated, it should be thoroughly cleaned as explained in Section 6.

Multiplexer connections

The following paragraphs provide the basic information needed to connect your external test circuitry to the multiplexer. The removal and installation of the backplane row jumpers on the relay card and the bank-to-bank jumpers on the connector card are included.

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.

Backplane row jumpers

The Model 7001/7002 mainframe has an analog backplane that allows the multiplex banks of a Model 7021 to be internally connected to a compatible switching card installed in the adjacent slot (See Section 2 for details).

The backplane row jumpers for the card are located on the relay card as shown in Figure 4-1. The card is shipped from the factory with the jumpers installed.

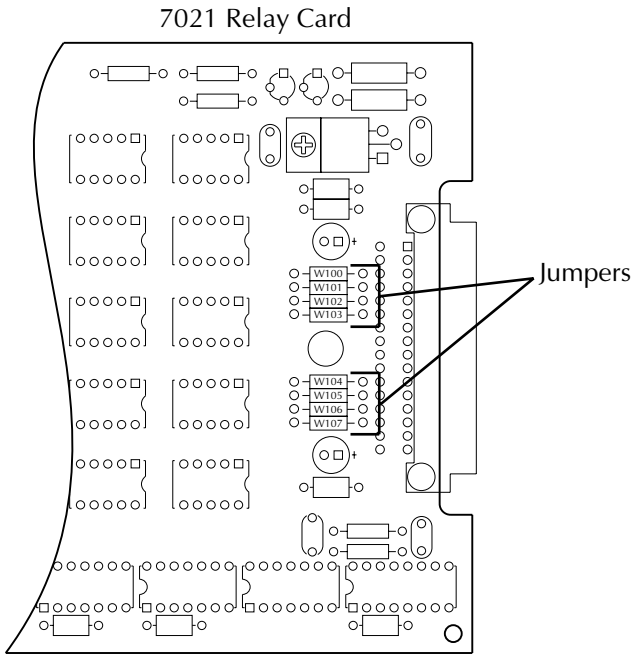


Figure 4-1
Backplane row jumpers

Backplane row jumper removal

Perform the following steps to remove the 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 4-1 to locate the jumper(s) 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.

Backplane row jumper installation

Referring to Figure 4-1 for jumper locations, perform the following steps to install the 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 Section 6.

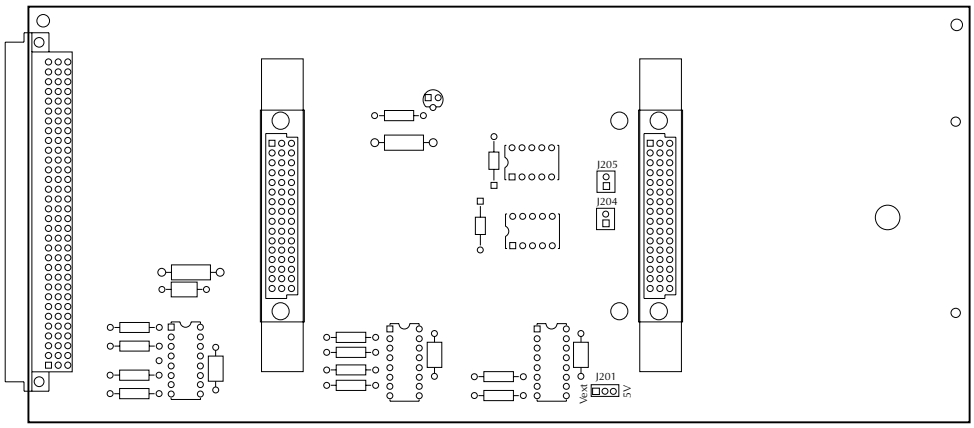


Figure 4-2
Bank-to-bank jumper locations

Bank-to-bank jumpers

As explained in Section 2, the multiplex banks can be connected together (using plug-in jumpers) to form large multiplexers. The locations of the bank-to-bank jumper terminals for the connector card are shown in Figure 4-2.

On the illustration, the two terminal pairs are labeled J204 and J205. J204 is used to connect the HI terminals of the banks. J205 is used to connect the LO terminals of the banks. Referring to Figure 4-2 for jumper locations, perform the following steps to install or remove 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. Remember to only handle the cards by the edges and shields to avoid contamination.
2. Refer to Figure 4-2 to determine which jumpers to install or remove.
3. Using Figure 4-3 as a guide, install the jumpers on, or remove the jumpers from, the appropriate terminal pairs.

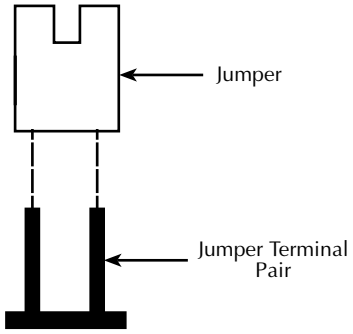


Figure 4-3
Bank-to-bank jumper installation

Digital I/O connections

Voltage source jumper

Digital output uses the internal +5V source as the high logic level. If higher voltages are required, a user-supplied voltage can be used (42V maximum). At the factory, the internal jumper is set to use the internal +5V source.

CAUTION

Failure to set J201 to the V_{ext} position when using external pull-up voltages may result in damage to the output drivers.

A plug-in jumper for the bank allows you to select the internal +5V source or an external source. In Figure 4-4, the banks are using the external voltage source.

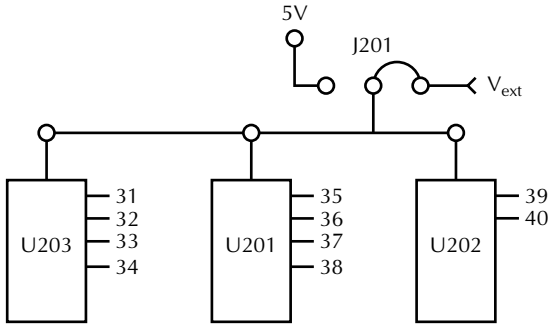


Figure 4-4
Voltage source jumper for output channels

The voltage source jumper is located on the connector board as shown in Figure 4-2. Figure 4-5 shows how the plug-in jumper is installed on J201.

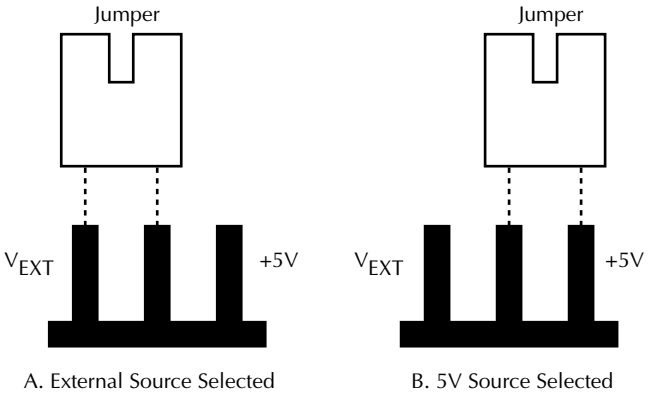


Figure 4-5
Voltage source jumper installation

Pull-up resistors

When interfacing outputs to high-impedance devices (i.e., logic devices), pull-up resistors are used to achieve the appropriate logic level. These resistors are installed at the factory.

Configuring digital I/O output logic

Referring to Figure 4-6 for the digital I/O output logic location, perform the following steps to configure J101:

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. Locate J101 on the relay board. Refer to Figure 4-6.
3. Determine if you require positive (high) or negative (low) logic.
4. Install the plug-in jumper in the appropriate position as shown in Figure 4-7.

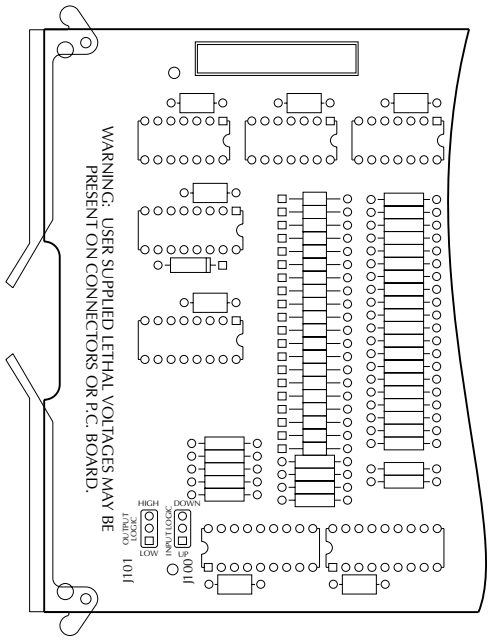


Figure 4-6
Digital I/O output logic location

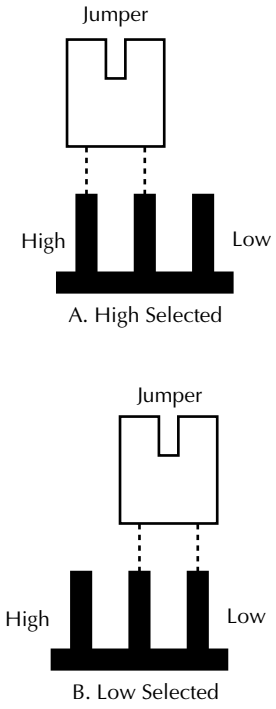


Figure 4-7
Digital I/O output logic selection

Configuring digital I/O input pull-up resistance

Referring to Figure 4-6 for digital I/O input pull-up resistance location, perform the following steps to configure J100:

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. Locate J100 on the relay board. Refer to Figure 4-6.
3. Determine if you require pull-up (5V) or pull-down (ground) input logic.
4. Install the plug-in jumper in the appropriate position as shown in Figure 4-8.

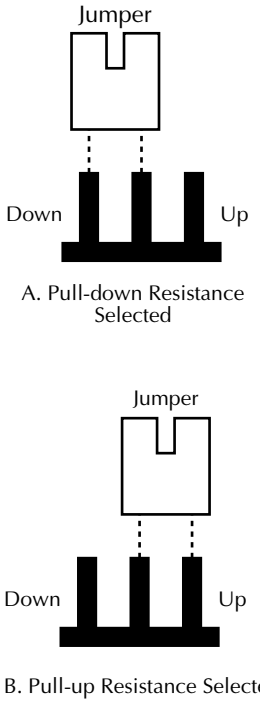


Figure 4-8
Digital I/O input pull-up resistance selection

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.

Keithley has a variety of cable and connector accessories available to accommodate connections from the connector card to test instrumentation and DUTs (devices under test). In general, these accessories, which are summarized in Table 4-1, utilize a round cable assembly for connections.

Table 4-1
Mass termination accessories

Model	Description
7011-KIT-R	96-pin female DIN connector and housing for round cable (provided with the Model 7021 card).
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.

Terminal identification for the DIN connector of the multi-pin connector card is provided by Figure 4-9 and Table 4-2. This connector will mate to a 96-pin female DIN connector.

Pins of the Model 7021 mass termination connector can be identified in one of three ways:

- Multiplex banks (A and B).
- Connector designation, consisting of rows a-c and columns 1-32.
- Schematic and component layout designation (1-96).

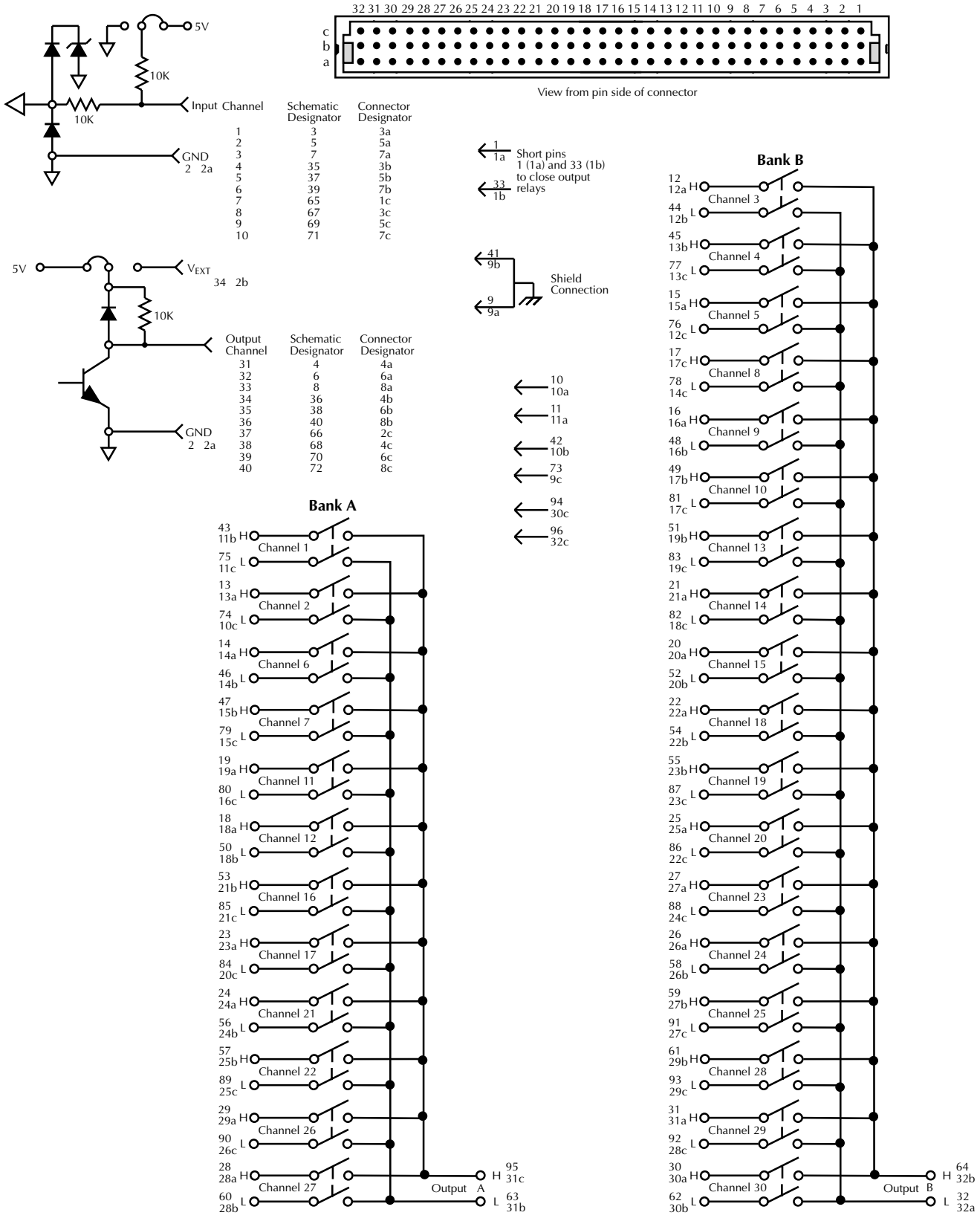


Figure 4-9
Multi-pin connector card terminal identification

Table 4-2
Pin designation identification

Mux terminal		**Conn. desig. 1a-32c**	**Schem. desig. 1-96**	**Mux terminal**		**Conn. desig. 1a-32c**	**Schem. desig. 1-96**	**Mux terminal**	**Conn. desig. 1a-32c**	**Schem. desig. 1-96**
Bank A	Chan 1, HI	11b	43	Bank A	Chan 16, HI	21b	53	OUT A, HI	31c	95
	Chan 1, LO	11c	75		Chan 16, LO	21c	85	OUT A, LO	31b	63
	Chan 2, HI	13a	13		Chan 17, HI	23a	23	OUT B, HI	32b	64
	Chan 2, LO	10c	74		Chan 17, LO	20c	84	OUT B, LO	32a	32
Bank B	Chan 3, HI	12a	12	Bank B	Chan 18, HI	22a	22	DIG OUT 31	4a	4
	Chan 3, LO	12b	44		Chan 18, LO	22b	54	DIG OUT 32	6a	6
	Chan 4, HI	13b	45		Chan 19, HI	23b	55	DIG OUT 33	8a	8
	Chan 4, LO	13c	77		Chan 19, LO	23c	87	DIG OUT 34	4b	36
	Chan 5, HI	15a	15		Chan 20, HI	25a	25	DIG OUT 35	6b	38
	Chan 5, LO	12c	76		Chan 20, LO	22c	86	DIG OUT 36	8b	40
Bank A	Chan 6, HI	14a	14	Bank A	Chan 21, HI	24a	24	DIG OUT 37	2c	66
	Chan 6, LO	14b	46		Chan 21, LO	24b	56	DIG OUT 38	4c	68
	Chan 7, HI	15b	47		Chan 22, HI	25b	57	DIG OUT 39	6c	70
	Chan 7, LO	15c	79		Chan 22, LO	25c	89	DIG OUT 40	8c	72
Bank B	Chan 8, HI	17a	17	Bank B	Chan 23, HI	27a	27	DIG IN 1	3a	3
	Chan 8, LO	14c	78		Chan 23, LO	24c	88	DIG IN 2	5a	5
	Chan 9, HI	16a	16		Chan 24, HI	26a	26	DIG IN 3	7a	7
	Chan 9, LO	16b	48		Chan 24, LO	26b	58	DIG IN 4	3b	35
	Chan 10, HI	17b	49		Chan 25, HI	27b	59	DIG IN 5	5b	37
	Chan 10, LO	17c	81		Chan 25, LO	27c	91	DIG IN 6	7b	39
Bank A	Chan 11, HI	19a	19	Bank A	Chan 26, HI	29a	29	DIG IN 7	1c	65
	Chan 11, LO	16c	80		Chan 26, LO	26c	90	DIG IN 8	3c	67
	Chan 12, HI	18a	18		Chan 27, HI	28a	28	DIG IN 9	5c	69
	Chan 12, LO	18b	50		Chan 27, LO	28b	60	DIG IN 10	7c	71
Bank B	Chan 13, HI	19b	51	Bank B	Chan 28, HI	29b	61	nc	10a	10
	Chan 13, LO	19c	83		Chan 28, LO	29c	93	nc	11a	11
	Chan 14, HI	21a	21		Chan 29, HI	31a	31	nc	10b	42
	Chan 14, LO	18c	82		Chan 29, LO	28c	92	nc	9c	73
	Chan 15, HI	20a	20		Chan 30, HI	30a	30	nc	30c	94
	Chan 15, LO	20b	52		Chan 30, LO	30b	62	nc	32c	96
Inter		1a	1	Shield		9a	9	Gnd	2a	2
Inter		1b	33	Shield		9b	41	Vext	2b	34

Typical connection techniques

All external circuitry, such as instrumentation and DUTs, that you wish to connect to the 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.

WARNING

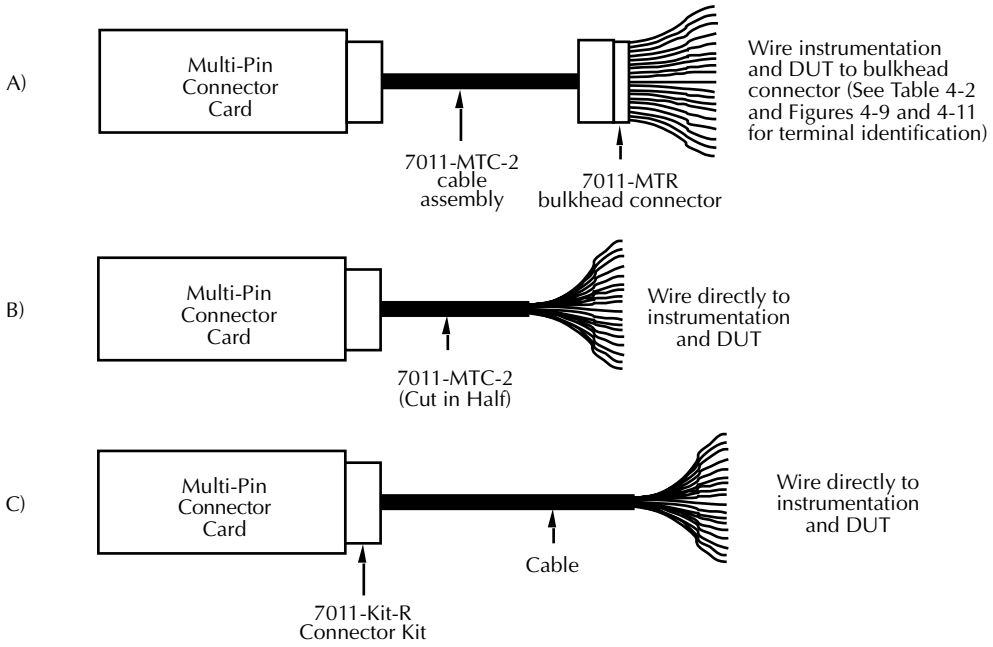
When wiring a connector or device under test, do not leave any exposed wires or connections. No conductive part of the circuit may be exposed. Properly cover the conductive parts, or death by electric shock may occur.

NOTE

It is recommended that external circuitry be connected (plugged in) after the Model 7021 is installed in the Model 7001/7002 mainframe and with the mainframe power off. Installation is covered at the end of this section.

Output relays — The multi-pin connector card uses a relay for each of the 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 the card. If building your own cable assembly, you must make sure that it shorts pins 1a to 1b of the card connector (Figure 4-11) when it is mated to the card. Shorting pins 1a to 1b allows the output relays to close.

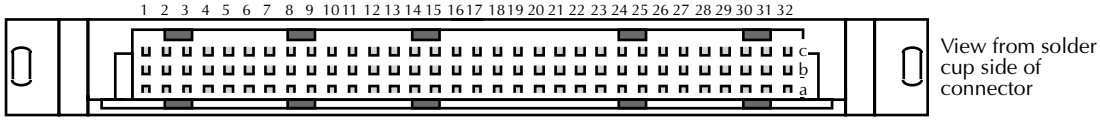
Round cable assemblies — Figure 4-10 shows typical round cable connection techniques using accessories available from Keithley.



Notes: Figure 4-12 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 4-10
Typical round cable connection techniques



Note: See Figure 4-9 for terminal identification.

Figure 4-11
Model 7011-MTR connector pinout

In Figure 4-10A, 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 4-11 provides pinout for the bulkhead connector. The view shown is from the solder cup end of the connector.

In Figure 4-10B, 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 4-10C, 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 4-12 provides an exploded view of the connector assembly and shows how the cable is connected. For further Model 7011-KIT-R assembly information, refer to the packing list provided with the kit. 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.

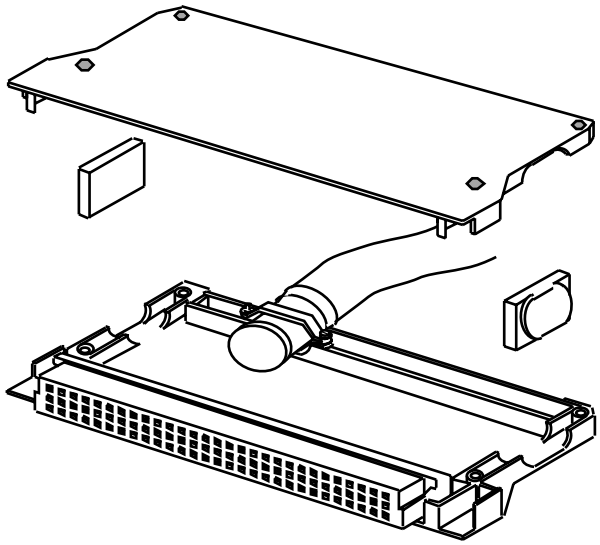


Figure 4-12
Model 7011-KIT-R (with cable) assembly

Typical multiplexer 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 the Multiplexer connections paragraph. Keep in mind that these are only examples to demonstrate various ways to wire a test system. Connection details for the connector card are provided in the Multi-pin (mass termination) connector card paragraph.

Single-card system

Figure 4-13 shows how external connections can be made to a single-card system that uses the multi-pin connector card. This single-card system is configured as dual 1 × 12 and 1 × 18 multiplex banks.

Instrumentation and DUTs 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 multiplexer using the Model 7011-MTC-2 round cable assembly. This cable mates directly to both the external bulkhead connector and the Model 7021. Notice that the bulkhead connector is shown mounted to a fixture to help keep the cabling stable during the test.

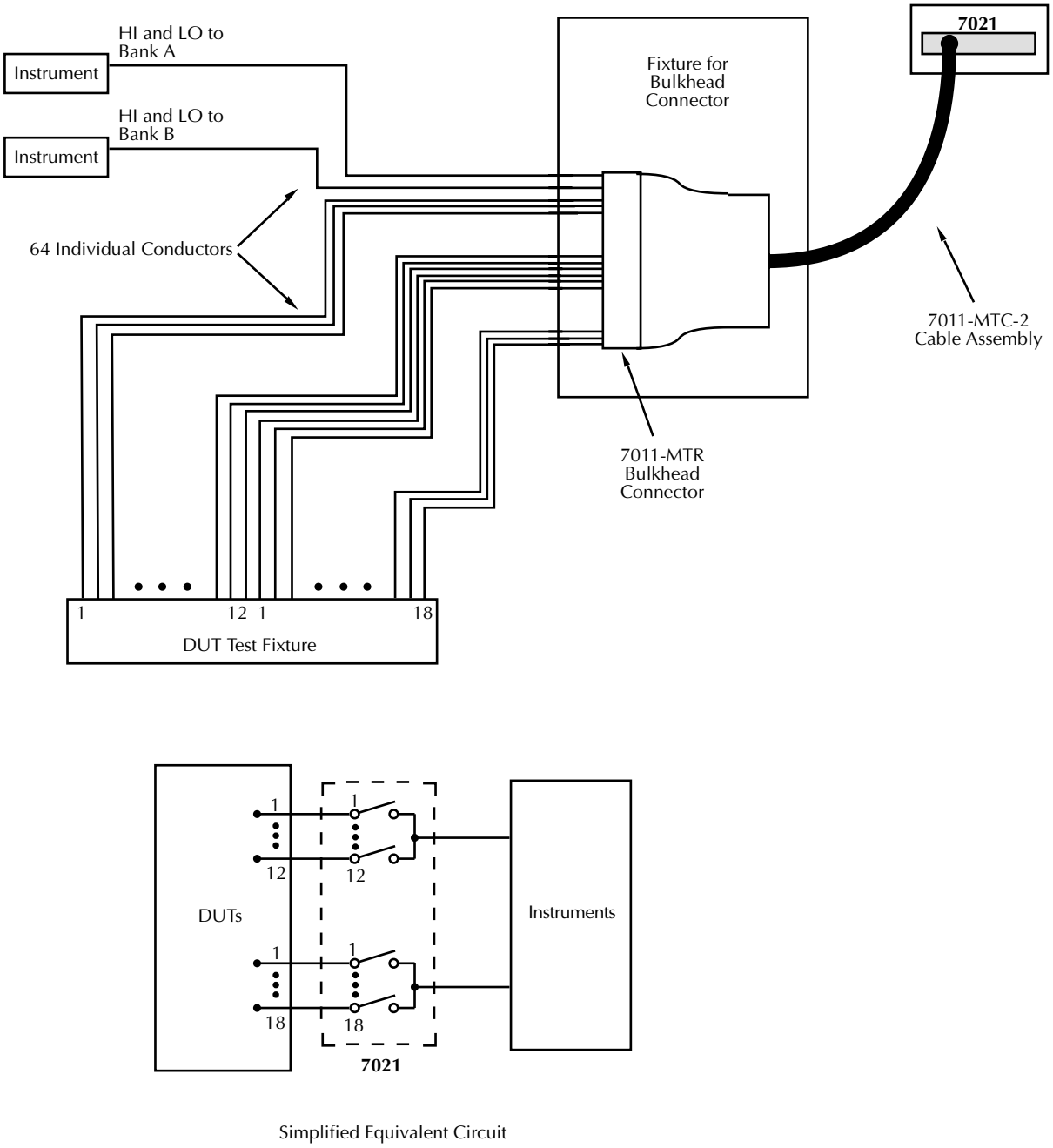


Figure 4-13
Single-card system example

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 7001/7002 mainframe:

1. Vacate the adjacent slot in the mainframe. If there is a Model 70XX card installed in the other slot, remove it.
2. Remove the backplane jumpers on the 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 adjacent slot.

Two-card system

Figure 4-14 shows a system using two Model 7021 cards installed in one Model 7001/7002 mainframe to configure a single 1 × 60 multiplexer system. Each card is configured as a single 1 × 30 multiplexer. To accomplish this, all bank-to-bank jumpers (both cards) are installed to connect banks A and B 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 mainframe resulting in the 1 × 60 configuration.

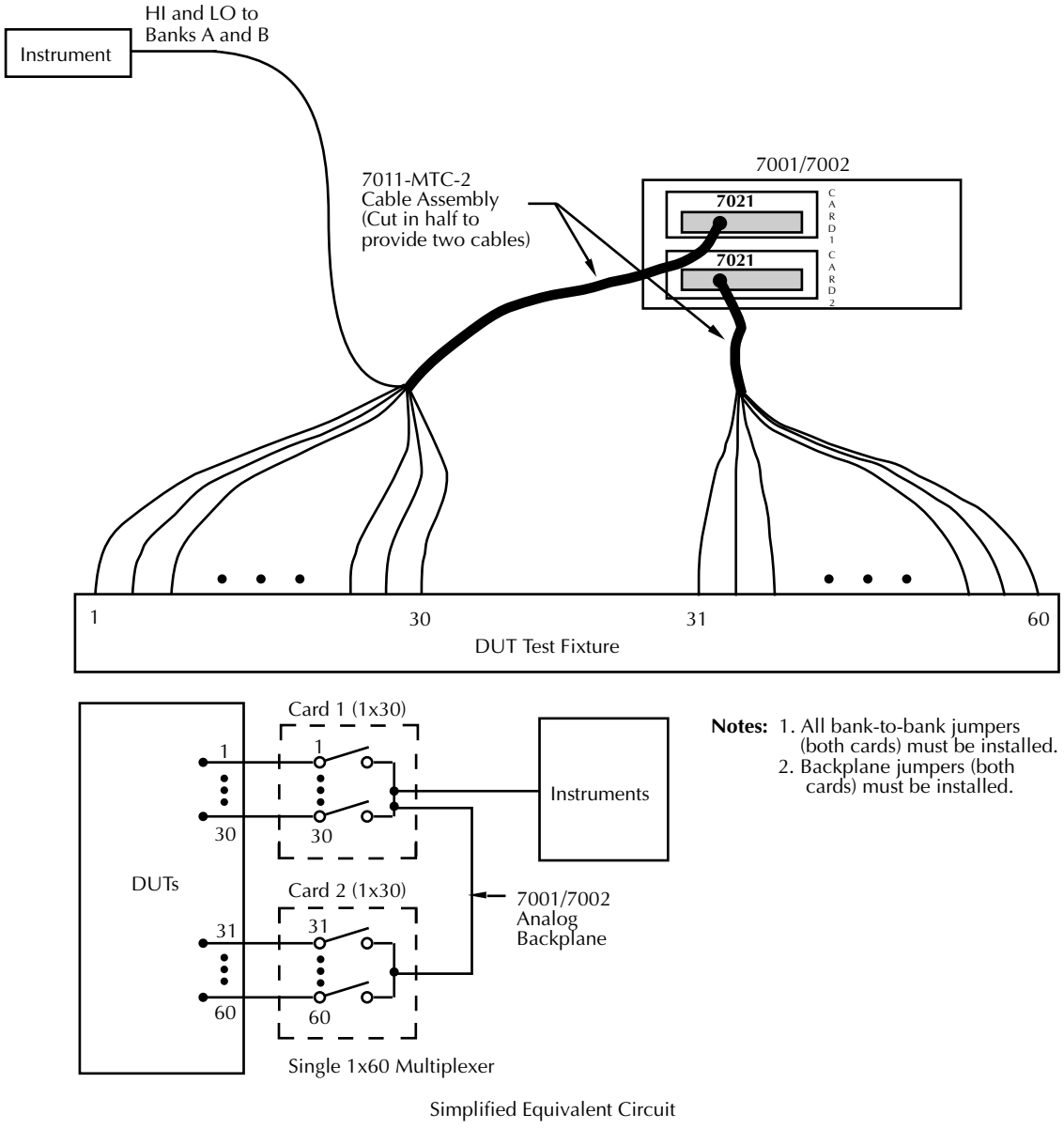


Figure 4-14
Two-card system example

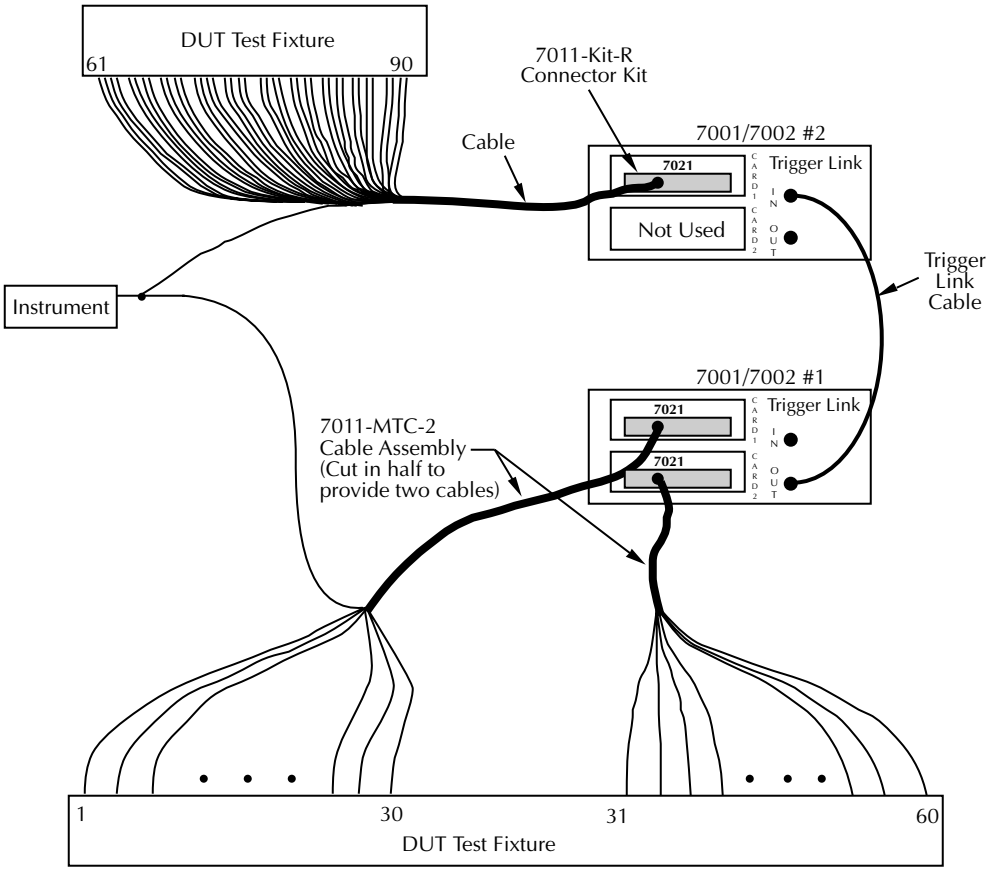
Figure 4-14 shows how external connections can be made for the multi-pin connector cards. In this example, a single Model 7011-MTC-2 round cable assembly is cut in half to provide two cables, each of which is unterminated at one end. The unterminated ends of the two cables are hard-wired to instrumentation and DUT as shown in the drawing. The other ends of these cables mate directly to the Model 7021 cards.

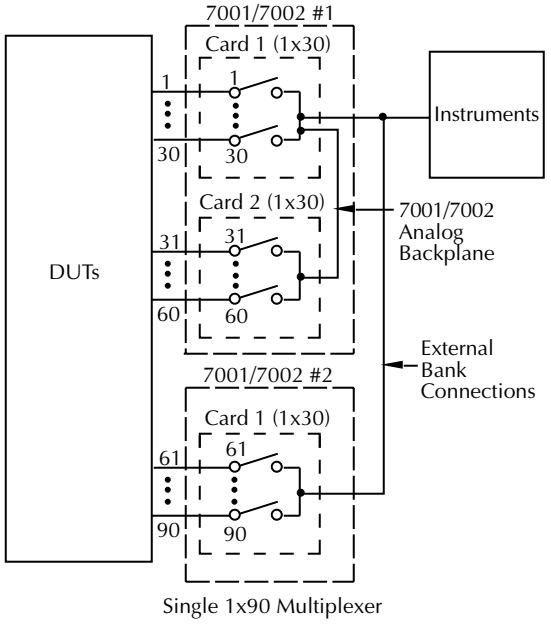
Two-mainframe system

Figure 4-15 shows a system using three multiplexer cards installed in two Model 7001/7002 mainframes to configure a single 1×90 multiplexer system. Each card is configured as a single 1×30 multiplexer. To accomplish this, bank-to-bank jumpers of all three cards must be installed to connect banks A and B 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 7001/7002 mainframe resulting in a 1×60 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 1×90 multiplexer system. This system is similar to the two-card system (see previous paragraph) except that a third card (installed in a second mainframe) is added.

Figure 4-15 shows the connection scheme for the multi-pin connector cards. External circuit connections to the Model 7001/7002 mainframe 1 are identical to the ones used for the two-card system. The third card (installed in Model 7001/7002 mainframe 2) 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) with two lengths of Hitachi cable P/N N2807-P/D-50TAB. This cable contains 50 conductors; two lengths provide 100 conductors. This cable will mate to the Model 7021. The unterminated end of the cable is connected directly to the instrumentation and DUT. Notice that the bank connections for the third card are made at the instruments.





Single 1x90 Multiplexer

Notes: 1. Backplane jumpers for both cards installed in 7001/7002 #1 must be installed.
2. All bank-to-bank jumpers, on all three cards, must be installed.

Simplified Equivalent Circuit

Figure 4-15
Two-mainframe system example

Typical digital I/O connection schemes

Output connection schemes

The following examples show output connections from the card to external circuitry and summarize the required internal connections on the card. Each example assumes negative true logic is used. To configure for positive true logic, refer to the Configuring digital I/O output logic paragraph.

Solenoid control — Figure 4-16 shows a digital output connection scheme to control solenoids. This example assumes that an external 24V source is being used. A solenoid is energized when the corresponding output channel is turned on (closed).

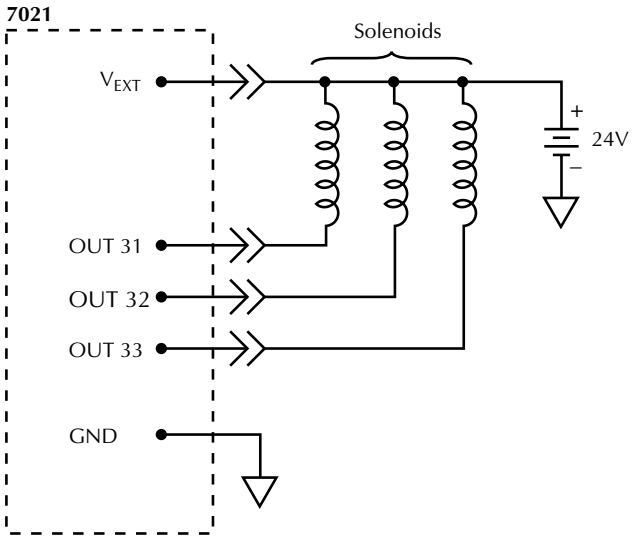


Figure 4-16
Digital output, solenoid control

Motor control — Figure 4-17 shows a digital output connection scheme to control small 12V dc motors. An external 12V source is used to provide the necessary voltage level. A motor is turned on when the corresponding output channel is turned on (closed).

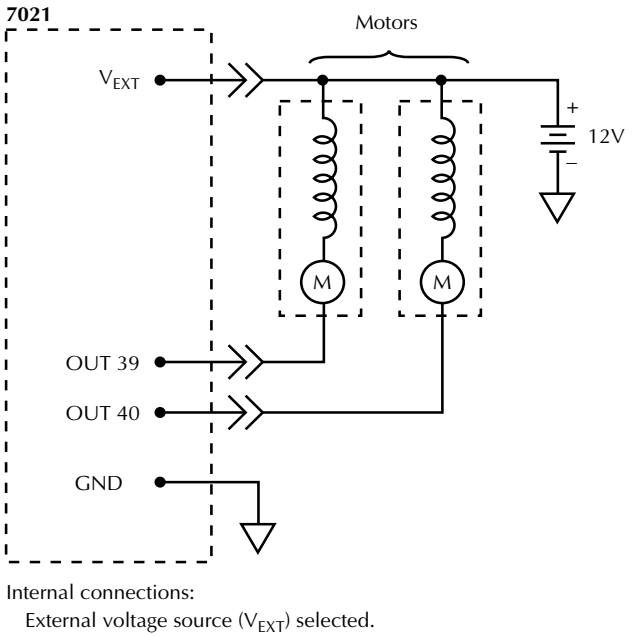


Figure 4-17
Digital output, motor control

Logic device control — Figure 4-18 shows a digital output connection scheme to control a logic device. This example assumes that an internal +5V voltage source is being used.

The logic device is a demultiplexer (DMUX). The binary pattern (value) seen at the input of the DMUX (lines A, B, and C) determines which DMUX output line (Y0 through Y7) is selected (pulled low). For example, with channels 31, 32, and 33 off (open), lines A, B and C are high. The binary 7 at the DMUX input (A = 1, B = 1 and C = 1) selects (pulls low) output Y7. If channel 32 is turned on (closed), line B goes low. The binary 5 seen at the DMUX input (1, 0, 1) selects (pulls low) Y5.

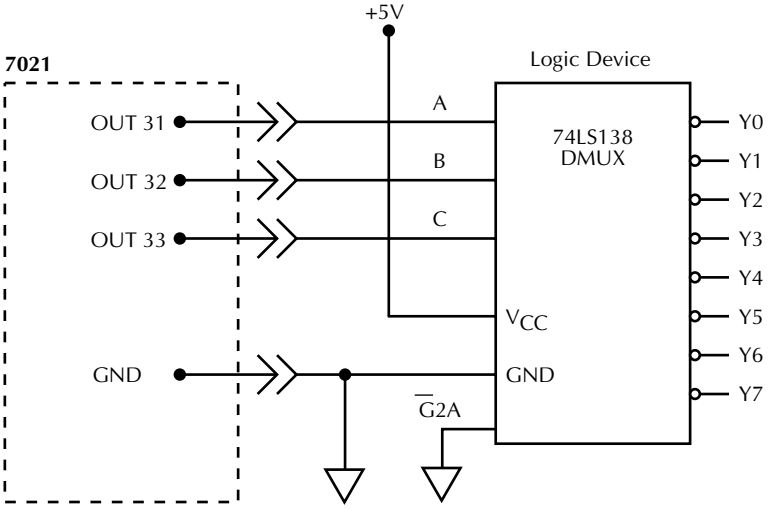


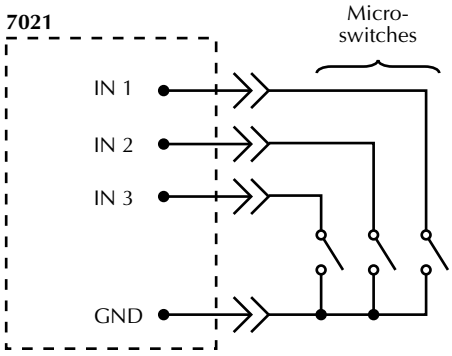
Figure 4-18
Digital output, logic device control

Input connection scheme

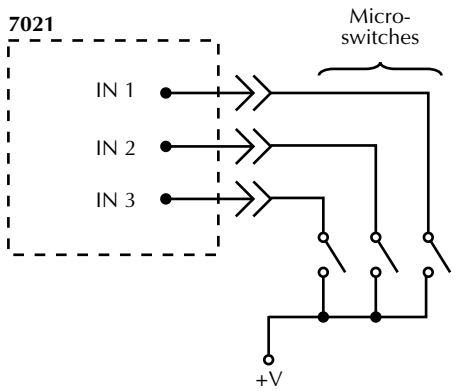
Figure 4-19 shows a digital input connection scheme to monitor the state of micro-switches. With a switch open and the input resistor configured for pull up, as shown in Figure 4-19A, the corresponding input channel is pulled high by the internal input resistor. As a result, the input channel is high (appears as a bar on the Model 7001 display or a lit LED on the Model 7002). When a switch is closed, the corresponding input channel is pulled low to ground. As a result, the input channel is low (appears as a single dot on the Model 7001 display or an unlit LED on the Model 7002).

With a switch open and the input resistance configuration set to pull down, as shown in Figure 4-19B, the corresponding input channel is pulled low by the internal input resistor. As a result, the input channel is low. When a switch is closed, the corresponding input channel is pulled high. As a result, the input channel is high.

For more information on configuring pull-up resistance, refer to the Configuring digital I/O input pull-up resistance paragraph.



A. Input resistor is set to pull up.



B. Input resistor is set to pull down.

Figure 4-19
Digital input, monitoring micro-switches

Model 7021 installation and removal

This following paragraphs explain how to install and remove the Model 7021 card from the Model 7001/7002 mainframe.

WARNING

Installation or removal of the Model 7021 is to be performed by qualified service personnel. Failure to recognize and observe standard safety precautions could result in personal injury or death.

CAUTION

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

Card installation

Perform the following steps to install the Model 7021 card in the Model 7001/7002 mainframe:

WARNING

Turn off power from all instrumentation (including the Model 7001/7002 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 mainframe, select the slot (CARD 1 or CARD 2) that you wish to install the Model 7021 card in.
3. Referring to Figure 4-20, feed the Model 7021 card into the desired slot so the edges of the relay card ride in the rails.
4. With the ejector arms in the unlocked position, push the Model 7021 card 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.

WARNING

To avoid electric shock that could result in injury or death, make sure to properly install and tighten the safety ground screw shown in Figure 4-20.

5. Install the screw shown in Figure 4-20.

Card removal

To remove the Model 7021 card, first unloosen the safety ground screw, unlock the card by pulling the latches outward, and then pull the card out of the mainframe. Remem-

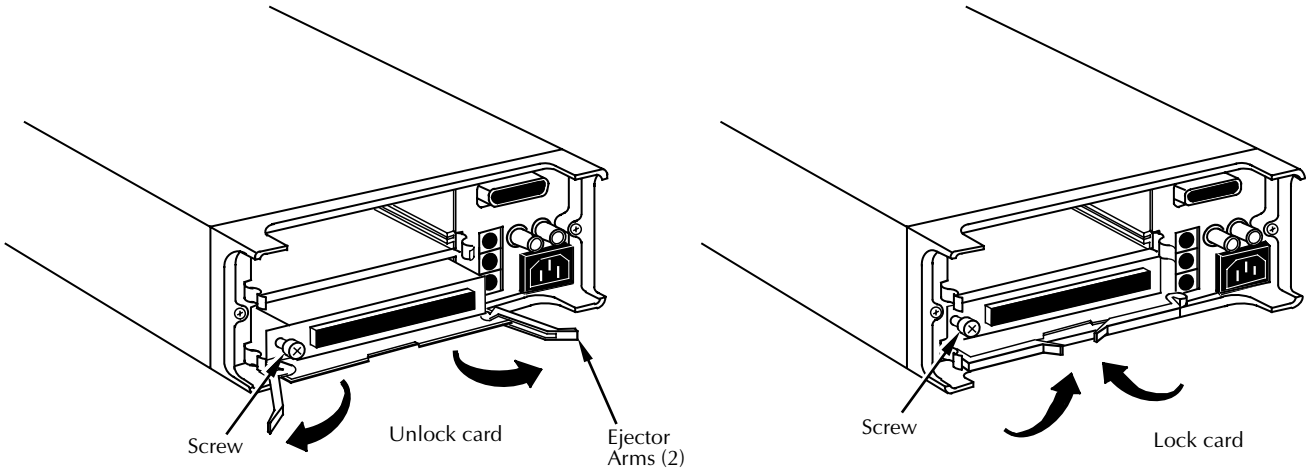


Figure 4-20
Model 7021 card installation in Model 7001

ber to handle the card by the edges and shields to avoid contamination that could degrade performance.

5
Operation

Introduction

The information in this section is formatted as follows:

- **Power limits** — Summarizes the maximum power limits of the Model 7021 multiplexer-digital I/O card.
- **Mainframe control of the card —** Summarizes programming steps to control the card from the Model 7001/7002 switch system mainframe.
- **Multiplexer switching examples —** Provides some typical applications for using the Model 7021.
- **Measurement considerations —** Reviews a number of considerations when using the Model 7021 to make measurements.

Power limits

CAUTION

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

Analog multiplexer maximum signal levels

To prevent overheating or damage to the relays, never exceed the following maximum signal levels: 110V DC or rms, 155V peak between any two inputs or chassis, 1A switched, 30VA (resistive load).

Digital I/O maximum signal levels

To ensure proper operation and prevent damage to the card, never exceed the following power limits:

Output channels

Maximum user-supplied pull-up voltage: 42V
Maximum sink current:
Per channel: 250mA
Per card: 1A

Input channels

Maximum voltage level: 42V peak

Mainframe control of the card

The following information pertains to the Model 7021. It assumes that you are familiar with the operation of the Model 7001/7002 mainframe—whichever is used.

If you are not familiar with the operation of the mainframe in use, proceed to Getting Started (Section 3) of the Model 7001 or Model 7002 Instruction Manual after reading the following information.

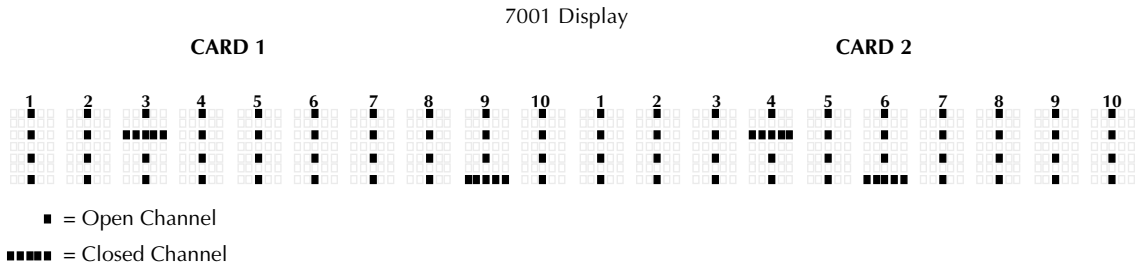


Figure 5-1
Model 7001 channel status display

Channel assignments

The Model 7001 has a channel status display (Figure 5-1) 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). For the Model 7002, channel status LED grids are used for the ten slots. The LED grid for slot 1 is shown in Figure 5-2.

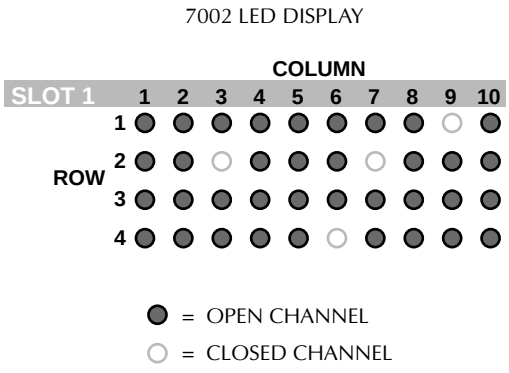


Figure 5-2
Model 7002 channel status display (slot 1)

Organization of the channel status display for each slot is shown in Figure 5-3. The card contains 40 channels and is made up of two multiplex banks (Bank A and B) totaling 30 channels and ten digital output channels as shown in the illustration.

The multiplex banks can be jumpered to the backplane of the mainframe to expand multiplexer inputs.

All digital input and output channels are isolated from the backplane of the mainframe. With the mainframe in the normal display state, the status (on or off) of the output channels is displayed. When the mainframe is in the read input channels mode, the status (on or off) of the input channels is displayed.

The hardware for the digital output channels is user configurable for negative or positive true logic. That is, depending on the user configuration, the output can go high or be pulled low when the channel is turned on (closed) or off (open). To configure output logic, refer to Section 4.

Input channels use positive true logic but can be configured to pull up or pull down. Thus, a channel can be pulled high or pulled low when the input is open depending on the jumper configuration. Input channels will be displayed as high (on) when the input has a high logic level applied. Conversely, an input channel will be displayed as low (off) when a low logic level is applied.

To control the card from the mainframe, each multiplexer input and digital output must have a unique channel assignment. The channel assignments for the card are provided in Figure 5-4. Each channel assignment is made up of the slot designator (1 or 2) and the channel (1 to 40). For the Model 7002, the slot designator can be from 1 to 10 since there are 10 slots. To be consistent with Model 7001/7002 operation, the slot designator and channel are separated by an exclamation point (!). Some examples of channel assignments are as follows:

CHANNEL 1!1 = Slot 1, Channel 1 (Input 1 of Bank A)
CHANNEL 1!40 = Slot 1, Channel 40 (Output 40 of Digital I/O)
CHANNEL 2!23 = Slot 2, Channel 23 (Input 13 of Bank B)
CHANNEL 2!36 = Slot 2, Channel 36 (Output 36 of Digital I/O)

These channels are displayed and controlled from the normal display state of the mainframe. If currently in the menu structure, return to the normal display state by pressing EXIT.

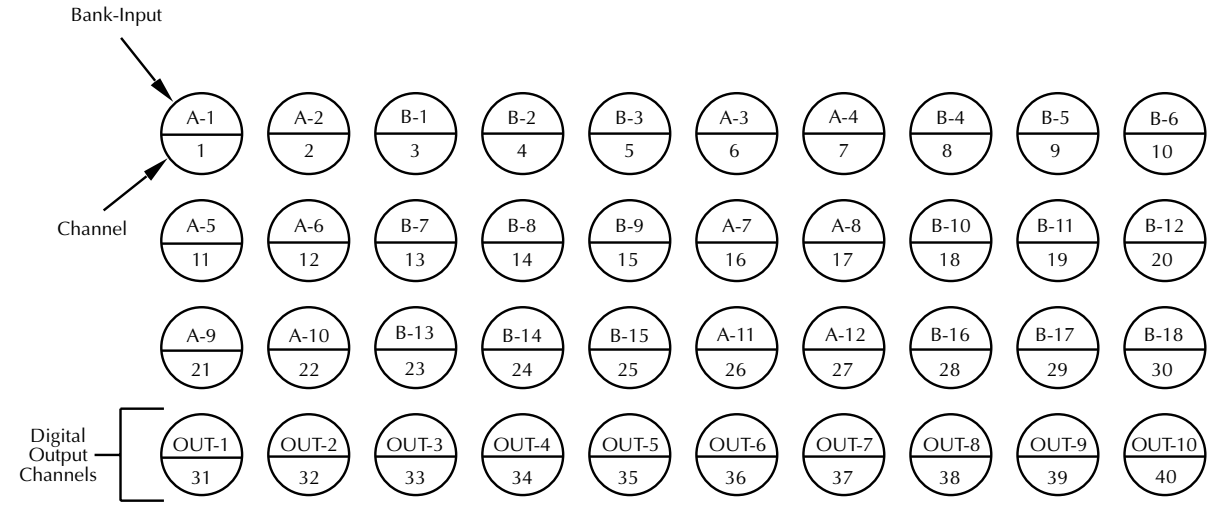


Figure 5-3
Display organization for multiplexer channels

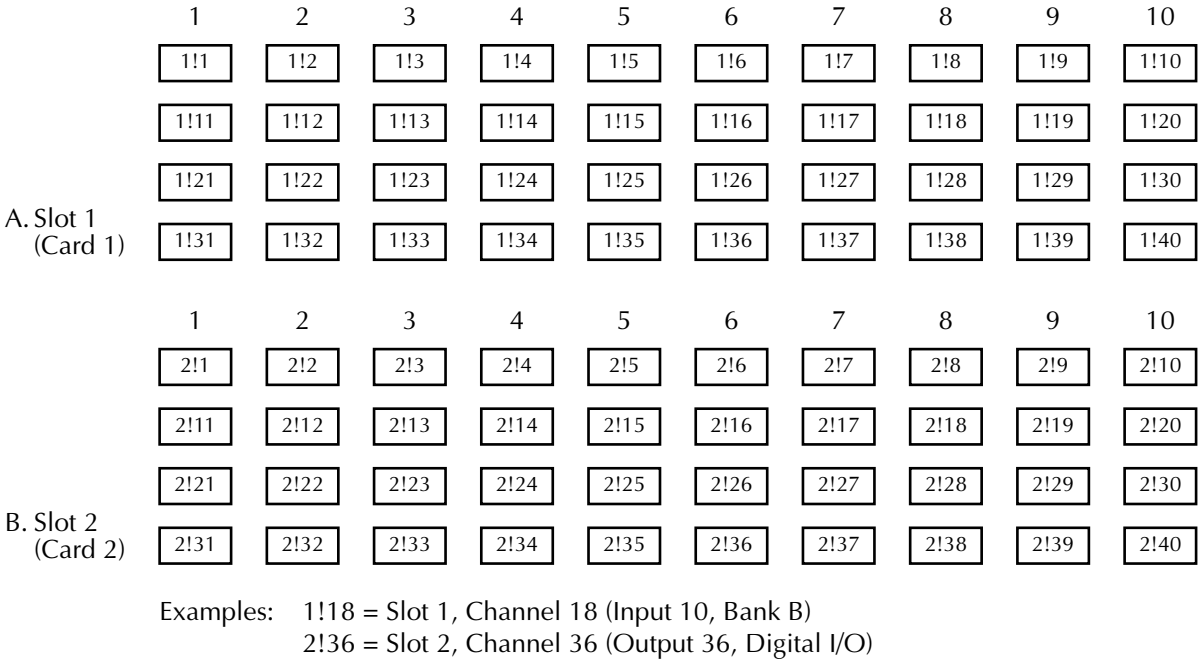


Figure 5-4
Model 7021 programming channel assignments

Closing and opening channels

NOTE

This procedure applies to multiplexer channels (channels 1!1 through 1!30) and digital output channels (1!31 through 1!40). Digital input channels are read only.

A channel is turned on (closed) by keying in the channel assignment and pressing CLOSE. For example, to turn on (close) channel 36 (Output 36 of Digital I/O) of a card installed in slot 2, key in the following channel list and press CLOSE:

SELECT CHANNELS 2!36

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

NOTE

For the Model 7002 mainframe, you can use the light pen to turn output channels on and off.

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.

Channel patterns can also be used in a channel list. This allows you to control specific bit patterns for logic circuits. Example:

SELECT CHANNELS 2!1, M1

Pressing CLOSE will turn on channel 2!1 and the channels that make up channel pattern M1. Refer to the mainframe instruction manual for information on defining channel patterns.

Scanning channels

Channels are scanned by creating a scan list and configuring the Model 7001/7002 to perform a scan. The scan list is created in the same manner as a channel list (See the Closing and opening channels paragraph). However, the scan list is specified from the SCAN CHANNELS 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.

Channel patterns can also be used in a scan list. This allows you to control specific bit channels or bit patterns. For example:

SCAN CHANNELS M1, M2, M3, M4

When M1 is scanned, the channels that make up channel pattern M1 will turn on. When M2 is scanned, the M1 channels will turn off and the channels that make up M2 will turn on. M3 and M4 are scanned in a similar manner. Refer to the instruction manual for the mainframe for information on defining channel patterns.

A manual scan can be performed by using the RESET default conditions of the Model 7001/7002. 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.

Reading input channels

Input channels are read from the READ-I/O-CARD option of the CARD CONFIG MENU of the mainframe. This menu is accessed by pressing the CARD key. In this “read input channels” display mode, the mainframe displays the real-time state of each input channel.

Input channels use positive true logic but can be configured to pull up or pull down. Open inputs will read high (on) if inputs are configured for pull up. Conversely, open inputs will read low (off) when configured for pull down. To configure pull-up resistance, refer to Section 4.

Perform the following steps to configure the mainframe to display the digital input channels.

1. Press the CARD CONFIGURATION key to display the CARD CONFIG MENU.
2. Use the ◀ and ▶ keys to place the cursor on READ-I/O-CARD and press ENTER.

   Model 7001 mainframe — The real-time state (on or off) of each input channel is provided on the first row of the display. Only digital I/O input channels are displayed.

   Model 7002 mainframe — The real-time state (on or off) of each input channel is provided on the first row of the appropriate LED display grid. Use the TYPE option of the CARD CONFIG MENU if you do not know which slot the card is installed in.
3. Use the EXIT key to exit from the "read input channels" display mode.

NOTE

With input channels displayed, you can turn off (open) all other channels by pressing OPEN ALL.

IEEE-488 bus operation

Bus operation is demonstrated using Microsoft QuickBASIC 4.5, the Keithley KPC-488.2 (or Capital Equipment Corporation) IEEE interface and the HP-style Universal Language Driver (CECHP). Refer to "QuickBASIC 4.5 Programming" in the mainframe manual for details on installing the Universal Language Driver, opening driver files and setting the input terminal. Program statements assume that the primary address of the mainframe is 07.

Turning channels on and off

The following SCPI commands are used to turn multiplexer and digital I/O output channels on and off:

`:CLOSe <list>`	Turn on specified channels
`:OPEN <list>|ALL`	Turn off specified (or all) channels.

The following program statement turns on channels 1!1, 1!4 through 1!6, and the channels that make up channel pattern M1.

```
PRINT #1, "output 07; clos (@ 1!1, 1!4:1!6, M1)"
```

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

Either of the following statements turns off channels 1!1, 1!4 through 1!6, and the channels of M1:

```
PRINT #1, "output 07; open (@ 1!1, 1!4:1!6, M1)"
PRINT #1, "output 07; open all"
```

Scanning output 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: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 7001/7002 out of the idle state.

The following program fragment will perform a single scan of channels 1 through 4 of slot 1 and the channels that make up channel pattern M1:

```
PRINT #1, "output 07; *rst"
PRINT #1, "output 07; trig:coun:auto on"
PRINT #1, "output 07; scan (@ 1!1:1!4, M1)"
PRINT #1, "output 07; init"
```

The first statement selects the *RST default configuration for the scan. The second statement sets channel count to the scan-list-length (5). The third statement defines the scan list, and the last statement takes the mainframe out of the idle state. The scan is configured to start as soon as the :INIT command is executed.

When the above program fragment is run, the scan will be completed in approximately 240 milliseconds (3msec delay for channel closures and 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 a statement to slow down the scan. Also, a statement is added to the beginning of the program to ensure that all channels are open before the scan is started. The two additional statements are indicated in bold typeface.

```
PRINT #1, "output 07; open all"
PRINT #1, "output 07; *rst"
PRINT #1, "output 07; trig:coun:auto on"
PRINT #1, "output 07; trig:del 0.5"
PRINT #1, "output 07; scan (@ 1!1:1!4, M1)"
PRINT #1, "output 07; init"
```

The first statement opens all channels, and the fourth statement sets a 1/2 second delay after each channel closes.

Reading digital I/O input channels

The following SCPI commands are used to read the status of digital I/O input channels:

`:SENSe2:DATA? <list>`	Read input channels; slot 1
`:SENSe3:DATA? <list>`	Read input channels; slot 2
`:SENSe4:DATA? <list>`	Read input channels; slot 3
`:SENSe5:DATA? <list>`	Read input channels; slot 4
`:SENSe6:DATA? <list>`	Read input channels; slot 5
`:SENSe7:DATA? <list>`	Read input channels; slot 6
`:SENSe8:DATA? <list>`	Read input channels; slot 7
`:SENSe9:DATA? <list>`	Read input channels; slot 8
`:SENSe10:DATA? <list>`	Read input channels; slot 9
`:SENSe11:DATA? <list>`	Read input channels; slot 10

The conventional form for the <list> parameter includes the slot and input channel number. However, for these commands you do not need to include the slot number. For example, you can send either of the following two commands to read input channel 2 in slot 6:

`:SENSe7:DATA? (@6!2)` or `:SENSe7:DATA? (@2)`

After the mainframe is addressed to talk, the response message will indicate the state of each listed input channel. A returned “0” indicates that the channel is off (open), and a returned “1” indicates that the channel is on (closed).

The following program fragment reads channel 3 of a digital I/O card installed in slot 1:

```
PRINT #1, "output 07; sens2:data? (@3)"
PRINT #1, "enter 07"
LINE INPUT #2, A$
PRINT A$
```

The first statement reads input channel 3 (slot 1). The second statement addresses the mainframe to talk (sends response message to computer). The third statement reads the response message, and the last statement displays the message (0 or 1) on the computer CRT.

The above program fragment is modified to read all 10 digital I/O input channels in slot 1 as follows. The modified statement is shown in bold typeface.

```
PRINT #1, "output 07; sens2:data? (@1:10)"
PRINT #1, "enter 07"
LINE INPUT #2, A$
PRINT A$
```

The response message will include a “0” (off) or “1” (on) for each of the 10 input channels (i.e., “0, 0, 0, 1, 0..... 0, 1”).

Multiplexer switching examples

This paragraph presents some typical applications for the Model 7021. These include resistor testing and transistor testing. It also shows how to use the Model 7021 with a matrix-digital I/O card (Model 7022).

Resistor testing

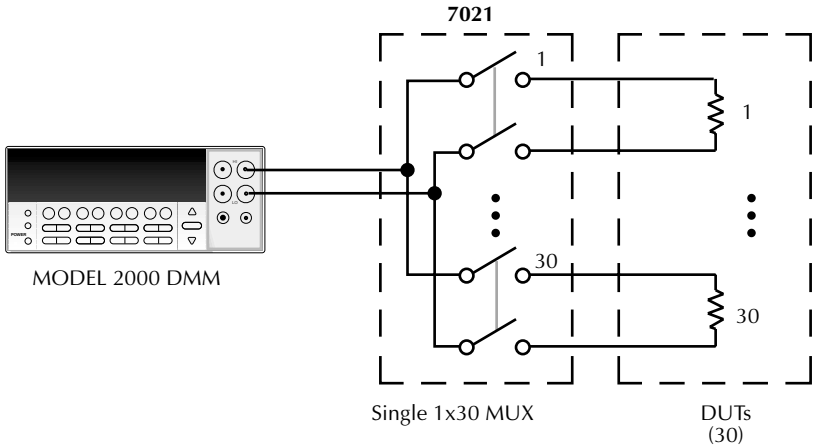
The Model 7021 can be used to test a large number of resistors using only one test instrument or group of instruments. Such tests include two-wire and four-wire resistance measurements using a DMM and low-resistance measurements using a current source and sensitive digital voltmeter, as discussed in the following paragraphs.

Two-wire resistance tests

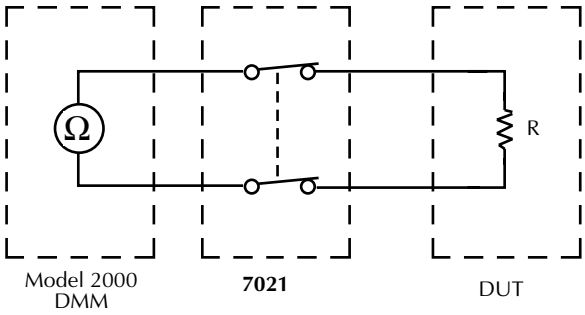
Figure 5-5 shows a typical test setup for making two-wire resistance measurements. The Model 7021 provides the switching function, while the resistance measurements are made by a Model 2000 DMM. Since only two-pole switching is required for this application, one Model 7021 card can be used to switch up to 30 resistors (additional multiplex 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

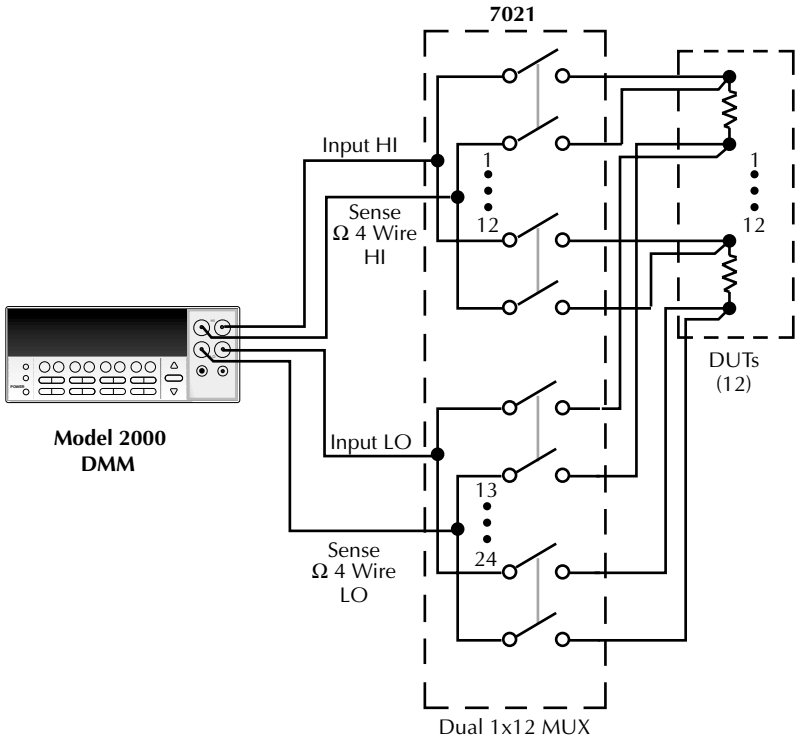


B. Simplified Equivalent Circuit

Figure 5-5
Two-wire resistance testing

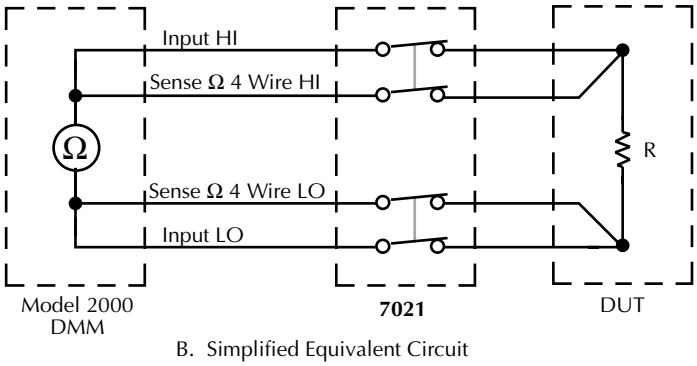
Four-wire resistance tests

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 5-6. Here, separate sense leads from the Model 2000 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 12 resistors per card can be tested using this configuration because two channels must close at the same time.



A. Test Configuration

Note: Jumpers between Banks A and B are removed.



B. Simplified Equivalent Circuit

Figure 5-6
Four-wire resistance testing

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 2000 DMM should be used.

Table 5-1
Paired channels in four-wire resistance example

Device under test	Channel pair	Connection designations
1	1 and 3	Bank A, In 1 and Bank B, In 3
2	2 and 4	Bank A, In 2 and Bank B, In 4
3	6 and 5	Bank A, In 6 and Bank B, In 5
4	7 and 8	Bank A, In 7 and Bank B, In 8
5	11 and 9	Bank A, In 11 and Bank B, In 9
6	12 and 10	Bank A, In 12 and Bank B, In 10
7	16 and 13	Bank A, In 16 and Bank B, In 13
8	17 and 14	Bank A, In 17 and Bank B, In 14
9	21 and 15	Bank A, In 21 and Bank B, In 15
10	22 and 18	Bank A, In 22 and Bank B, In 18
11	26 and 19	Bank A, In 26 and Bank B, In 19
12	27 and 20	Bank A, In 27and Bank B, In 20

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 5-7 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 7021 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, flowing in the opposite direction. The resistance can then be calculated as follows:

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

Note that 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. See Section 4.

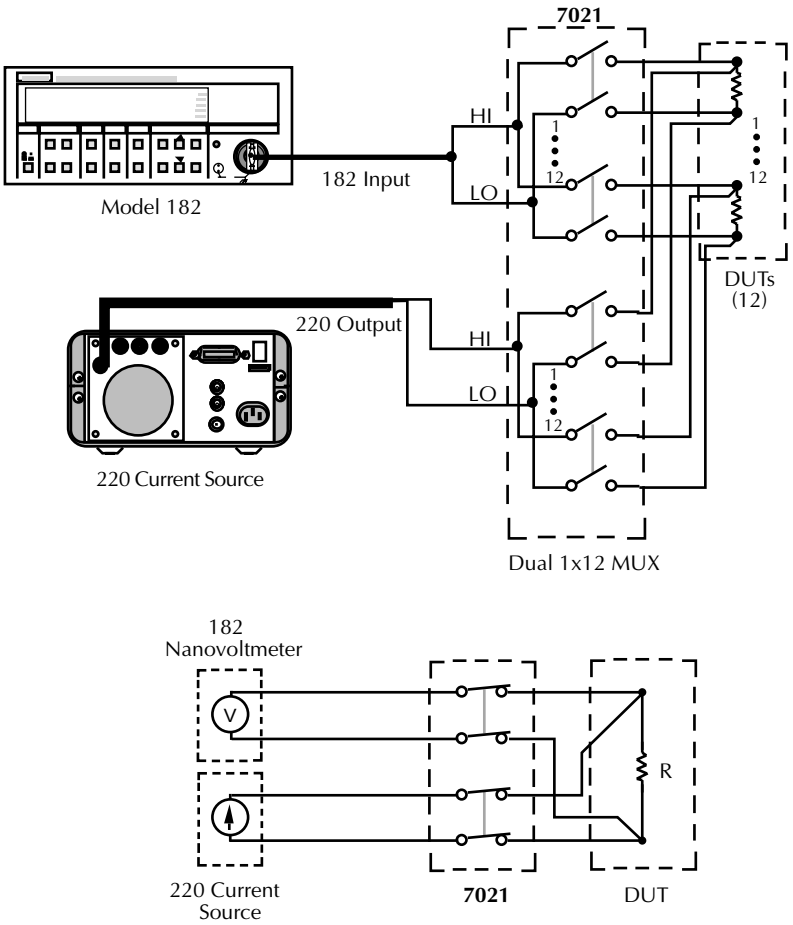


Figure 5-7
Low resistance testing

Transistor testing

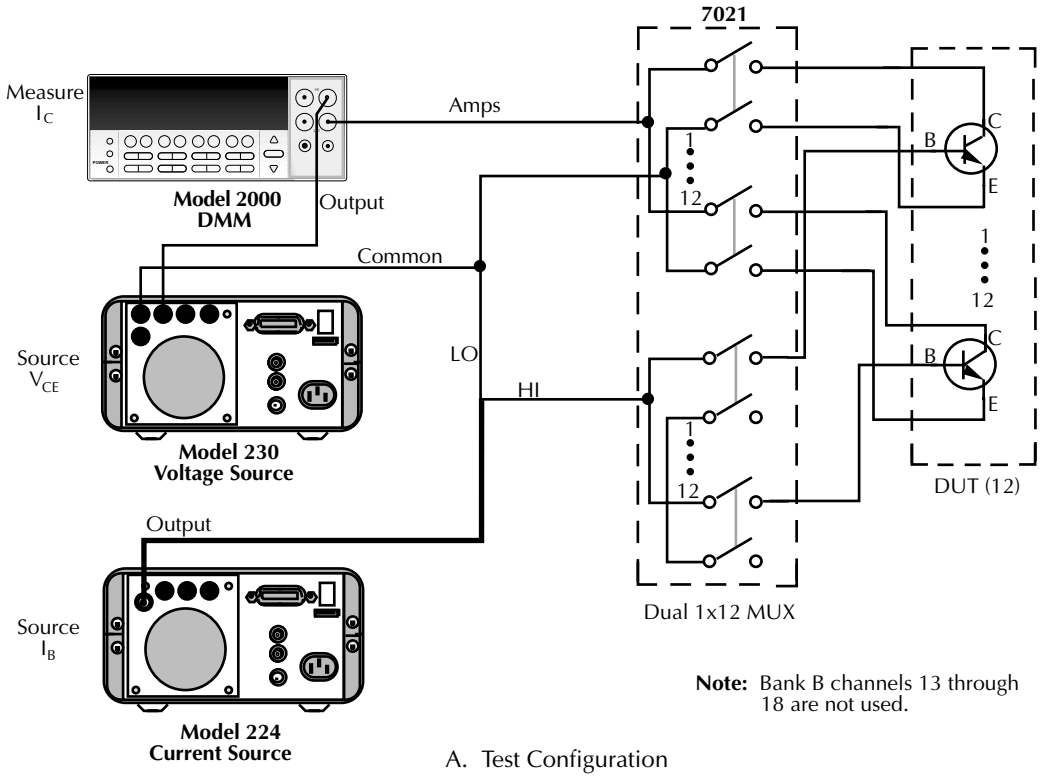
Typical transistor tests that can be performed with the aid of the Model 7021 include current gain tests, leakage tests, as well as tests to determine the common-emitter characteristics of the device. The following paragraphs discuss these tests and give typical equipment configurations for the tests.

Current gain tests

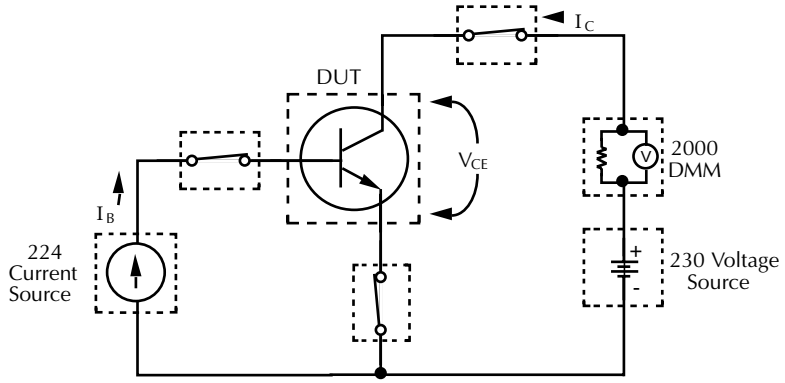
The DC or static common-emitter current gain of a transistor can be determined by biasing the transistor for a specific value of base current, I_B, and then measuring the collector current, I_C. The DC common-emitter current gain, β, of the transistor is then determined as follows:

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

Figure 5-8 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 2000 DMM. Switching among the transistors being tested is performed by the Model 7021.



A. Test Configuration



B. Simplified Equivalent Circuit

Figure 5-8
Configuration for current gain and common-emitter test

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 in the previous paragraph.

In order to reduce errors caused by voltage burden, use a higher current range on the Model 2000 DMM. Doing so will result in the loss of one or two decades of resolution, but 3 1/2 or 4 1/2-digit resolution will probably be adequate for most situations.

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 results are plotted, the result is the familiar family of common-emitter curves (Figure 5-9).

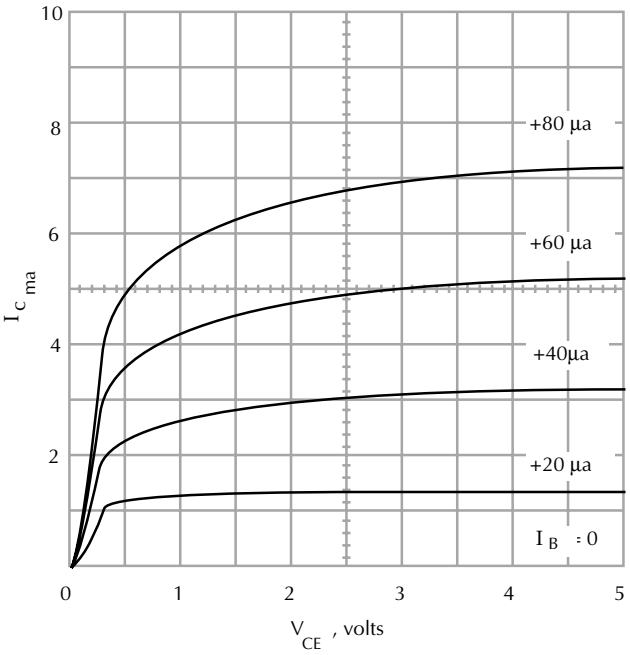


Figure 5-9
Typical common-emitter characteristics

The same test configuration 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 2000 DMM measures the collector current, I_C.

Testing with matrix-digital I/O cards

The Model 7021 can be added to a matrix switching system to enhance the test capabilities of that system. The following paragraphs discuss an overall multiplexer/matrix switching system and also briefly outline a typical test that can be made with such a system.

Multiplexer and matrix card connections

Figure 5-10 shows a typical system using Model 7022 and 7021 cards together. In this instance, the multiplexer-digital I/O card is configured as dual 1 × 12 and 1 × 18 multiplexers. Note that the rows of the matrix-digital I/O card are connected to the banks of the multiplexer-digital I/O card through the analog backplane of the mainframe; no external wiring is necessary to connect the two cards together.

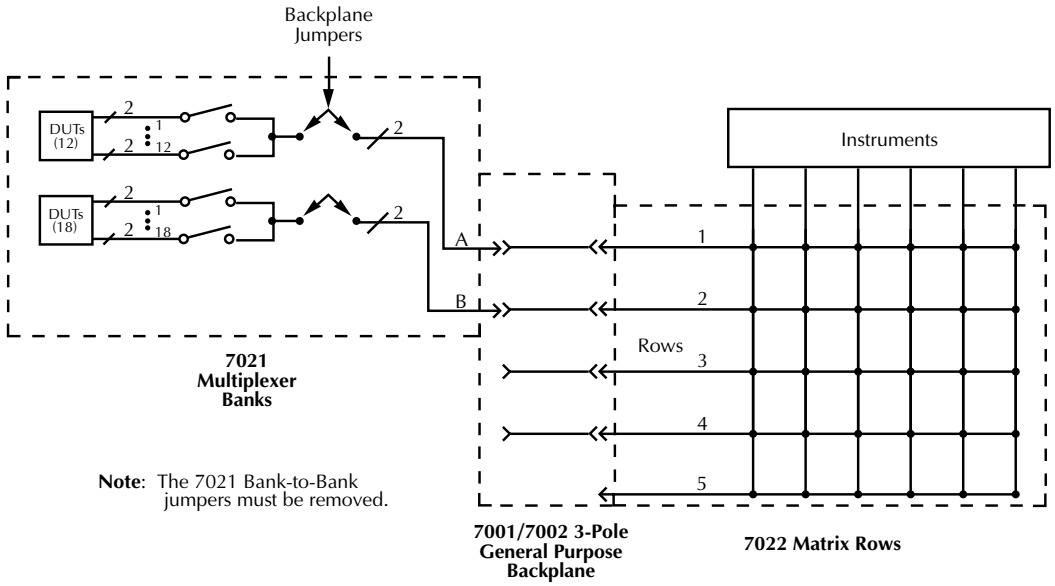


Figure 5-10
Connecting model 7021 and model 7022 cards together

In this application, the DUTs are connected to the bank inputs on the multiplexer and allow a large number of DUTs to be switched through the matrix-digital I/O card. Also, the instruments are connected to the columns on the matrix-digital I/O card. This particular configuration is best suited for applications requiring a large number of DUTs to be connected to several instruments. In other cases, the test configuration may call for a large number of instruments and few DUTs. In those situations, the instruments would be connected to the multiplexer inputs, and the DUTs would be connected to the columns.

Measurement considerations

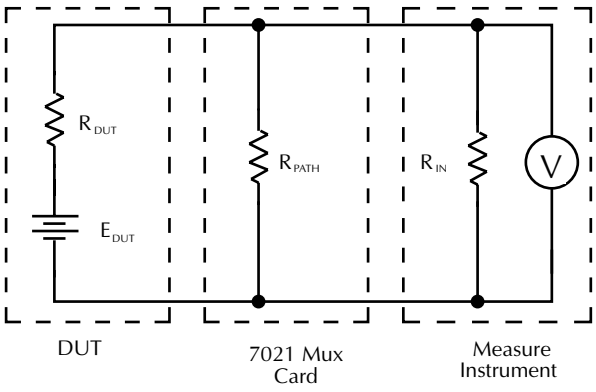
Many measurements made with the Model 7021 are subject to various effects that can seriously affect low-level measurement accuracy. The following paragraphs discuss these effects and ways to minimize them.

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 5-11. 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 5-12. Also, leakage currents can be generated through these resistances by voltage sources in the system.

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 multiplexer-digital I/O 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.



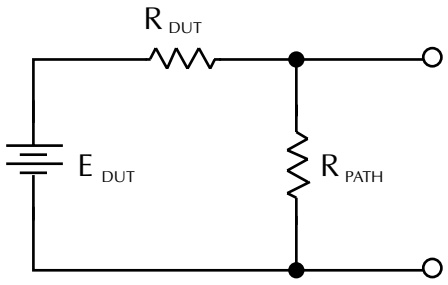
R_{DUT} = Source Resistance of DUT

E_{DUT} = Source EMF of DUT

R_{PATH} = Path Isolation Resistance

R_{IN} = Input Resistance of Measuring Instrument

Figure 5-11
Path isolation resistance



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

Figure 5-12
Voltage attenuation by path isolation resistance

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 multiplexer 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.

Radio frequency interference

Radio Frequency Interference (RFI) 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.

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 5-13, 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.

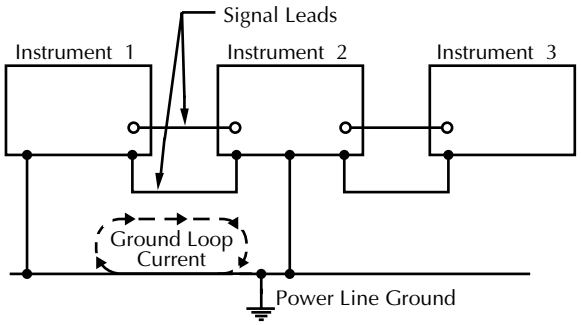


Figure 5-13
Power line ground loops

Figure 5-14 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.

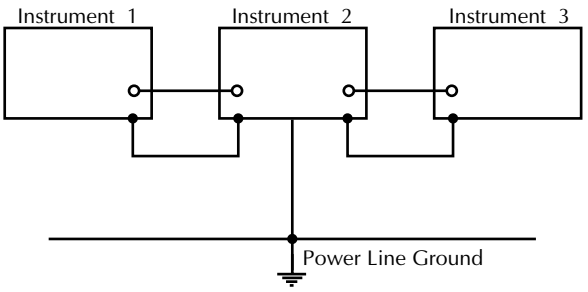


Figure 5-14
Eliminating ground loops

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.

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-digital I/O card should be used only in clean, dry environments to avoid contamination.

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

AC frequency response

The AC frequency response of the Model 7021 is important in test systems that switch AC signals. Refer to the specifications at the front of this manual.

6
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.

Introduction

This section contains information necessary to service the Model 7021 multiplexer-digital I/O card and is arranged as follows:

- **Handling and cleaning precautions —** Discusses handling precautions and methods to clean the card should it become contaminated.
- **Performance verification —** Covers the procedures necessary to determine if the multiplexer meets stated specifications.
- **Functionality test —** Provides a test procedure to determine if a digital I/O input or output channel is functioning properly.
- **Special handling of static-sensitive devices —** Reviews precautions necessary when handling static-sensitive devices.
- **Principles of operation —** Briefly discusses circuit operation.
- **Troubleshooting —** Presents some troubleshooting tips for the Model 7021 including relay replacement precautions.

Handling and cleaning precautions

Because of the high impedance areas on the Model 7021, care should be taken when handling or servicing the card to prevent possible contamination, which could degrade performance. The following precautions should be taken when servicing the card.

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.

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

If making solder repairs on the circuit board, use an OA-based (organic activated) flux. Remove the flux from the work areas when the repair is complete. Use pure water along with plenty of clean cotton 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 blowdry 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.

Performance verification

The following paragraphs discuss performance verification procedures for the Model 7021, including path resistance, offset current, contact potential, and isolation.

With the Model 7021's backplane jumpers installed, the performance verification procedures must be performed with only one card (the one being checked) installed in the Model 7001/7002 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 and shields. 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 card is contaminated. See the Handling and cleaning precautions paragraph to clean the card.

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%.

Recommended equipment

Table 6-1 summarizes the equipment necessary for performance verification, along with an application for each unit.

Multiplexer connections

The following information summarizes methods that can be used to connect test instrumentation to the card. Detailed connection information is provided in Section 4.

One method to make instrument connections to the card is by hard-wiring a 96-pin female DIN connector and then mating it to the connector on the Model 7021. Input and output shorting connections can also be done at the connector. The connector in the Model 7011-KIT-R connection kit (Table 4-1) can be used for this purpose. Pin identification for the connector is provided by Figure 4-9 and Table 4-2.

Table 6-1
Verification equipment

Description	Model	Specifications	Applications
DMM	Keithley Model 2000	100Ω; 0.01%	Path resistance
Electrometer w/voltage source	Keithley Model 6517A	20pA, 200pA; 1% 100V source; 0.15%	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

WARNING

When wiring a connector and device under test, do not leave any exposed wires or connections. No conductive part of the circuit may be exposed. Properly cover the conductive parts, or death by electric shock may occur.

CAUTION

After making solder connections to a connector, remove solder flux as explained in the Handling and cleaning precautions paragraph. Failure to clean the solder connections could result in degraded performance and prevent the card from passing verification tests.

Before pre-wiring any connectors or plugs, study the following test procedures to fully understand the connection requirements.

Channel resistance tests

Referring to Figure 6-1, 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 7001/7002 if it is on.
2. Turn on the Model 2000 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 6-1.
4. Set the Model 2000 to the 100Ω range and connect the four test leads to the INPUT and INPUT Ω 4 WIRE jacks.
5. Short the four test leads together and zero the Model 2000. Leave zero enabled for the entire test.
6. Connect INPUT HI and INPUT Ω 4 WIRE HI of the Model 2000 to the common terminal (jumper on bank A inputs). It is recommended that the physical connections be made at the inputs of bank A, as shown in Figure 6-1.
7. Connect INPUT LO and INPUT Ω 4 WIRE LO to the HI (H) terminal of bank A.
8. Install the Model 7021 in slot 1 (CARD 1) of the Model 7001/7002.
9. Turn on the Model 7001/7002 and program it to close channel 1!1 (bank A, input 1). Verify that the resistance of this path is <1.25Ω.
10. Open channel 1!1 and close channel 1!2 (bank A, input 2). Verify that the resistance of this path is <1.25Ω.
11. Using the basic procedure in steps 9 and 10, check the resistance of bank A HI (H) terminal paths for the rest of the bank A inputs (channels 1!6, 1!7, 1!11, 1!12, 1!16, 1!17, 1!21, 1!22, 1!26, and 1!27).
12. Turn off the Model 7001/7002 and move the INPUT LO and INPUT Ω 4 WIRE 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!1, 1!2, 1!6, 1!7, 1!11, 1!12, 1!16, 1!17, 1!21, 1!22, 1!26, and 1!27).
14. Repeat the basic procedure in steps 1 through 13 for bank B (channels 1!3-1!5, 1!8-1!10, 1!13-1!15, 1!18-1!20, 1!23-1!25, and 1!28-1!30).

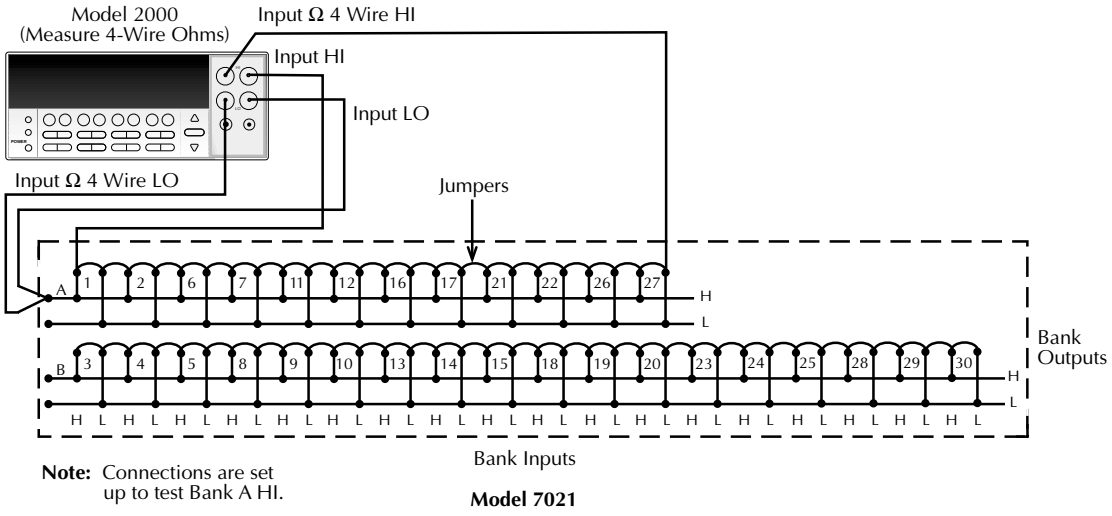


Figure 6-1
Path resistance test connections

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 measuring the leakage current with an electrometer. In the following procedure, the Model 6517A is used to measure the leakage current.

Referring to Figure 6-2, perform the following procedure to check offset current:

1. Turn off the Model 7001/7002 if it is on, and remove any jumpers or wires connected to the card.
2. Connect the triax cable to the Model 6517A, but do not connect it to the card at this time.
3. Turn on the Model 6517A and allow the unit to warm up for two hours before testing. After warm up, select the 200pA range, enable zero check, and zero correct the instrument. Leave zero correct enabled for the entire procedure.
4. Connect the triax cable to bank A HI and LO, as shown in Figure 6-2A.
5. Install the Model 7021 in slot 1 (CARD 1) of the mainframe.
6. Turn on the Model 7001/7002.
7. Program the unit to close channel 1!1 (bank A, input 1).
8. On the Model 6517A, disable zero check and allow the reading to settle. Verify that the reading is <100pA. This measurement is the offset (leakage) current of the pathway.
9. Enable zero check on the Model 6517A and open channel 1!1 from the front panel of the mainframe.
10. Repeat the basic procedure in steps 7 through 9 to check the rest of the pathways of bank A (channels 1!2, 1!6, 1!7, 1!11, 1!12, 1!16, 1!17, 1!21, 1!22, 1!26, and 1!27).
11. Turn off the mainframe and change the electrometer connections to bank B.
12. Repeat the basic procedure in steps 7 through 10 to check the bank B inputs (channels 1!3-1!5, 1!8-1!10, 1!13-1!15, 1!18-1!20, 1!23-1!25, and 1!28-1!30).
13. Turn off the Model 7001/7002 and change the electrometer connections, as shown in Figure 6-2B. 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. Turn on the Model 7001/7002.
15. Repeat steps 7 through 12 to check that the common-mode offset current is <100pA.

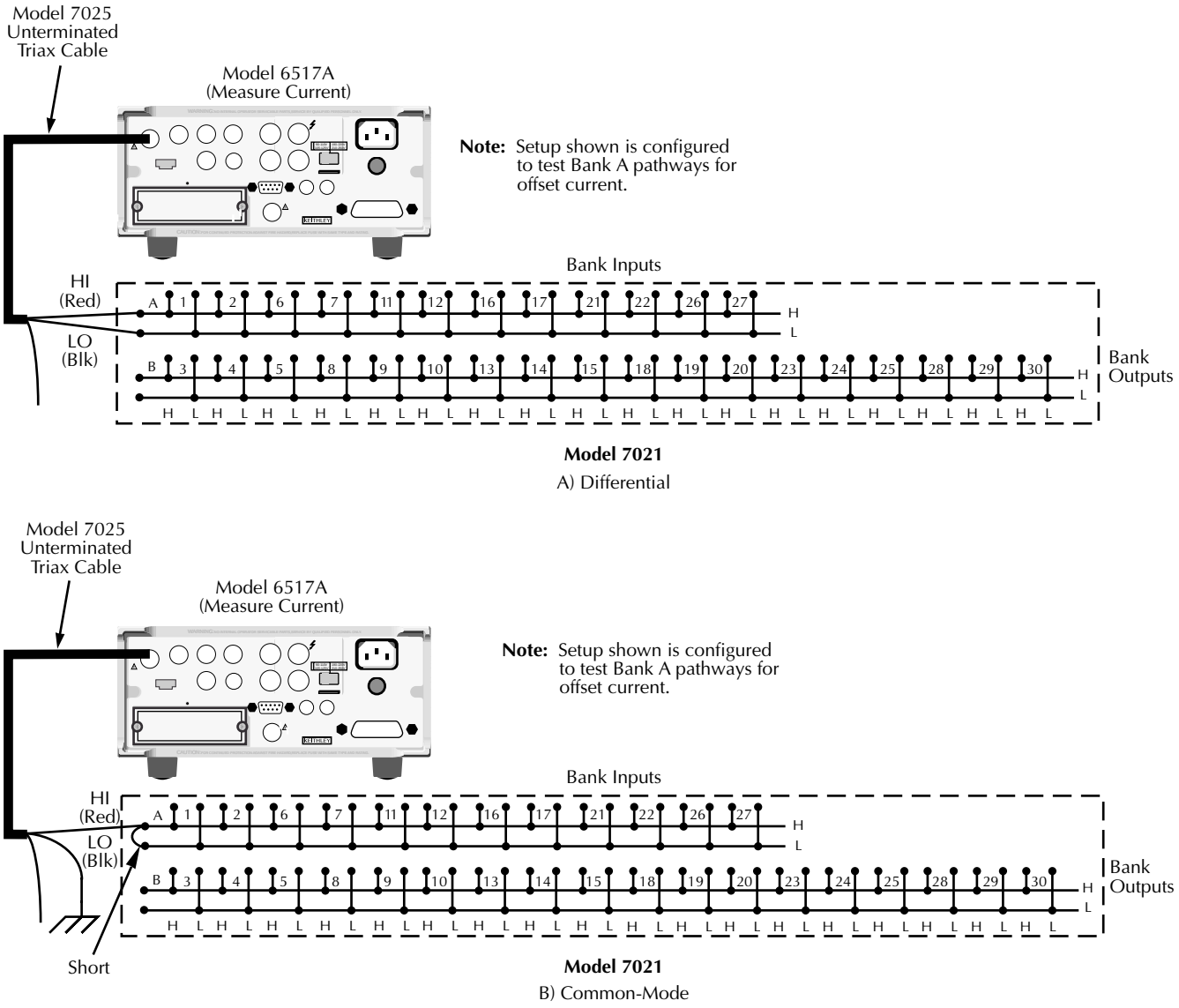


Figure 6-2
Offset current test connections

Contact potential tests

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

Referring to Figure 6-3, perform the following procedure to check contact potential of each path:

1. Turn off the Model 7001/7002 if it is on.
2. Place jumpers between banks A and B.
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 1!1-1!30).
5. Place a short between HI to LO on output bank B (long enough to cut with wire cutters).
6. Connect the Model 182 input leads to HI and LO on output bank A using copper wires.
7. Install the Model 7021 in the Model 7001/7002 slot 1, and turn on the mainframe.
8. Allow Models 7001/7002, 7021, 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 mainframe. Remove the Model 7021 from slot 1. Cut the short on bank B output HI to LO.
12. Install the Model 7021 in mainframe slot 1, and turn power on.
13. Wait 15 minutes.
14. Program the mainframe to close channel 1!1.
15. After settling, verify that reading on the Model 182 is <3µV. This measurement represents the contact potential of the pathway.
16. From the mainframe, open channel 1!1.
17. Repeat steps 14 through 16 for all 30 channels.

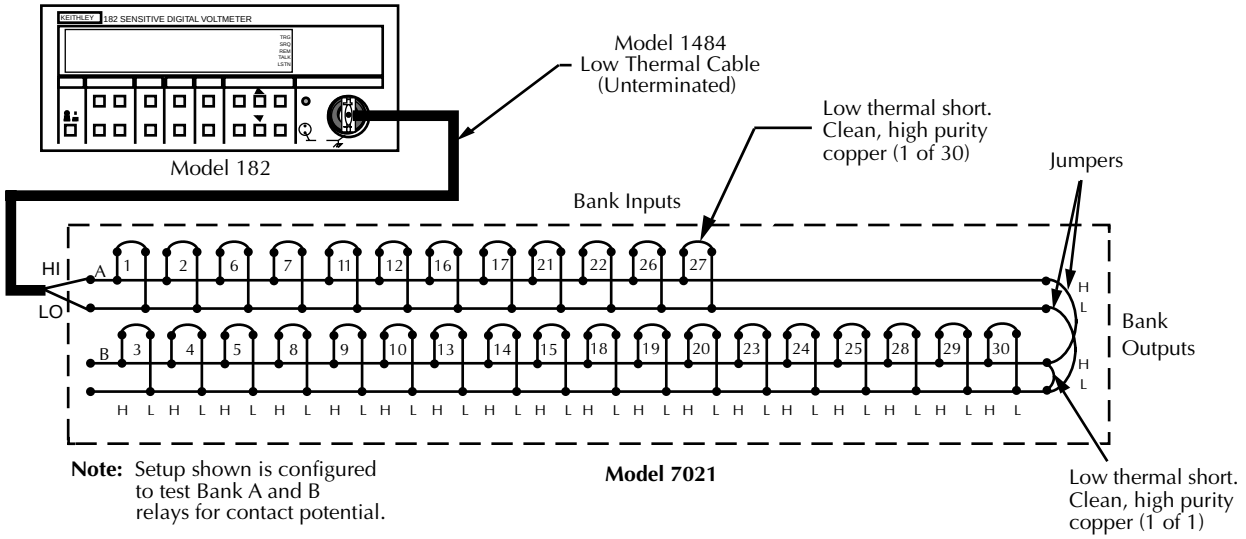


Figure 6-3
Contact potential test connections

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 6517A functions as both a voltage source and an ammeter. In the R function, the Model 6517A 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 7001/7002 if it is on, and remove any jumpers or test leads connected to the card.
2. Turn on the Model 6517A and allow the unit to warm up for two hours before testing.
3. Connect the electrometer to the Model 7021, as shown in Figure 6-4. Make sure the voltage source is off. Also, make sure there are no other connections to the card.
4. Install the Model 7021 in slot 1 (CARD 1) and turn on the mainframe.

WARNING

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

5. Place the Model 6517A in the R measurement function.
6. Turn on and program the Model 7001/7002 to close channels 1!1 and 1!4 (bank A, input 1 and bank B, input 4).
7. On the Model 6517A, source +100V.
8. After allowing the reading on the Model 6517A to settle, verify that it is >1GΩ (10^9Ω). This measurement is the leakage resistance (bank isolation) between bank A, input 1 and bank B, input 4.
9. Using Table 6-2 as a guide, repeat the basic procedure of steps 6 through 8 for the rest of the path pairs (test numbers 2 through 12 in the table).
10. Turn off the Model 6517A voltage source.

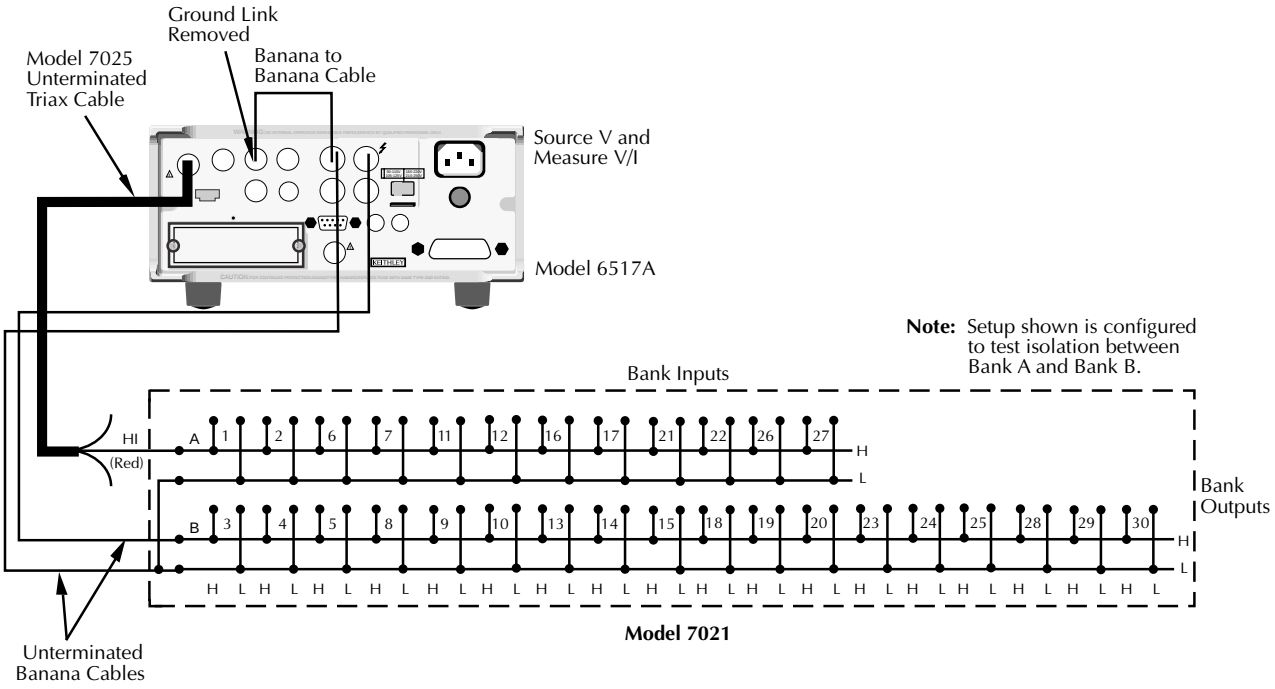


Figure 6-4
Bank isolation test connections

NOTE

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

11. Turn off the mainframe and connect the Model 6517A to the card as shown in Figure 6-5.
12. Install the Model 7021 in slot 1 and turn on the mainframe.
13. Program the mainframe to close channel 1!2 (bank A, input 2). Make sure all other channels are open.
14. On the Model 6517A, source 100V.
15. After allowing the reading on the Model 6517A to settle, verify that it is >1GΩ (10^9Ω).
16. Turn off the Model 6517A voltage source.
17. Using Table 6-3 as a guide, perform tests 2 through 11 for the remaining bank A inputs. Remember to move bank input connections as indicated in the table.
18. Use Table 6-3 (test numbers 12 through 28) and the above procedure to test bank B inputs.

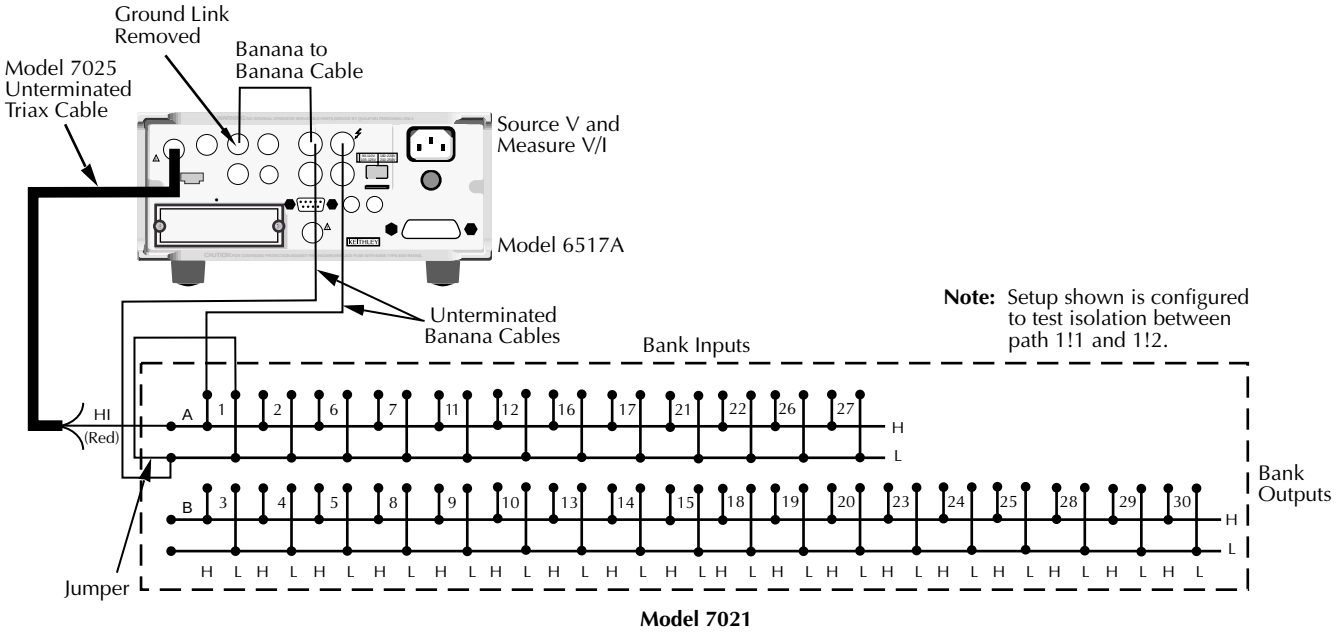


Figure 6-5
Channel-to-channel isolation test connections

Table 6-2
Bank isolation test summary

Test number	Bank isolation	Test equipment location	Channels closed*
1	Bank A, Input 1 to Bank B, Input 4	Bank A and Bank B	1!1 and 1!4
2	Bank A, Input 2 to Bank B, Input 5	Bank A and Bank B	1!2 and 1!5
3	Bank A, Input 6 to Bank B, Input 8	Bank A and Bank B	1!6 and 1!8
4	Bank A, Input 7 to Bank B, Input 9	Bank A and Bank B	1!7 and 1!9
5	Bank A, Input 11 to Bank B, Input 10	Bank A and Bank B	1!11 and 1!10
6	Bank A, Input 12 to Bank B, Input 13	Bank A and Bank B	1!12 and 1!13
7	Bank A, Input 16 to Bank B, Input 14	Bank A and Bank B	1!16 and 1!14
8	Bank A, Input 17 to Bank B, Input 15	Bank A and Bank B	1!17 and 1!15
9	Bank A, Input 21 to Bank B, Input 18	Bank A and Bank B	1!21 and 1!18
10	Bank A, Input 22 to Bank B, Input 19	Bank A and Bank B	1!22 and 1!19
11	Bank A, Input 26 to Bank B, Input 20	Bank A and Bank B	1!26 and 1!20
12	Bank A, Input 27 to Bank B, Input 23	Bank A and Bank B	1!27 and 1!23

*Assumes Model 7021 is installed in slot 1 of mainframe. Programmed as slot (1) and channel.

Table 6-3
Channel-to-channel isolation test summary

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

*Assumes Model 7021 is installed in slot 1 of mainframe. Programmed as slot (1) and channel.

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 6517A functions as a voltage source and an ammeter. In the R function, the Model 6517A 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 7001/7002 mainframe if it is on, and remove any jumpers and test leads connected to the card.
2. Turn on the Model 6517A and allow the unit to warm up for two hours for rated accuracy.

WARNING

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

3. On the Model 6517A, set the voltage source for +100V. Make sure the voltage source is off.
4. Place the Model 6517A in the R measurement function.
5. Make sure the Model 6517A voltage source is off and connect the electrometer to bank A as shown in Figure 6-6.
6. Install the Model 7021 in slot 1 (CARD 1), and turn on the mainframe.
7. Make sure all the relays are open.
8. On the Model 6517A, source 100V.
9. After allowing the reading on the Model 6517A to settle, verify that it is >1GΩ (10^9Ω). This measurement is the differential leakage resistance (isolation) of bank A.
10. Turn off the Model 6517A voltage source.
11. Program the mainframe to close channel 1!1 (bank A, input 1).
12. On the Model 6517A, source +100V.
13. After allowing the reading on the Model 6517A to settle, verify that it is also >1GΩ (10^9Ω). This measurement checks the differential isolation of input 1.

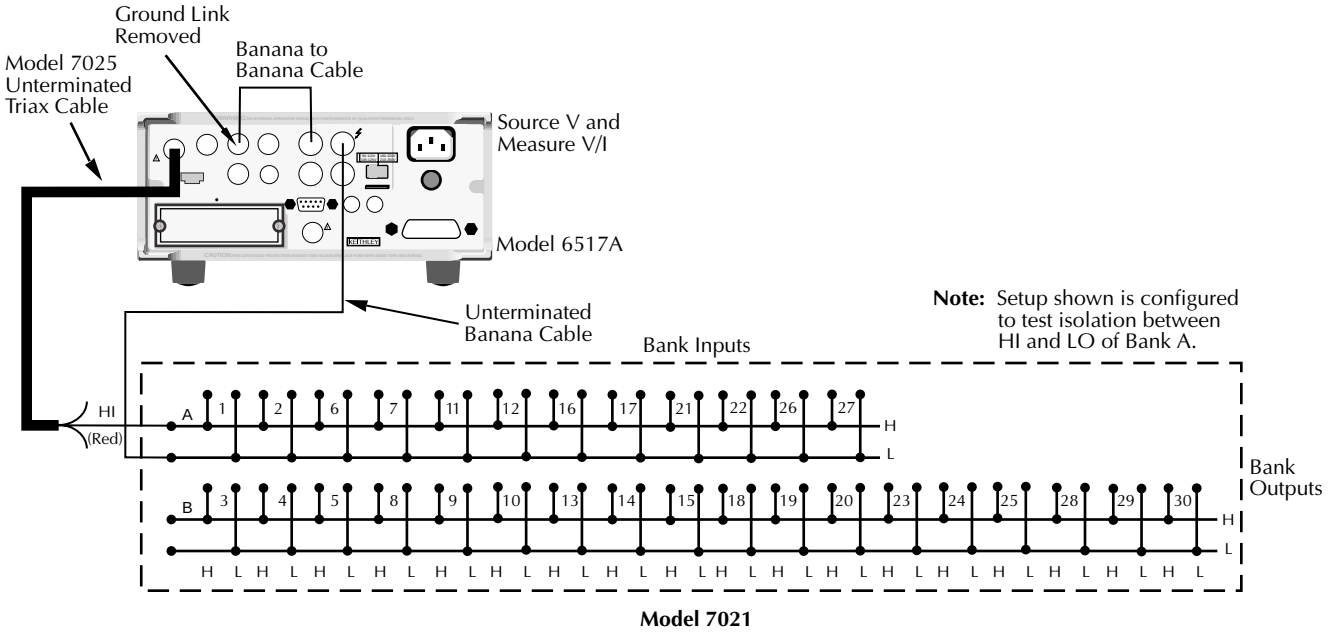


Figure 6-6
Differential isolation test connections

14. Using Table 6-4 as a guide, repeat the basic procedure in steps 10 through 13 to test the rest of the inputs of bank A (test numbers 3 through 13 of the table).
15. Use Table 6-4 (test numbers 14 through 32) and steps 5 through 13 to test bank B.
16. Turn off the Model 6517A voltage source.

NOTE

Refer to Figure 6-7 for the following procedure to check common-mode isolation.

17. Turn off the mainframe, and connect the electrometer to the Model 7021 as shown in Figure 6-7.
18. Repeat steps 3 through 15 to check common-mode isolation. Verify that each reading is >1GΩ (10^9Ω).

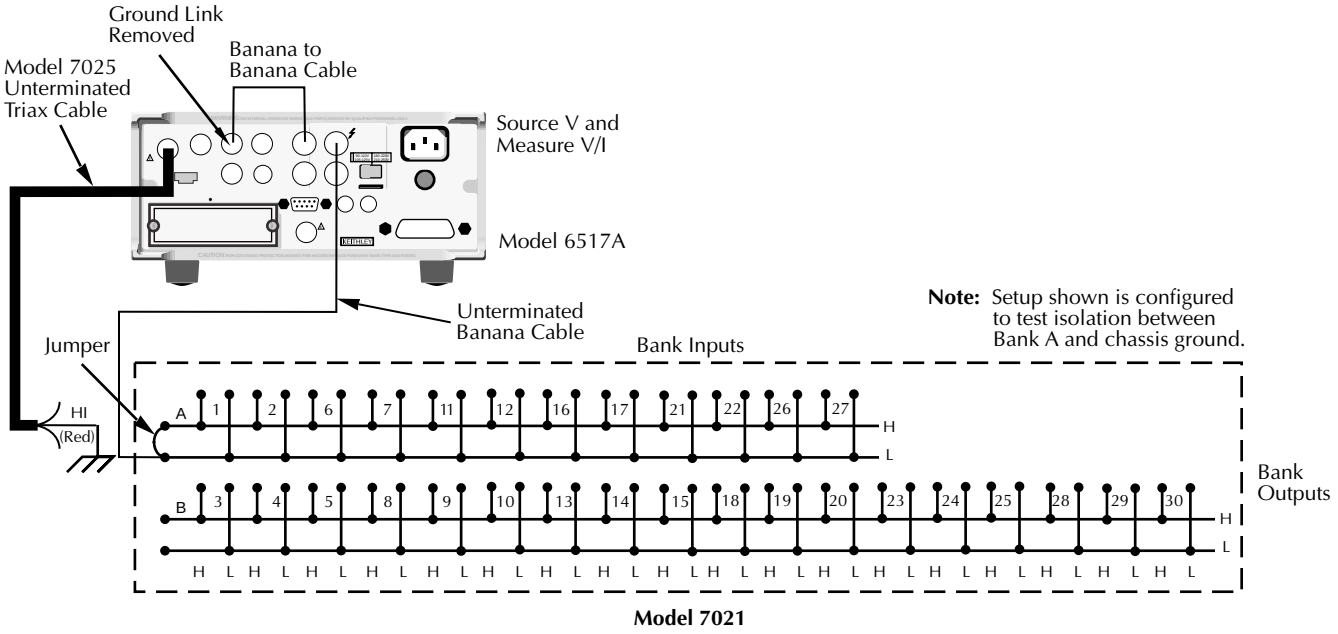


Figure 6-7
Common-mode isolation test connections

Table 6-4
Differential and common-mode isolation testing

Test number	Differential or common-mode isolation	Channel closed*
1	Bank A	None
2	Bank A, Input 1	1!1
3	Bank A, Input 2	1!2
4	Bank A, Input 6	1!6
5	Bank A, Input 7	1!7
6	Bank A, Input 11	1!11
7	Bank A, Input 12	1!12
8	Bank A, Input 16	1!16
9	Bank A, Input 17	1!17
10	Bank A, Input 21	1!21
11	Bank A, Input 22	1!22
12	Bank A, Input 26	1!26
13	Bank A, Input 27	1!27
14	Bank B	None
15	Bank B, Input 3	1!3
16	Bank B, Input 4	1!4
17	Bank B, Input 5	1!5
18	Bank B, Input 8	1!8
19	Bank B, Input 9	1!9
20	Bank B, Input 10	1!10
21	Bank B, Input 13	1!13
22	Bank B, Input 14	1!14
23	Bank B, Input 15	1!15
24	Bank B, Input 18	1!18
25	Bank B, Input 19	1!19
26	Bank B, Input 20	1!20
27	Bank B, Input 23	1!23
28	Bank B, Input 24	1!24
29	Bank B, Input 25	1!25
30	Bank B, Input 28	1!28
31	Bank B, Input 29	1!29
32	Bank B, Input 30	1!30

*Assumes Model 7021 is installed in slot 1 of mainframe. Programmed as slot (1) and channel.

Channel functionality test

1. As shown in Figure 6-8, connect the suspect input or output channel to an output or input channel that is known to be functioning properly. The internal 5V supply must be used.
2. From the front panel of the mainframe, turn on (close) the output channel. Verify that the display indicates that the output channel is on (closed). Keep in mind that the output can be high (positive) or low (negative) when the channel is turned on, depending on the logic configuration.
3. Place the mainframe in the "read input channels" display mode. Verify on the display that the input channel is off (open).
4. On the mainframe, turn off (open) the output channel and verify on the display that the input channel turns on (closes).
5. On the mainframe, return the instrument to the normal display mode and verify on the display that the output channel is off (open).

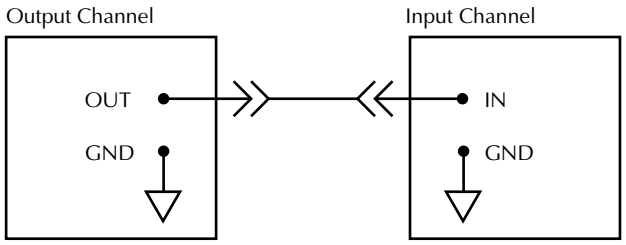


Figure 6-8
Testing an input or output channel

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 buildup. 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.

Principles of operation

The following paragraphs discuss the basic operating principles for the Model 7021 and can be used as an aid in troubleshooting the card. Schematic drawings 7021-106 and 7021-172 are located in Section 7.

Block diagram

Figure 6-9 shows a simplified block diagram of the Model 7021. Key elements include the ROM, which contains card ID and configuration information, multiplexer relay drivers and relays, and digital I/O output channel drivers and digital I/O input channel registers. These various elements are discussed in the following paragraphs.

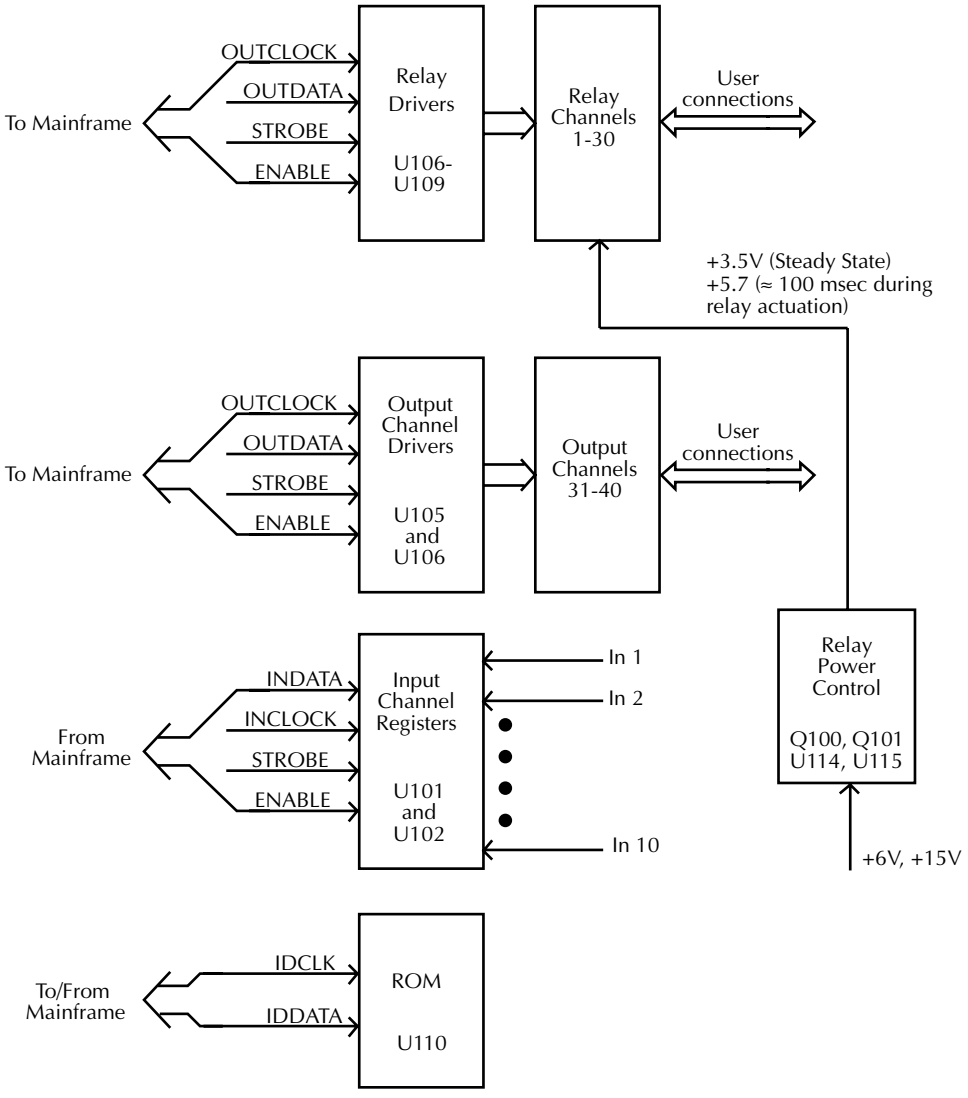


Figure 6-9
Model 7021 block diagram

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 and channel configuration information.

ID data is contained within an on-card EEPROM (U110). In order to read this information, the sequence described below is performed on power-up.

1. The IDDATA line (pin 5 of U110) is set from high to low while the IDCLK line (pin 6 of U110) is held high. This action initiates a start command to the ROM to transmit data serially to the mainframe (Figure 6-10).
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 6-11).
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 (Figure 6-10).

Multiplexer 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.

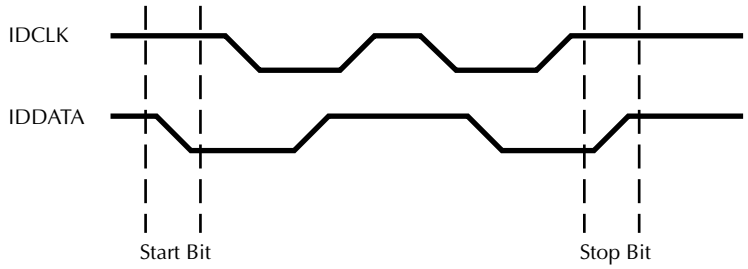


Figure 6-10
Start and stop sequences

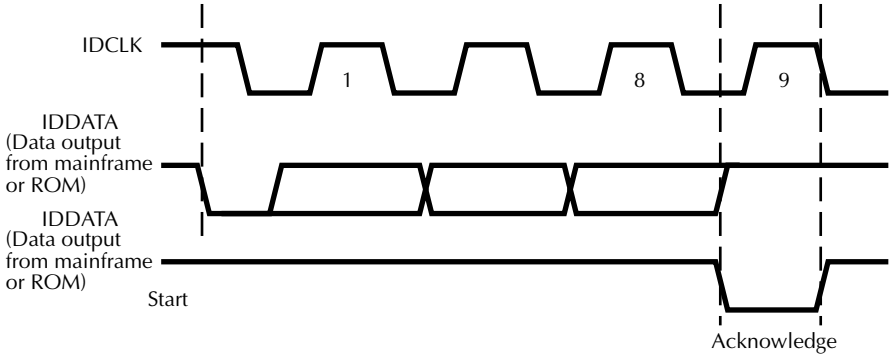


Figure 6-11
Transmit and acknowledge sequence

Multiplexer relay power control

A relay power control circuit, made up of U114, U115, Q100, Q101, and associated components, keeps power dissipated in relay coils at a minimum, thus reducing possible problems caused by thermal EMFs.

During steady-state operation, the relay supply voltage, +V, is regulated to +3.5V to minimize coil power dissipation. When a relay is first closed, the STROBE pulse applied to U114 changes the parameters of the relay supply voltage regulator, Q100, allowing the relay supply voltage, +V, to rise to +5.7V for about 100msec. This brief voltage rise ensures that relays close as quickly as possible. After the 100msec period has elapsed, the relay supply voltage (+V) drops back down to its nominal steady-state value of +3.5V.

Digital I/O output channel control

Digital output channels are controlled by serial data transmitted from the mainframe to the card via the OUTDATA line. A total of two bytes are shifted in a serial fashion into latches located in the output channel driver ICs. The serial data is clocked in by the OUTCLK line. As data overflows one register, it is fed out the Q's line of the register down the chain.

Once all bytes have shifted into the card, the STROBE line is set high to latch the output channel information into the Q outputs of the output channel drivers. Note that a channel driver output can go low or high when it is turned on (closed) depending on its logic configuration.

Digital I/O input channel control

The mainframe reads digital input channels of the I/O card from a serial, two-byte data stream (via INDATA line).

Digital inputs are applied in a parallel fashion to the two input channel registers (U102 contains eight channels and U101 contains two channels). When the digital inputs are read, the STROBE line goes high to latch the input channel information. The INCLOCK line then clocks out the information as a serial, two-byte data stream (via INDATA line) to the mainframe. As data empties from the lead register (U101), it is replaced by data via the Q7 line of the registers down the chain.

Power-on safeguard

NOTE

The power-on safeguard circuit discussed below is actually located on the digital board in the mainframe.

A power-on safeguard circuit, made up of a D-type flip-flop and associated components ensures that relays and digital I/O output channels do not randomly energize on power-up and power-down. This circuit disables all relays and output channels (all relays and output channels 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 card relay/output channel driver IC enable pin (U105-U109, 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 and output channels (driver IC enable pins are high). After the reset condition elapses (≈200msec), 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 and output channel drivers simultaneously. Note that Q out stays low, (enabling relay drivers and output channel drivers) until the 68302 processor goes into a reset condition.

Troubleshooting

WARNING

Lethal voltages are present within the Model 7001/7002 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 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.

Troubleshooting equipment

Table 6-5 summarizes recommended equipment for troubleshooting the Model 7021.

Table 6-5
Recommended troubleshooting equipment

Description	Manufacturer and model	Application
Multimeter	Keithley 2000	Measure DC voltages
Oscilloscope	TEK 2243	View logic waveforms

Troubleshooting access

In order 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 mainframe cover.
3. Install the relay card in the CARD 1 slot location.
4. Turn on Model 7001/7002 power to measure voltages (see the Troubleshooting procedure paragraph).

Troubleshooting procedure

Table 6-6 summarizes multiplexer-digital I/O card troubleshooting.

Table 6-6
Troubleshooting procedure

Step	Item/component	Required condition	Comments
1	GND pad		All voltages referenced to digital ground (GND pad).
2	Q100, pin 2	+6VDC	Relay voltage.
3	U101, pin 16	+5VDC	Logic voltage.
4	R135	+15VDC	Relay bias voltage.
5	Q100, pin 3	+3.5VDC*	Regulated relay voltage.
6	U110, pin 6	IDCLK pulses	During power-up only.
7	U110, pin 5	IDDATA pulses	During power-up only.
8	U106, pin 7	STROBE pulse	End of relay update sequence.
9	U106, pin 2	CLK pulses	During relay update sequence only.
10	U106, pin 3	DATA pulses	During relay update sequence only.
11	U105-U109, pins 10-18	Low with relay energized; high with relay de-energized.	Relay driver outputs.

*+3.5VDC present at +V pad under steady-state conditions. This voltage rises to +5.7VDC for about 100msec when relay configuration is changed.

7
Replaceable Parts

Introduction

This section contains replacement parts information, schematic diagrams, and component layout drawings for the Model 7021.

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.

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 7021
2. Card serial number
3. Part description
4. Circuit description, if applicable
5. Keithley part number

Factory service

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

1. Complete the service form at the back of this manual and include it with the card.
2. Carefully pack the card in the original packing carton.
3. Write ATTENTION REPAIR DEPT on the shipping label.

NOTE

It is not necessary to return the mainframe with the card.

Component layouts and schematic diagrams

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

Table 7-1 — Parts List, Relay Card for 7021.
7021-100 — Component Layout, Relay Card for 7021.
7021-106 — Schematic, Relay Card for 7021.

NOTE

The Model 7021 and 7022 use the same relay card; only the connector cards are different.

Table 7-2 — Parts List, Mass Terminated Connector Card for 7021.

7021-170 — Component Layout, Mass Terminated Connector Card for 7021.

7021-172 — Schematic, Mass Terminated Connector Card for 7021.

Table 7-3 — Parts List, Model 7011-KIT-R 96-pin Female DIN Connector Kit.

Table 7-1
Relay card for Model 7021 parts list

Circuit designation	Description	Keithley part no.
	2-56X3/16 PHILLIPS PAN HEAD SCREW (BOARD TO SHIELD)	3-56X3/16PPH
	2-56X5/8 PHILLIPS PAN HEAD FASTENER (FOR P2001 TO STANDOFF AND SHIELD)	FA-245-1
	2-56X7/16 PHILLIPS PAN HEAD SCREW (BOARD TO SHIELD)	2-56X7/16PPH
	4-40X3/16 PHILLIPS PAN HEAD SEMS SCREW (FOR Q100)	4-40X3/16PPHSEM
	4-40 PEM NUT	FA-131
	EJECTOR ARM	7011-301B
	IC, SERIAL EPROM, 24C01P	IC-737
	ROLL PIN (FOR EJECTOR ARMS)	DP-6-1
	SHIELD	7011-305C
	STANDOFF, 2 CLEARANCE	ST-204-1
C100-112,114,115, 118,121,122,125	CAP, 0.1µF, 20%, 50V, CERAMIC	C-365-.1
C116,117,126	CAP, 150PF, 10%, 1000V, CERAMIC	C-64-150P
C119,127	CAP, 1µF, 20%, 50V, CERAMIC	C-237-1
C120	CAP, 0.001µF, 20%, 500V, CERAMIC	C-22-.001
C123,124	CAP, 10µF, -20+100%, 25V, ALUM ELEC	C-314-10
CR100-119	DIODE, SILICON, IN4148 (D0-35)	RF-28
J100,101	CONN, BERG	CS-339
J1002,1003	CONN, 48-PIN, 3-ROW	CS-736-2
K100-129	RELAY, ULTRA-SMALL POLARIZED TF2E-5V	RL-149
P2001	CONN, 32-PIN, 2-ROW	CS-775-1
Q100	TRANS, NPN PWR, TIP31 (T0-220AB)	TG-253
Q101	TRANS, N CHAN MOSPOW FET, 2N7000 (T0-92)	TG-195
R100-130,132	RES, 10K, 5%, 1/4W, COMPOSITION OR FILM	R-76-10K
R131	RES, 1K, 5%, 1/4W, COMPOSITION OR FILM	R-76-1K
R133	RES, 220K, 5%, 1/4W, COMPOSITION OR FILM	R-76-220K
R134,135	RES, 560, 10%, 1/2W, COMPOSITION	R-1-560

Table 7-1 (continued)
Relay card for Model 7021 parts list

Circuit designation	Description	Keithley part no.
R136	RES, 2.49K, 1%, 1/8W, METAL FILM	R-88-2.49K
R137	RES, 1.15K, 1%, 1/8W, METAL FILM	R-88-1.15K
R138	RES, 1K, 1%, 1/8W, METAL FILM	R-88-1K
S110	SOCKET	S0-72
ST1	STANDOFF, 4-40X0.812LG	ST-137-20
U100,103,104	IC, QUAD 2-INPUT EXCLUSIVE OR 74HCT86	IC-707
U101,102	IC, 8-BIT PARALLEL TO SERIAL, 74HCT165	IC-548
U105-109	IC, 8-BIT, SERIAL-IN LATCH DRIVER, 5841A	IC-536
U110	EPROM PROGRAM	7021-800A01
U111	IC, HEX INVERTER, 74HCT04	IC-444
U112	IC, QUAD 2 INPUT OR 74HCT32	IC-443
U113	IC, HIGH SPEED BUFFER, 74HC125	IC-451
U114	IC, RETRIG MONO MULTIVIB, 74HC123	IC-492
U115	IC, AJD SHUNT REGULATOR, TL431CLP	IC-677
VR100	DIODE, ZENER, 5.1V, IN751 (D0-7)	DZ-59
W100-107	JUMPER	J-15

Table 7-2
Mass terminated connector card for Model 7021 parts list

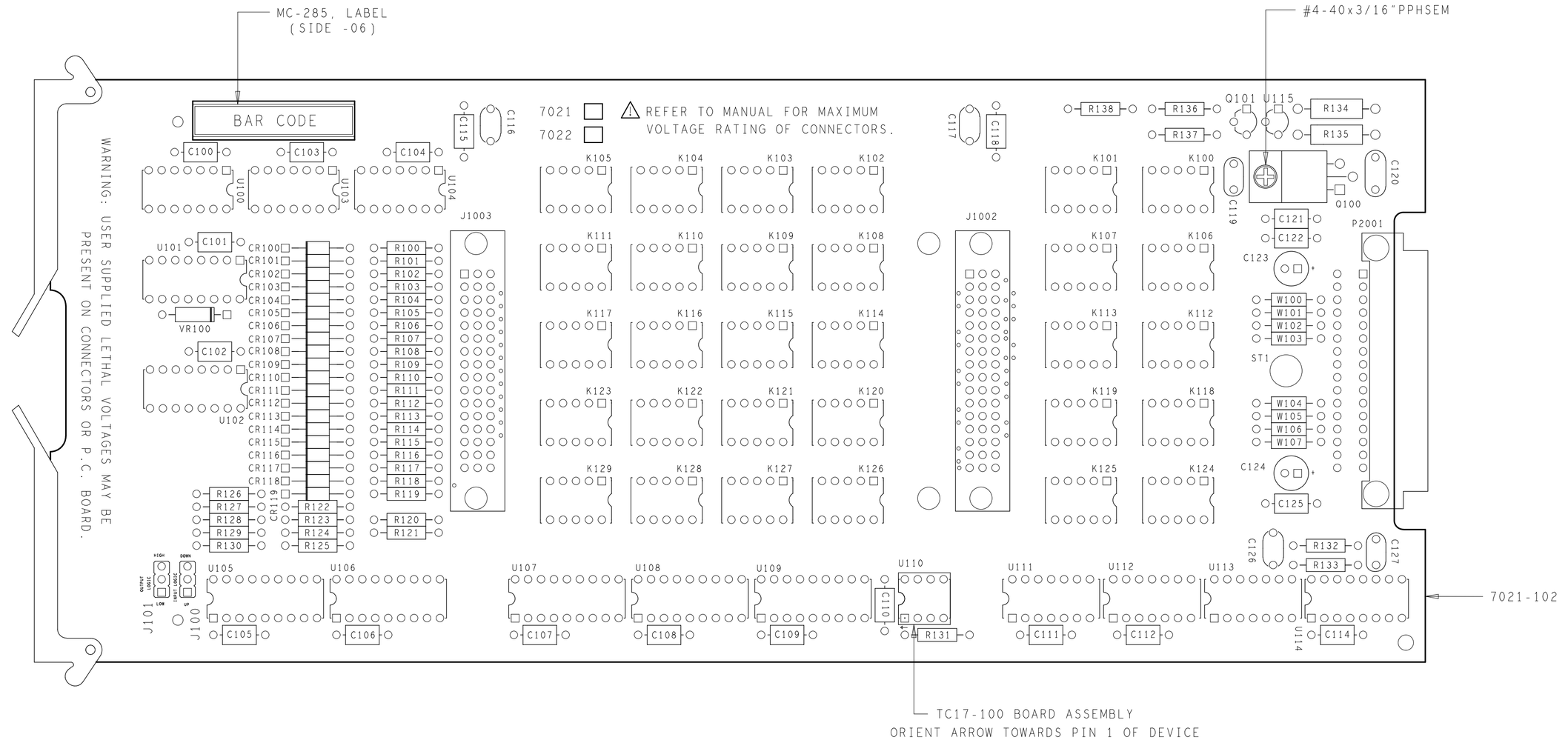
Circuit designation	Description	Keithley part no.
	2-56X3/16 PHILLIPS PAN HEAD SCREW (FOR SHIELD)	2-56X3/16PPH
	2-56X3/8 PHILLIPS PAN HEAD SCREW (FOR BRACKET)	2-56X3/8PPH
	2-56X7/16 PHILLIPS PAN HEAD SCREW	2-56X7/16PPH
	4-40X1/4 PHILLIPS PAN HEAD SEMS SCREW (CONNECTS RELAY BOARD TO CONNECTOR BOARD)	4-40X1/4PPHSEM
	BRACKET	7011-307
	CONN, JUMPER	CS-476
	SHIELD	7011-311A
	STANDOFF	ST-203-1
C201-204	CAP, 0.1µF, 20%, 50V, CERAMIC	C-365-.1
CR201,202	DIODE, SILICON, IN4148 (D0-35)	RF-28
J201,204,205	CONN, BERG	CS-339
J202,203	CONN SHIM	7011-309A
J1004	CONN, 96-PIN, 3-ROW	CS-514
K201,202	RELAY, ULTRA-SMALL POLARIZED TF2E-4.5V	RL-162
P1002,1003	CONNECTOR, 48-PIN, 3-ROW	CS-748-3
Q201	TRANS, NPN SILICON, 2N3904 (T0-92)	TG-47
R201-205,207-210,212	RES, 10K, 5%, 1/4W, COMPOSITION OR FILM	R-76-10K
R206	RES, 100K, 5%, 1/4W, COMPOSITION OR FILM	R-76-100K
R211,213	RES, 220, 10%, 1/2W, COMPOSITION	R-1-220
U201-203	IC, 4-CHANNEL PWR DRIVER, 2549B	IC-1044

Table 7-3
Model 7011-KIT-R 96-pin female DIN connector kit parts list

Description	Keithley part no.
96-PIN FEMALE DIN CONNECTOR	CS-787-1
BUSHING, STRAIN RELIEF	BU-27
CABLE ADAPTER, REAR EXIT (INCLUDES TWO CABLE CLAMPS)	CC-64
CONNECTOR HOUSING	CS-788

NO. 7021-100

LTR.	ECA NO.	REVISION	ENG.	DATE
B	19587	RELEASED	SZ	2-11-97
C	19744	REVISED ARTWORK	SZ	3-24-97
D	19814	REVISED ARTWORK	SZ	6/12/97
D1	25918	CHANGED U110 TO TC17-100	ELS	6/20/01

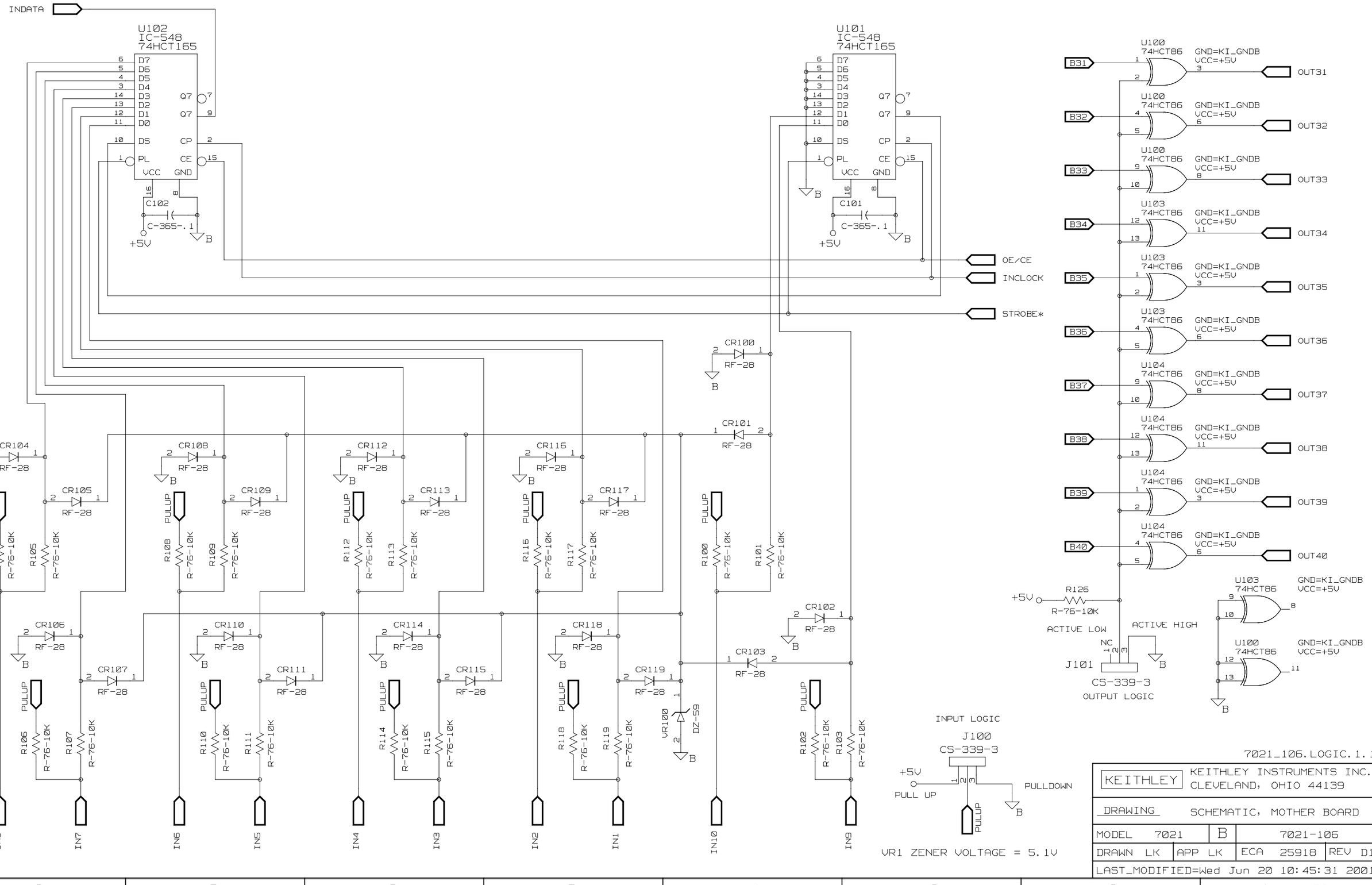


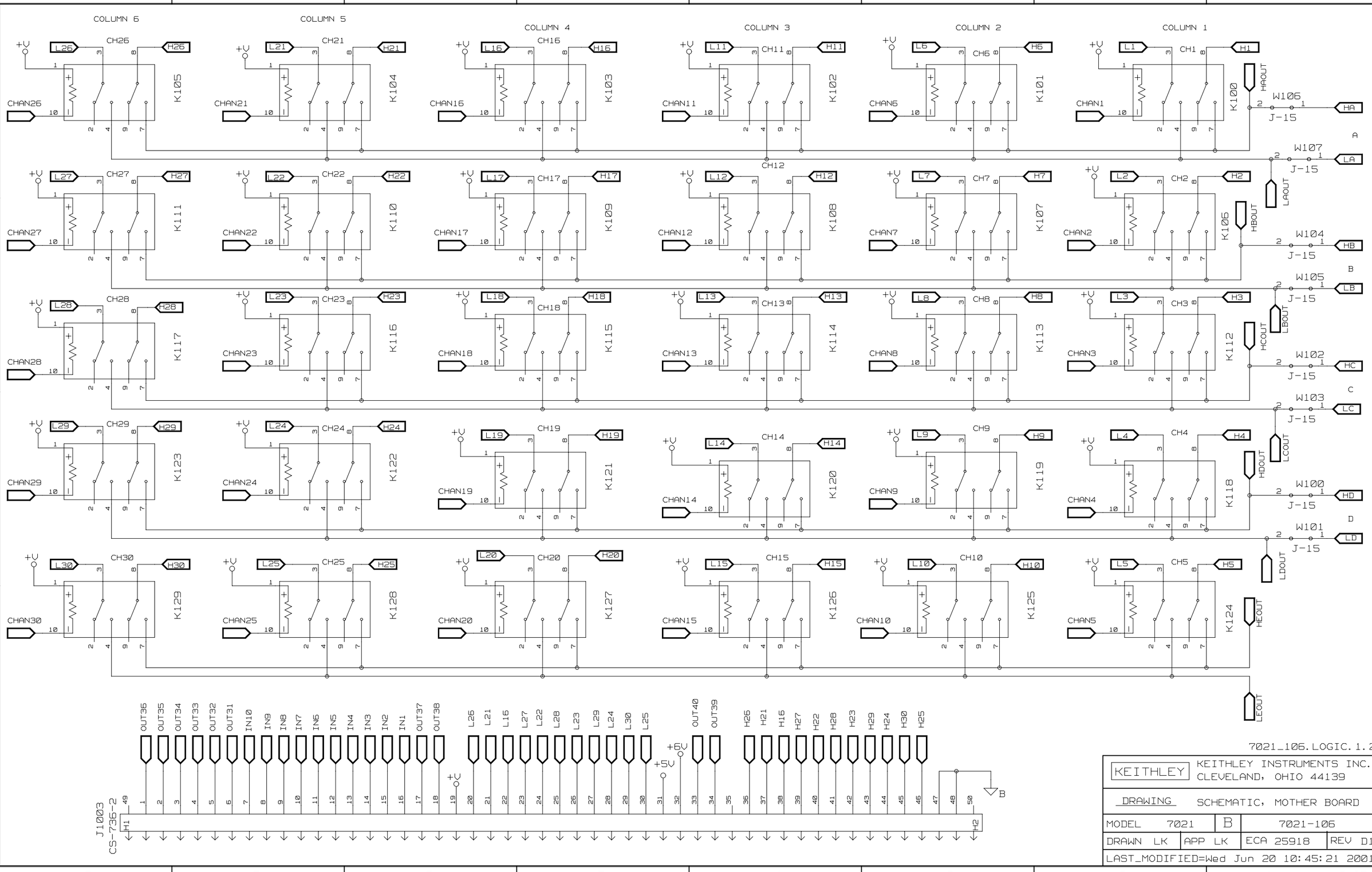
NOTE: FOR COMPONENT INFORMATION,
REFER TO 7021 PRODUCT STRUCTURE.

7021	C7021-101	1
MODEL	NEXT ASSEMBLY	QTY.
USED ON		

KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN. UNLESS OTHERWISE NOTED	DATE 12/27/96	SCALE 3:2	TITLE COMPONENT LAYOUT RELAY MOTHER BOARD
DIM. TOL. UNLESS OTHERWISE SPECIFIED	DRN AJS	APPR. P.S.	
XX=+.01 ANG.=+1 XXX=+.005 FRAC.=+1/64	DO NOT SCALE THIS DRAWING	C	NO. 7021-100


INDATA
U102
IC-548
74HCT165
D7
D6
D5
D4
D3
D2
D1
D0
DS
PL
Q7
CP
CE
VCC
GND
C102
C-365-.1
+5V
B
U101
IC-548
74HCT165
C101
C-365-.1
OE/CE
INCLOCK
STROBE*
CR100
CR101
CR102
CR103
CR104
CR105
CR106
CR107
CR108
CR109
CR110
CR111
CR112
CR113
CR114
CR115
CR116
CR117
CR118
CR119
RF-28
PULLUP
R104
R105
R106
R107
R108
R109
R110
R111
R112
R113
R114
R115
R116
R117
R118
R119
R100
R101
R102
R103
R-76-10K
VR100
DZ-59
IN8
IN7
IN6
IN5
IN4
IN3
IN2
IN1
IN10
IN9
U100
74HCT86
GND=KI_GNDB
VCC=+5V
B31
B32
B33
B34
B35
B36
B37
B38
B39
B40
OUT31
OUT32
OUT33
OUT34
OUT35
OUT36
OUT37
OUT38
OUT39
OUT40
R126
ACTIVE LOW
ACTIVE HIGH
NC
J101
CS-339-3
OUTPUT LOGIC
INPUT LOGIC
J100
PULL UP
PULLDOWN
VR1 ZENER VOLTAGE = 5.1V
7021_106.LOGIC.1.1
KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139
DRAWING
SCHEMATIC, MOTHER BOARD
MODEL 7021
B
7021-106
DRAWN LK
APP LK
ECA 25918
REV D1
LAST_MODIFIED=Wed Jun 20 10:45:31 2001
PG. 1 OF 4


COLUMN 6
COLUMN 5
COLUMN 4
COLUMN 3
COLUMN 2
COLUMN 1
CH26
CH21
CH16
CH11
CH6
CH1
CH27
CH22
CH17
CH12
CH7
CH2
CH28
CH23
CH18
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CH8
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K119
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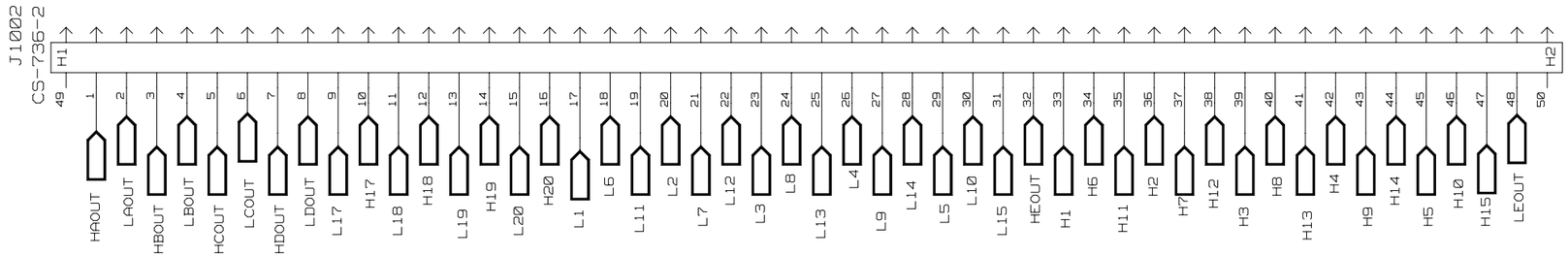
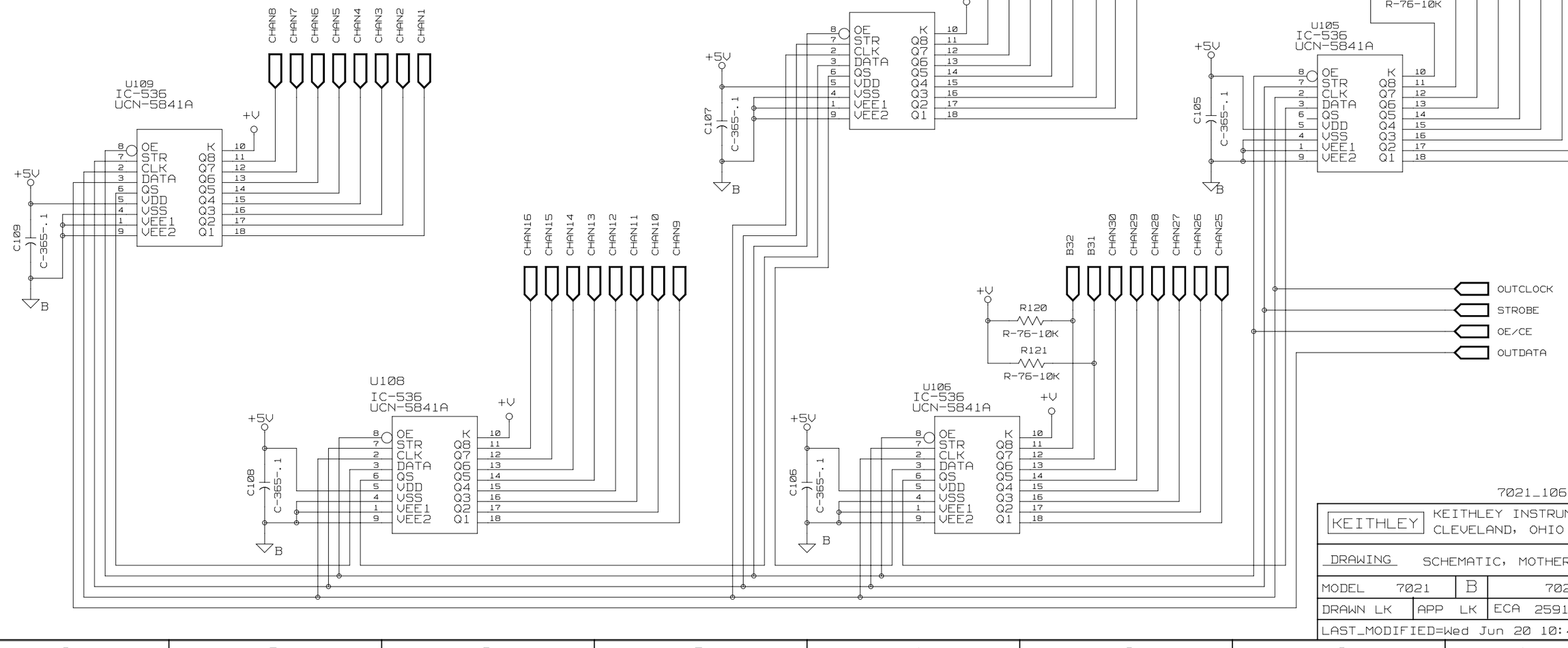
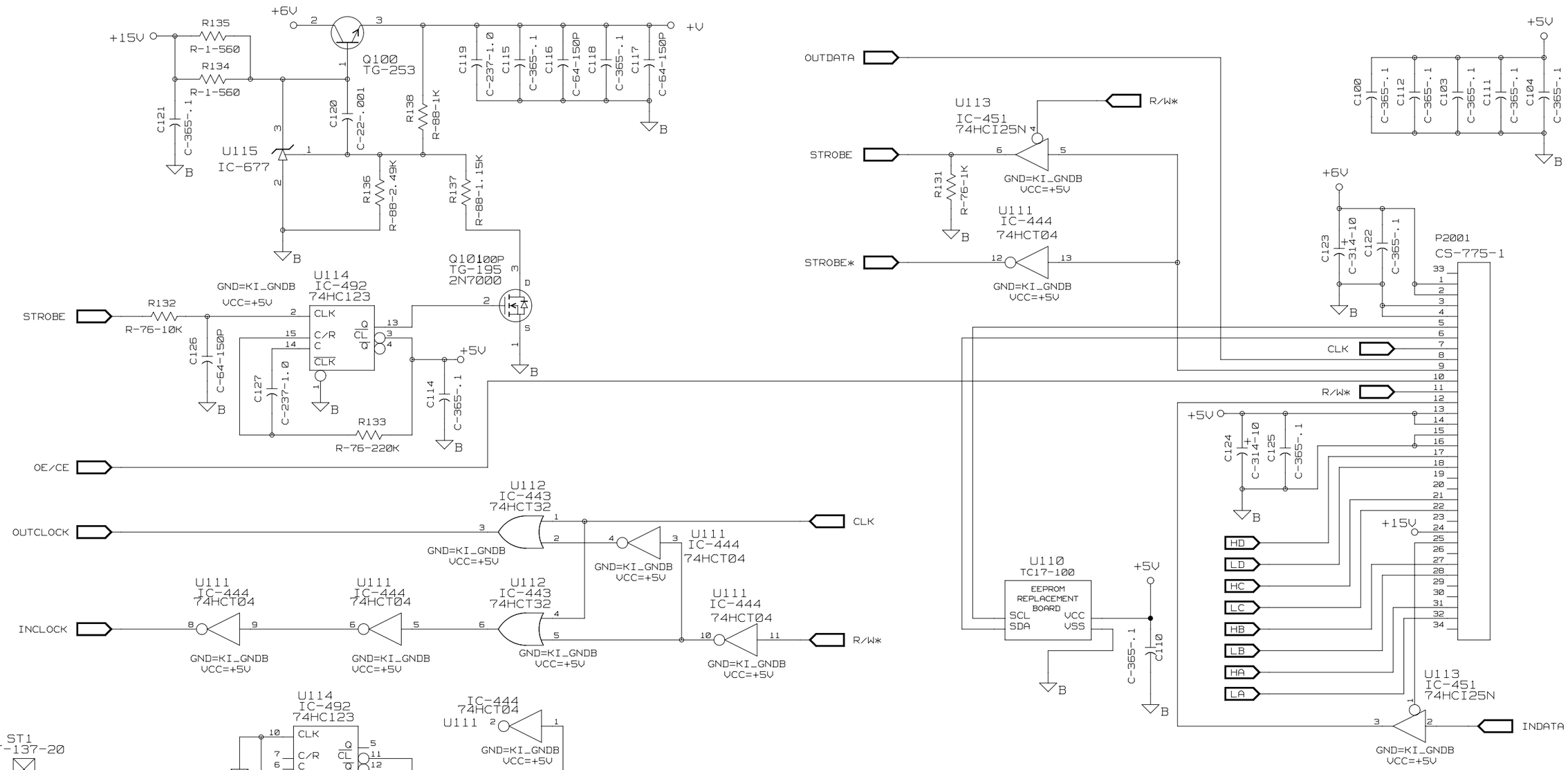
K129
K128
K127
K126
K125
K124
HAOUT
HBOUT
LAOUT
HCOUT
LBOUT
HDOUT
LCOUT
HEOUT
LDOUT
LEOUT
W106
W107
W104
W105
W102
W103
W100
W101
J-15
HA
LA
HB
LB
HC
LC
HD
LD
J1003
CS-736-2
+5V
B
7021_106.LOGIC. 1.2
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139
DRAWING SCHEMATIC, MOTHER BOARD
MODEL 7021
B
7021-106
DRAWN LK
APP LK
ECA 25918
REV D1
LAST_MODIFIED=Wed Jun 20 10:45:21 2001
PG. 2 OF 4





7021_105.LOGIC.1.3

KEITHLEY	KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139
DRAWING	SCHEMATIC, MOTHER BOARD
MODEL 7021 / B / 7021-105	
DRAWN LK / APP LK / ECA 25918 / REV D1	
LAST_MODIFIED=Wed Jun 20 10:45:10 2001	

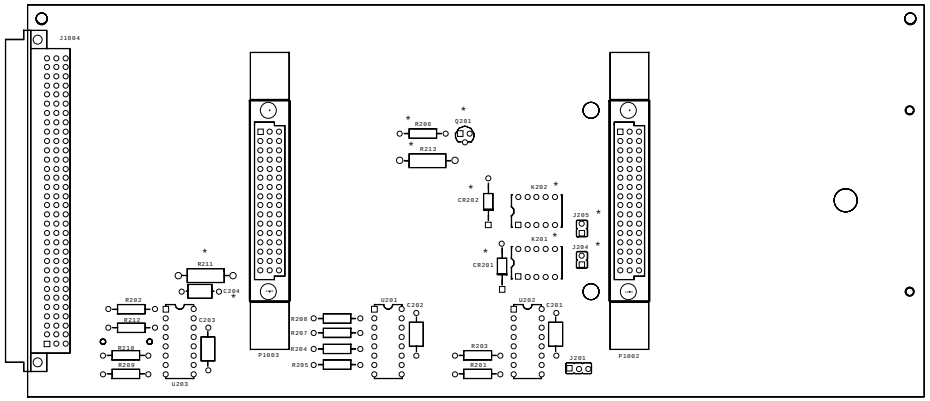


7021_105.LOGIC.1.4

KEITHLEY	KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139		
DRAWING	SCHEMATIC, MOTHER BOARD		
MODEL 7021	B	7021-105	
DRAWN LK	APP LK	ECA 25918	REV D1
LAST_MODIFIED=Wed Jun 20 10:52:09 2001			

LTR.	ECA NO.	REVISION	ENG.	DATE
A	19587	RELEASED	SZ	2/11/97
A1		ADDED NO POP NOTE FOR MODEL 7037,K201,K202 CR202,CR201,J204,J205,C204,R211,R206,R213,Q201		

TOP SIDE COMPONENTS (SIDE -06)



NOTE: FOR COMPONENT INFORMATION, SEE PRODUCT STRUCTURE.
*DO NOT POPULATE THESE PARTS FOR MODEL 7037;
R211,C204,K202,CR202,Q201,R213,R206,CR201,K201,J204,J205.

MODEL	NEXT ASSEMBLY	QTY.
USED ON		

KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN. UNLESS OTHERWISE NOTED
DIM. TOL. UNLESS OTHERWISE SPECIFIED
XX=+.01 ANG.=+1
XXX=+.005 FRAC.=+1/64
DO NOT SCALE THIS DRAWING

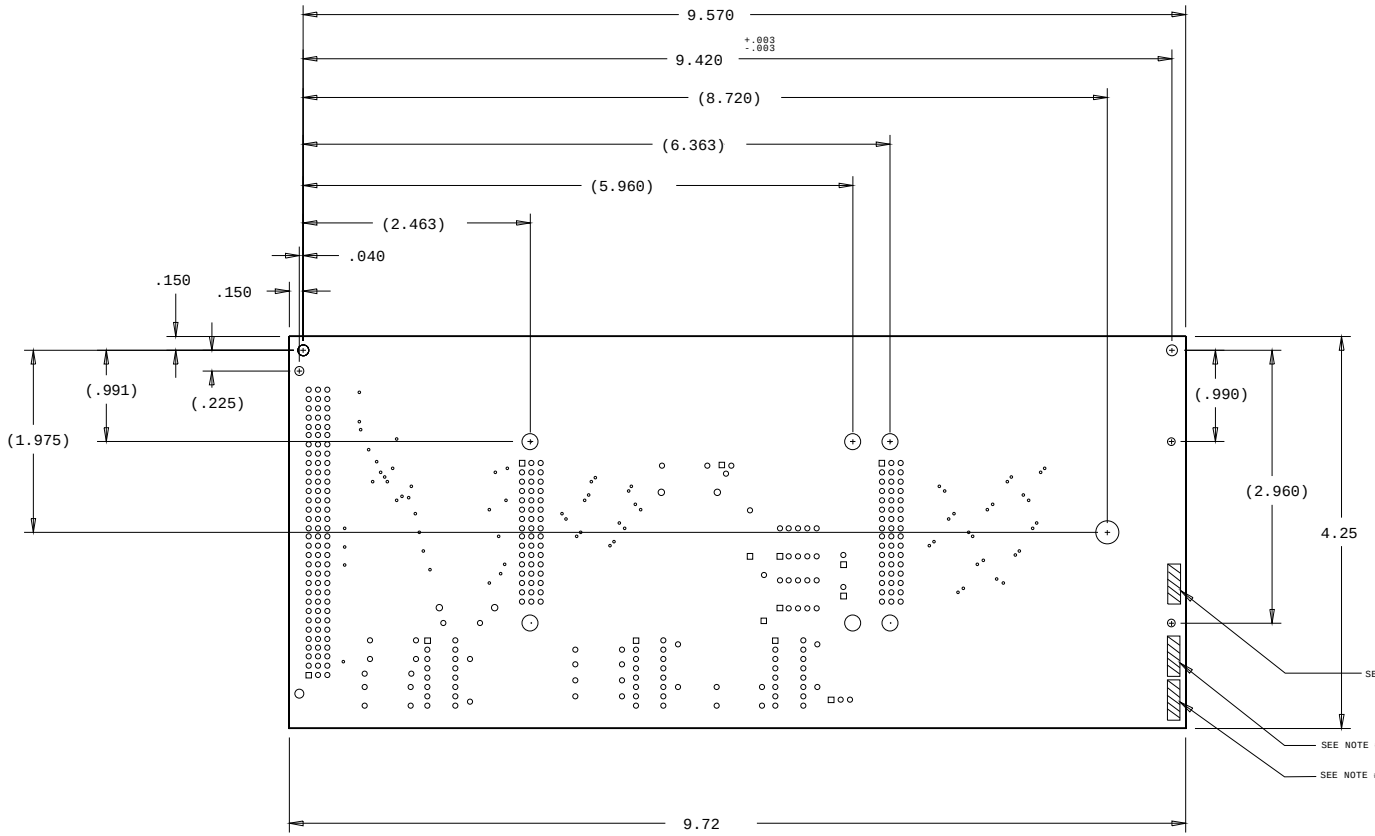
DATE 1/6/97 SCALE 1:1
DRN CAB APPR.

TITLE COMPONENT LAYOUT, CONNECTOR BOARD

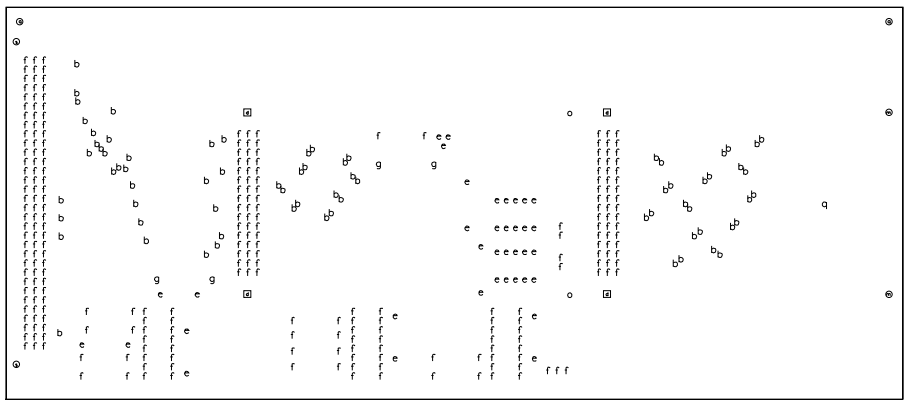
C NO. 7021-170

NO. 7021-172

LTR.	ECA NO.	REVISION	ENG.	DATE
A		RELEASED		



NOTES:
1. MUST COMPLY TO KEITHLEY SPECIFICATION #QS-354.
2. BOARD MUST BE FABRICATED USING UL APPROVED MATERIAL AND PROCESSES.
3. SUBSTRATE: NEMA GRADE FR4
   - BASE COPPER (OZ.): 1 OZ.
   - FINISHED COPPER PER SIDE (OZ.): 2 OZ.
   - BASE INNER LAYER COPPER (OZ.): 1 OZ.
   - FINISHED BOARD THICKNESS (IN.): .062 +.007 -.003
4. SUPPLIED DATA:
   - ETCH PER ARTWORK: 7021-173-06,-05,-04,-03,-02,-01A
   - DRILL PAD MASTER: NA
   - NC DRILL: FILE
   - SOLDERMASK ARTWORK: 7021-174-06,-01A
     SOLDERMASK ARTWORK CONTAINS SELECTED AREAS OF SOLDERMASK RELIEF ON GUARD TRACES.
   - SILKSCREEN ARTWORK: 7021-175-06A
5. SOLDERMASK: LEARONAL OR DYNACHEM PHOTOIMAGEABLE
6. SILKSCREEN COLOR: WHITE SIDES: -06
7. VENDOR UL APPROVAL LOGO ETCHING LOCATION.
8. VENDOR DATE CODE ETCHING LOCATION.
9. ELECTRICAL TEST VERIFICATION STAMP LOCATION.
10. QUOTING DATA:
    - TECHNOLOGY TYPE: PTH
    - MINIMUM TRACE SIZE: .010
    - MINIMUM PAD SIZE: .025
    - MINIMUM COPPER TO COPPER SPACING: .010



HOLE SIZE LEGEND
/ FIGURE / HOLESIZE / QTY /

b	.015-P	73
e	.035-P	37
f	.040-P	269
g	.043-P	4
o	.110-P	2
q	.125-P	1
▣	.128-P	4
◎	.093-N	2
◎	.104-N	2
◎	.125-N	2

MODEL	NEXT ASSEMBLY	QTY.
USED ON		

KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN. UNLESS OTHERWISE NOTED
DIM. TOL. UNLESS OTHERWISE SPECIFIED
XX=+.01 ANG.=+1
XXX=+.005 FRAC.=+1/64
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DATE 1/3/97 | SCALE 1:1
DRN CAB | APPR.

TITLE: HOLESIZE CONNECTOR BOARD
C NO. 7021-172

Index

KEITHLEY

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
❑ Data required
❑ Certificate of calibration 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.

KEITHLEY

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

Printed in the U.S.A.