KEITHLEY

Model 7168 Scanner Card

Instruction Manual

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Model 7168 Scanner Card Instruction Manual

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SPECIFICATIONS

MODEL 7168 nV SCANNER CARD

CHANNELS PER CARD: 8

CONTACT CONFIGURATION: 2 poles per channel, input HI and LO.

CONNECTOR TYPE: Screw terminal to bare copper printed circuit pad.

MAXIMUM SIGNAL LEVEL: 10V, 50mA, peak (resistive load)

CHANNEL TO CHANNEL CROSSTALK: −46dB (typical) at 1KHz with 20KΩ terminations.

CONTACT RESISTANCE: <12Ω

CONTACT POTENTIAL (HI to LO) BETWEEN CHANNELS: <30nV when properly zeroed with supplied leads (see manual for recommended procedure). Typically <60nV without zeroing.

Temperature Coefficient: <6nV/°C between channels

CONTACT TYPE: Solid-state JFET switch

ACTUATION TIME: <3ms, exclusive of mainframe

INPUT LEAKAGE: <50pA per channel at 23°C

INPUT ISOLATION: $>10^9\Omega$, <40pF between any input terminals or between any input terminal and earth.

COMMON MODE VOLTAGE: 30V peak

MAXIMUM VOLTAGE BETWEEN ANY TWO TERMINALS: 10V

GENERAL

WARMUP: 2 hours in mainframe for thermal stability.

ENVIRONMENT,

Operating: 0° to 40°C, up to 35°C at 70% RH

Storage: −25°C to 60°C

DIMENSIONS, WEIGHT: 32mm high × 114mm wide × 272mm long (1¼″ × 4½″ × 10¾″). Net weight 0.53kg (18.5 oz.)

ACCESSORIES SUPPLIED: 7168-316 Input Cable, Eight supplied
Model 1507 Input Cable

ACCESSORY AVAILABLE: Model 1483 Low Thermal Connection Kit

Specifications subject to change without notice.

SAFETY PRECAUTIONS

The following safety precautions should be observed before operating the Model 7168 and associated instruments.

This card is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the manual carefully before using the scanner card.

Exercise extreme caution when a shock hazard is present at the test circuit. The American National Standards Institute (ANSI) states that a shock hazards exists when voltage levels greater than 30V RMS or 42.4V peak are present. **A good safety practice is to expect that a hazardous voltage is present in any unknown circuit before measuring.**

Do not exceed 30V peak between inputs and outputs, and earth ground.

Inspect your test leads for possible wear, cracks or breaks before each use.

For maximum safety do not touch the test cables or any instruments while power is applied to the circuit under test. Turn the power off and discharge all capacitors before connecting or disconnecting the instrument.

Do not touch any object which 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 nV Card's maximum allowable input as defined in the specifications and operation section of this manual.

Do not subject the lithium batteries to temperatures greater than 60°C (140°F).

Safety Precautions

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

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

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

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

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

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

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

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

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

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

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

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

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

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

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

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

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a ⏚ screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

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

The ⚡ symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

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

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

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

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

HOW TO USE THIS MANUAL

SECTION 1 General Information

Contains information on the Model 7168 features, specifications, and supplied accessories.

SECTION 2 Operation

Details installation of the Model 7168 nV Scanner Card within the Model 705 Scanner, outlines connections, and also discusses measurement considerations and scanner mainframe programming.

SECTION 3 Applications

Gives two typical applications for low-voltage measurements with the Model 7168 when used with a Keithley Model 181 Digital Nanovoltmeter.

SECTION 4 Service Information

Contains performance verification and troubleshooting procedures for the Model 7168.

SECTION 5 Replaceable Parts

Lists replacement parts, and also includes component layout and schematic drawings for the nV Scanner Card.

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SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

This section contains general information about the Model 7168 nV Scanner Card and is arranged in the following manner:

1.2 Features
1.3 Warranty Information
1.4 Manual Addenda
1.5 Safety Symbols and Terms
1.6 Specifications
1.7 Unpacking and Inspection
1.8 Repacking for Shipment
1.9 Recommended Equipment
1.10 Scanner Compatibility
1.11 Optional Accessories

1.2 FEATURES

The Model 7168 nV Scanner Card is designed to switch voltages in the nV and μV range with minimum effects on signals being switched. Key Model 7168 features include:

- Eight 2-pole input channels.
- Solid-state JFET switching for maximum reliability and minimum offsets.
- Low contact potential for minimal offset effects on low-level signals.

1.3 WARRANTY INFORMATION

Warranty information is located on the inside front cover of this instruction manual. Should your Model 7168 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the scanner card for repair, be sure to fill out and include the service form at the back of this manual in order to provide the repair facility with the necessary information.

1.4 MANUAL ADDENDA

Any improvements or changes concerning the scanner card or manual will be explained on an addendum included with the unit. Please be sure to note these changes and incorporate them into the manual before operating or servicing the unit.

1.5 SAFETY SYMBOLS AND TERMS

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

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

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

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

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

1.6 SPECIFICATIONS

Model 7168 specifications may be found at the front of this manual. These specifications are exclusive of scanner mainframe specifications, which may be found in the instruction manual for that equipment.

1.7 UNPACKING AND INSPECTION

1.7.1 Inspection for Damage

Upon receiving the Model 7168, carefully unpack it from its shipping carton and inspect the card for any obvious signs of physical damage. Report any such damage to the shipping agent immediately. Save the original packing carton for possible future reshipment.

1.7.2 Shipment Contents

The following items are included with every Model 7168 order:

- Model 7168 nV Scanner Card.
- Model 7168 Instruction Manual.
- Standard accessories (summarized in Table 1-1).
- Additional accessories as ordered.

1.7.3 Additional Instruction Manuals

If an additional instruction manual is required, order the manual package, Keithley part number 7168-901-00. The manual package includes an instruction manual and any pertinent addenda.

Table 1-1. Supplied Accessories

Model	Description	Application
1507	Low thermal input cable	Connect 7168 Scanner Card to Model 181 Nanovoltmeter
7168-316 (8)	Low-thermal cable (10 ft.) terminated with copper lugs.	Connect 7168 Scanner Card to sources.

1.8 REPACKING FOR SHIPMENT

Should it become necessary to return the Model 7168 for repair, carefully pack the unit in its orginal packing carton or the equivalent, and include the following information:

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

1.9 RECOMMENDED EQUIPMENT

Table 1-2 summarizes recommended equipment to be used in conjunction with the Model 7168 to make low-level voltage measurements. Two packages incorporating this equipment are available from Keithley Instruments: the Model 705/7168 includes both a Model 705 Scanner and the Model 7168 nV Scanner Card, while the Model 68 includes a Model 181 Digital Nanovoltmeter along with the Models 705 and 7168.

Table 1-2. Recommended Equipment

Description	Application
Model 705 Scanner	Control Model 7168 Scanner Card
Model 181 Digital Nanovoltmeter	Measure voltage with 10nV sensitivity

Key features of the equipment summarized in Table 1-2 are summarized below.

Model 181 Digital Nanovoltmeter: The Model 181 is recommended to measure the low-level signal voltages switched by the Model 7168. Important Model 181 features include:

- 10nV sensitivity.
- 6½ digit display resolution.
- Standard IEEE-488 interface and full bus programmability.
- Pushbutton zero for ease in nulling offsets.

Model 705 Scanner: The Model 7168 nV Scanner Card plugs into and is controlled from the Model 705 Scanner, which can accommodate two scanner cards. Key Model 705 features include:

- Standard IEEE-488 interface and full bus programmability.
- Daisy chain operation allowing up to four scanner slaves to be controlled from one master scanner mainframe.
- Front panel programs for easier system configuration.
- Built-in day/time clock for time stamping of data.

1.10 SCANNER COMPATIBILITY

Although the Model 7168 is intended for use primarily with the Model 705 Scanner, it can also be used in the Keithley Model 706 Scanner. Note, however, that the Model 7168 should not be used with those scanners equipped with switching power supplies because of noise considerations. Only earlier versions of the Model 706 are equipped with switching power supplies; contact your Keithley representative or the factory for details.

1.11 OPTIONAL ACCESSORIES

The following accessories are available for use with the Model 7168.

Model 1483 Low Thermal Connection Kit

The Model 1483 Low Thermal Connection Kit contains a crimp tool, pure copper lugs, alligator clips, and assorted hardware. The Model 1483 can be used to prepare the ends of the supplied Model 7168-316 Input Cables.

Model 1484 Refill Kit

The Model 1484 contains replacement parts for the Model 1483 kit, including lugs, clips, and hardware.

SECTION 2
OPERATION

2.1 INTRODUCTION

This section contains information on scanner card connections, installation, measurement considerations, and scanner programming, and is arranged as follows:

2.2 **Handling Precautions:** Details certain precautions such as high impedance and static discharge considerations that should be observed when handling the scanner card.

2.3 **Environmental Considerations:** Outlines warm-up period and temperature variation considerations.

2.4 **Connections:** Discusses card connectors, wire preparation, terminal cleaning, as well as connecting methods.

2.5 **Card Installation and Removal:** Covers the basic procedures for installing and removing the card from the Model 705 Scanner.

2.6 **Measurement Considerations:** Discusses important considerations that should be taken into account when making low-level measurements with the Model 7168.

2.7 **Front Panel Scanner Programming:** Summarizes programming steps to control the nV card from the front panel of the Model 705 Scanner.

2.8 **IEEE-488 Bus Programming:** Reviews methods to control the Model 7168 through a Model 705 Scanner mainframe over the IEEE-488 bus.

2.2 HANDLING PRECAUTIONS

High impedance considerations, and static discharge and lithium battery precautions are discussed in the following paragraphs.

2.2.1 High Impedance Considerations

Because of the high-impedance circuits located on the scanner card, care should be taken when handling it to avoid contamination from such foreign materials as body oils. Such contamination can substantially lower leakage resistances, degrading performance.

To avoid possible contamination, always grasp the card only by the edges. When you remove the shield to make connections, be careful not to touch board surfaces or exposed parts.

Dirt build-up over a period of time is another possible source of contamination. To avoid possible problems in this area, operate the scanner and scanner card only in a clean environment. If contamination is suspected, the card should be carefully cleaned using the procedure given in paragraph 4.2 of this instruction manual.

2.2.2 Static Precautions

Although the scanner input and output terminals are static protected, the switching JFETs are static-sensitive and can be damaged by static discharge, rendering the card partially or completely inoperative. For that reason, ground yourself with a wrist strap if static is thought to be a problem.

CAUTION
Avoid static discharge to exposed circuits to avoid card damage, which may invalidate the warranty. Keep the card in the supplied anti-static pouch when not in use.

2.2.3 Lithium Batteries

Two lithium batteries, mounted on the scanner card circuit board, provide bias voltages for the switching JFETs. These batteries will be exposed when you remove the shield to make card connections. Be careful when working near the batteries.

WARNING

Be sure not to expose the lithium batteries to excessive heat (>60°C).

Paragraph 4.4 of this manual discusses replacement procedures and disposal precautions for the lithium batteries.

2.3 ENVIROMENTAL CONSIDERATIONS

2.3.1 Warm-Up Period

The Model 7168 can be used when power is first applied. However, for thermal stability, the scanner mainframe power should be turned on and the unit allowed to warm up for at least two (2) hours with the scanner card installed before use.

2.3.2 Temperature Variations

In order to minimize thermal EMFs, the Model 7168 and host scanner mainframe should be operated in stable temperature environments. Paragraph 2.6.2 discusses thermal considerations in more detail.

2.4 CONNECTIONS

Card connectors, shield removal, wire preparation, and terminal cleaning are discussed in the following paragraphs.

NOTE

The Model 1483 Low Thermal connection kit is recommended for making connections.

2.4.1 Shield Removal

In order to gain access to the input and output screw terminals, the shield must be removed as follows:

1. Remove the four screws from the shield, as shown in Figure 2-1.
2. Remove the top shield from the card by carefully lifting the shield off the printed circuit board. Do not separate the bottom shield PC board from the component board.
3. To replace the shield, line up its holes with those in the circuit board and replace the screws.

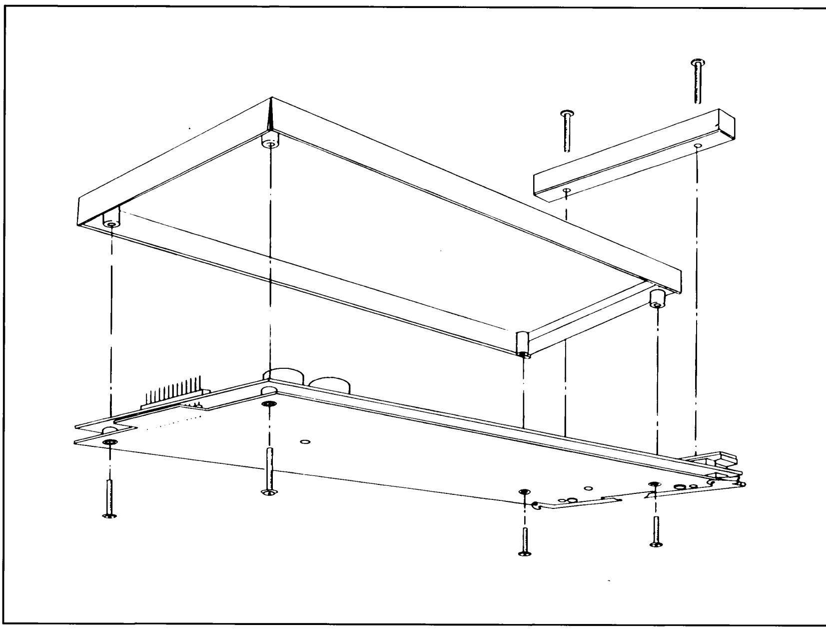


Figure 2-1. Shield Removal

2.4.2 Card Connectors

The input and output connecting screw terminals are shown in Figure 2-2. Each of the eight input channels has a LO (L) and HI (H) terminal, while the single output also has similarly marked HIGH and LOW terminals.

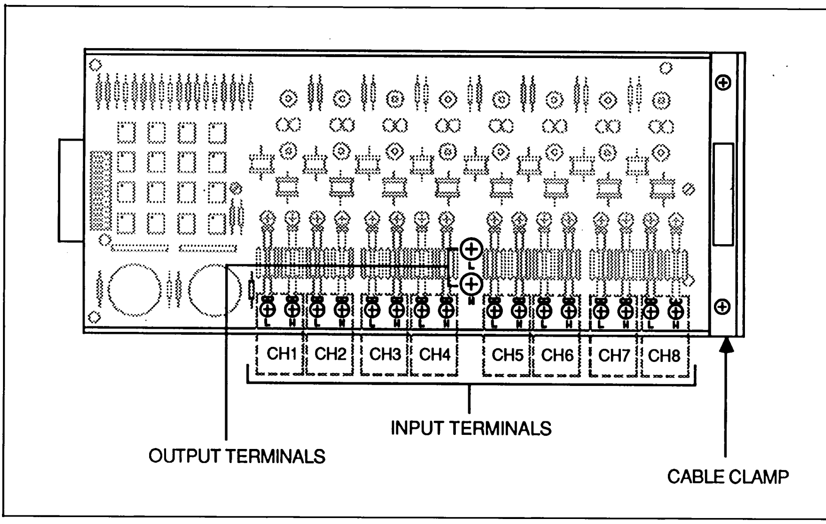


Figure 2-2. Input and Output Connection

2.4.3 Equivalent Circuit

Figure 2-3 shows an equivalent circuit of the Model 7168. The low and high terminals of each channel are routed to a pair of JFETs acting as switches. When the "contacts" are closed, the signals connected to that channel are routed to the output. Note that one or more channels may be connected to the card output simultaneously, depending on scanner programming, which is covered in paragraphs 2.7 and 2.8.

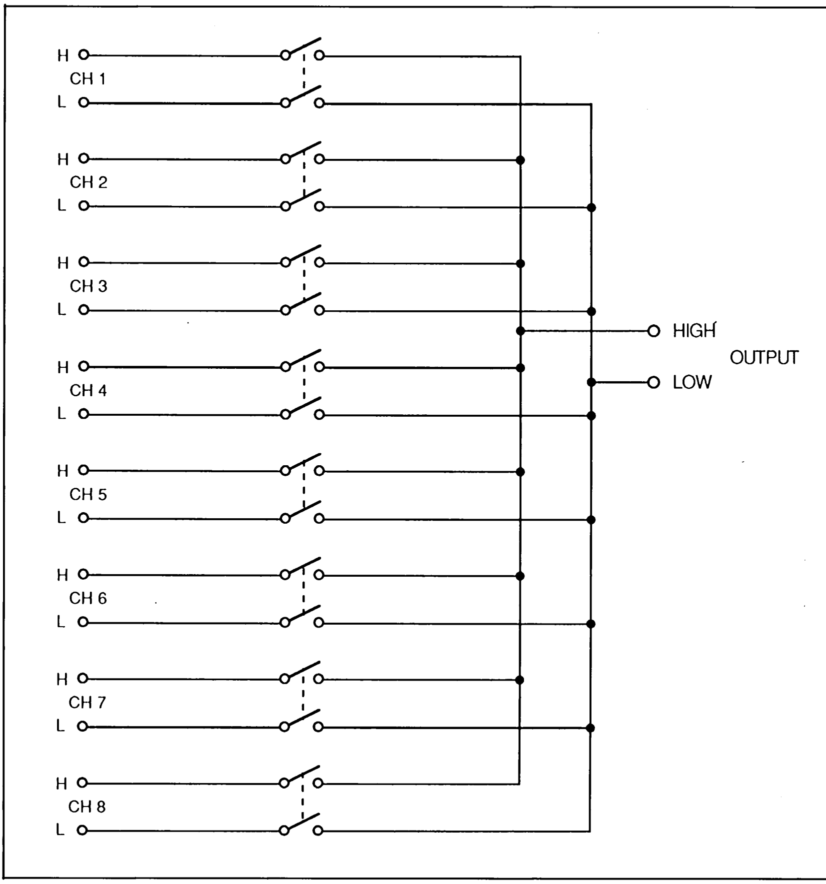


Figure 2-3. Equivalent Switching Circuit

2.4.4 Input Cable Preparation

The supplied 7168-316 input cables have lugs already installed for connection to the Model 7168 inputs. The unterminated ends can be prepared using the procedure below. Refer to Figure 2-4 for the following steps.

NOTE

To minimize offset voltages, use only copper lugs and wires and do not solder the lugs to the wires.

These instructions are for attaching solid copper lugs to the wires similar to the prepared ends of the cables. The bare wires may also be used to make voltage source connections.

1. Use an X-acto® knife to cut and strip the outer insulation back about 1½ inches.
2. Remove the piece of insulation and the aluminum-polyester shield, fold back the tinned copper drain (shield) wire.
3. Carefully strip the insulation on the red and black wires back ¼ inch. Slide a length of black heat shrink tubing down over the black wire and a length of red heat shrink tubing down over the red wire.
4. Place a clean, solid copper lug over each of the red and black wires' bare copper strands. Crimp the lugs on.
5. Slide the red and black heat shrink tubing over the wire/lug connection and shrink.

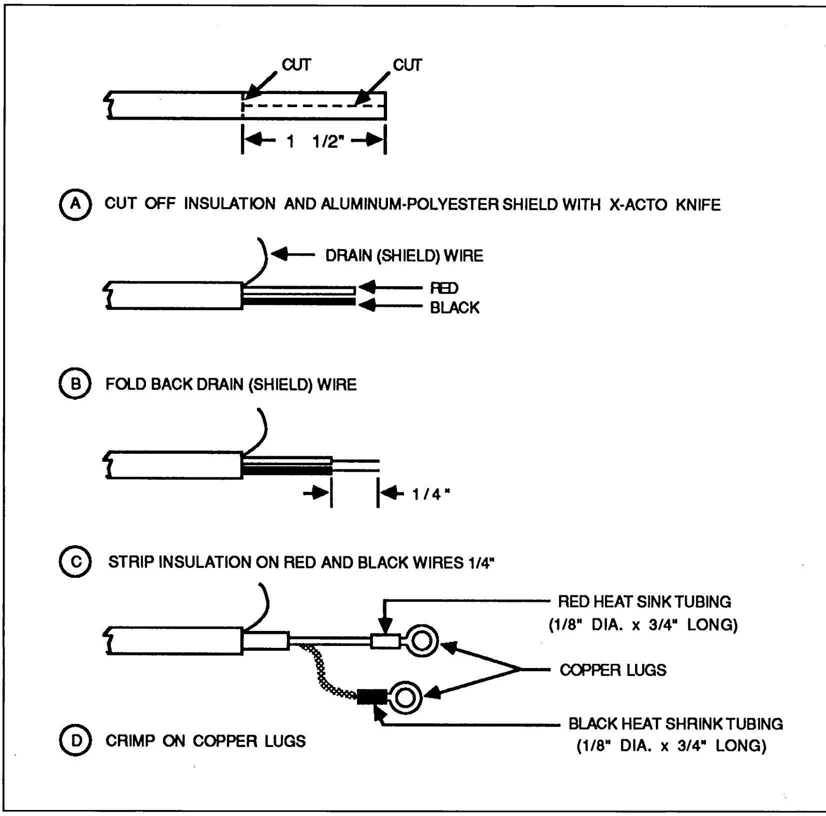


Figure 2-4. Input Cable Preparation

2.4.5 Terminal Cleaning

In order to minimize offsets due to thermoelectric potentials, it is important that all copper terminals and lugs be kept clean and free of oxidation. Before making connections, carefully inspect all connecting points; clean any oxidized connections with Scotchbrite® abrasive pad, then make the connections immediately.

The importance of clean connections is illustrated by comparing offset voltage generation for clean and oxidized copper connections. Clean copper-to-copper connections result in typical offsets of 0.2μV/°C or less, while a copper to copper-oxide junction may yield offsets as high as 1000μV/°C. More information on thermoelectric potentials may be found in paragraph 2.6.2.

2.4.6 Making Connections

Use the following general procedure to connect the card inputs and output. Figure 2-5 shows the card connected to a Model 181 Digital Nanovoltmeter and includes two input connections. Note that only copper wires and copper lugs should be used to minimize thermoelectric potentials.

WARNING
Maintain all inputs and outputs within 30V of earth ground.

CAUTION
The maximum input voltage is ±10V. Exceeding this value may cause damage to the scanner card.

NOTE
Connections should be carefully made as outlined below in order to minimize crosstalk and thermal offsets.

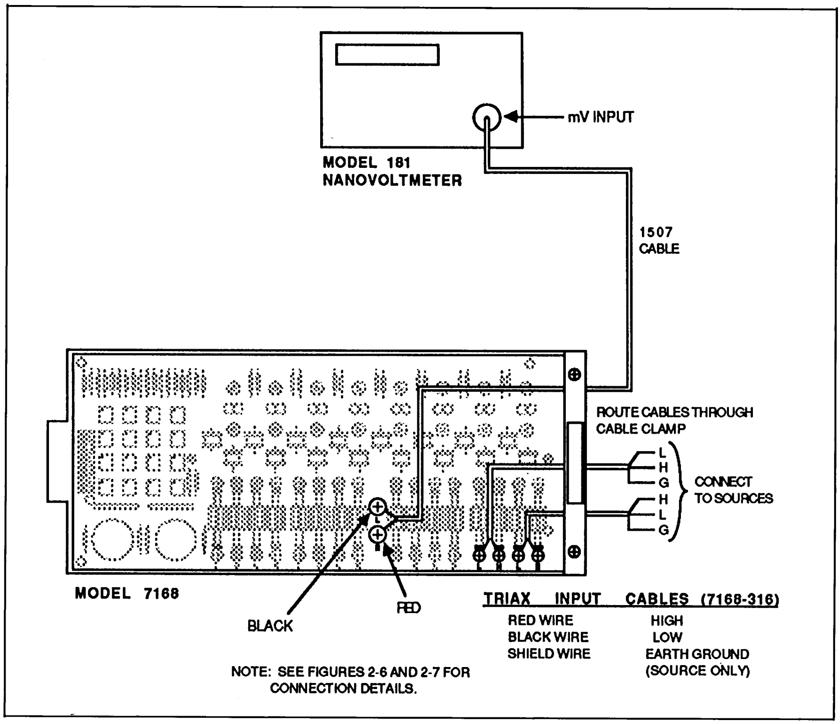


Figure 2-5. Typical Connections

1. Loosen the two screws that secure the cable clamp on the end of the card to allow wires to pass between the foam rubber strips.
2. Remove the top shield as discussed in paragraph 2.4.1.
3. Route all connecting wires between the rubber strips of the cable clamp, and bend the lugs as shown in Figure 2-6(D).
4. Connect the supplied Model 1507 cable to the output terminals as follows (see Figure 2-7 for details):
   A. Remove the screws from the output terminals.
   B. Clean the PC board output terminal pads and the bottom side of the Model 1507 cable lugs with Scotchbrite® .
   C. Place the lugs on the pads with the orientation shown in Figure 2-7.

D. Replace the screws and tighten them securely, making sure the lugs do not rotate from the proper position.

5. Connect the input cables to the H and L terminals of the respective channels as follows (see Figure 2-6 for details).

   A. Remove the input connection screws from the circuit board.

   B. Clean the circuit board copper pads, both sides of the 7168-316 input cable lugs, and the bottom side of the coil lugs with Scotchbrite® . Be careful not to clean near PCB traces.

   C. Put the input cable lugs on top of the circuit board pads with the orientation shown in Figure 2-6(E).

   D. Place the coil wire lugs on top of the input cable lugs (see Figure 2-6(E) for orientation).

   E. Replace the screws and tighten them securely. When tightening the screws, be sure that adjacent lugs do not rotate and touch one another, or be in a position to short the shield or shield standoffs when the shield is installed.

6. Connect the opposite ends of the input cables to the low and high terminals of the signal sources to be measured.

7. Connect the opposite end of the Model 1507 cable to the mV input of the Model 181 Digital Nanovoltmeter, as shown in Figure 2-5.

8. Route all cables as necessary to clear the shield, then install the shield using the screws removed earlier.

9. Tighten the screws on the strain relief so that all cables are secure.

10. Install the Model 7168 in the scanner, as discussed in the following paragraph.

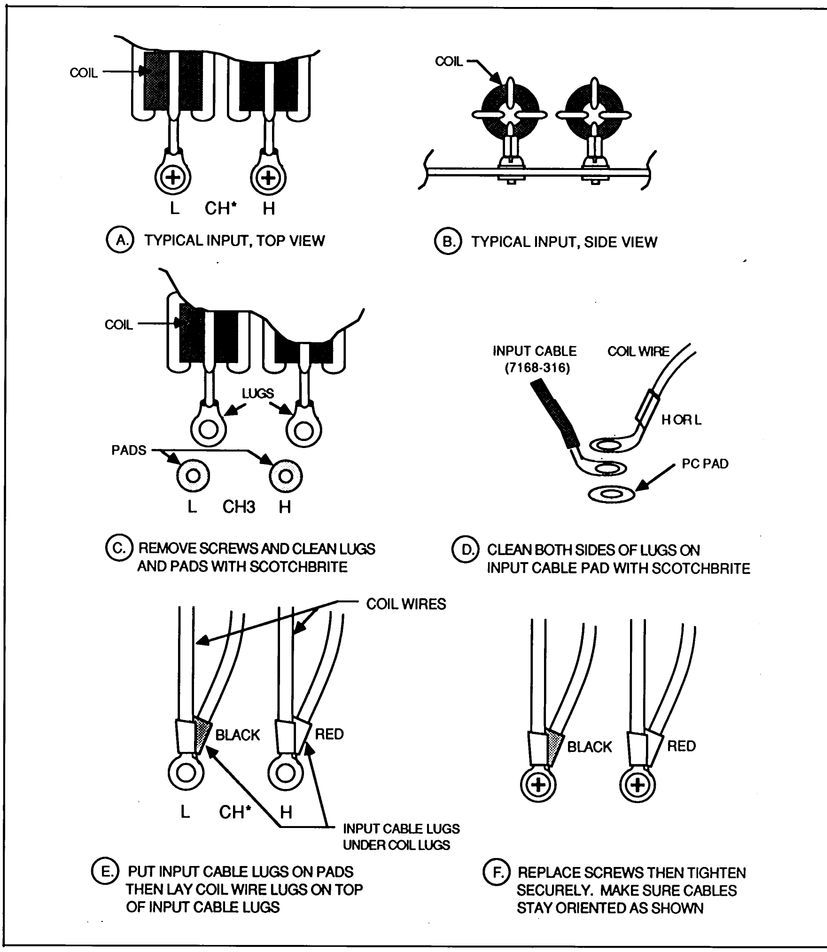
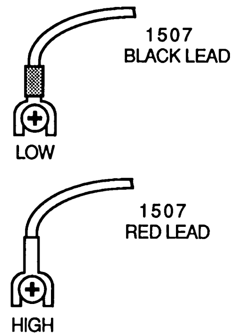


Figure 2-6. Detail of Input Connections



OUTPUT CONNECTIONS :

1. REMOVE SCREWS.
2. CLEAN PADS AND BOTTOM SIDE OF LUGS WITH SCOTCHBRITE.
3. PLACE LUGS ON PADS AS SHOWN.
4. REPLACE SCREWS AND TIGHTEN SECURELY.

Figure 2-7. Detail of Output Connections

2.4.7 Dual Multiplexer Operation

The Model 7168 can also be used as two isolated 8-to-1 multiplexers, allowing the card to control two independent groups of signals and route them to two separate outputs. To use the card in this manner, route one group of signal paths through the HI inputs and output, and the second set of signal paths through the LO inputs and output. When using this configuration, external signal return paths (such as power line ground) must be provided. Keep in mind, however, that the HI and LO paths for a given channel are switched simultaneously, and there is no way to independently control the HI and LO inputs for a given channel.

2.5 CARD INSTALLATION AND REMOVAL

The Model 7168 can be installed in and removed from the Model 705 Scanner using the following procedures.

WARNING
Turn off the scanner power and disconnect the line cord before installing or removing scanner cards.

2.5.1 Installation in the Model 705 Scanner

Install the card in the Model 705 as follows, using Figure 2-8 as a guide.

1. Slide the card into the desired slot with the shield side facing up. Make sure the card edges of the bottom shield board are properly aligned with the grooves in the receptacle.
2. Once the card is almost all the way in the slot, and you encounter resistance, push firmly on the edge of the card to seat it firmly in the edge connector.
3. Once the card is fully seated, lock the card in place by placing the tabs in the locked position, as shown in Figure 2-8.

2.5.2 Card Removal

To remove the scanner card, first unlock the two tabs by pulling them outward, then grasp the end of the card at the edges, and pull the card free of the scanner mainframe.

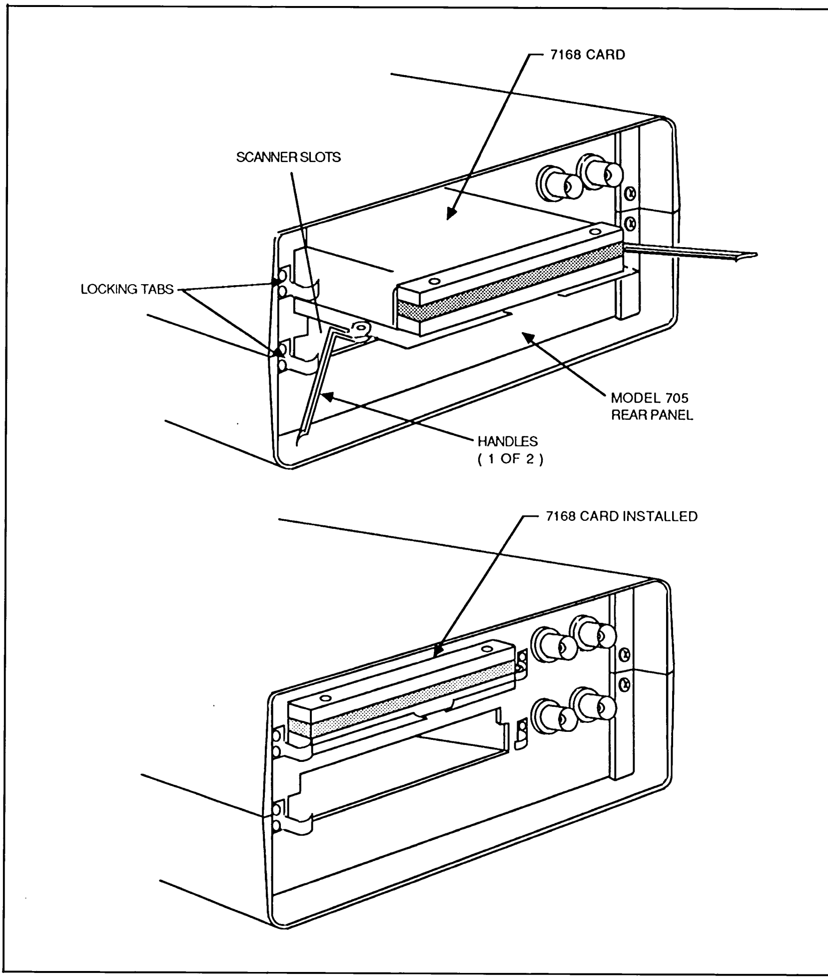


Figure 2-8. Card Installation

2.6 MEASUREMENT CONSIDERATIONS

Low-level voltage measurements are subject to various types of noise that can make it extremely difficult to obtain accurate voltage readings. Because the measuring instrument cannot distinguish between signals and noise voltages, the presence of unwanted low-level signals can seriously affect the measurement.

Some of the phenomena that can cause unwanted noise include: thermocouple junctions (thermoelectric effects), cable flexing (triboelectric effects), and the battery action of two terminals (galvanic action). The following paragraphs discuss possible noise sources in more detail.

2.6.1 Source Resistance Noise

Noise that is present in the source resistance itself is frequently the limiting factor in the ultimate resolution of a measurement system. The amount of noise present in a given resistance is given by the Johnson noise equation as follows:

$$E_{RMS} = \sqrt{4KTRF}$$

Where: E_{RMS} = RMS value of the noise voltage

K = Boltzman's constant (1.38×10^{-23} J/K)

T = Temperature (°K)

R = Source resistance (ohms)

F = Noise bandwidth (Hz)

At a room temperature of 293°K (20°C), the above equation can be simplified as follows:

$$E_{RMS} = 1.27 \times 10^{-10} \sqrt{RF}$$

Since it has been statistically shown that the peak to peak noise is five times the RMS value 99% of the time, we can equate the following:

$$E_{p\text{-}p} = 6.35 \times 10^{-10} \sqrt{RF}$$

From these equations, it is obvious that noise voltage can be reduced in several ways: (1) lower the temperature; (2) reduce the source resistance; and (3) narrow the bandwidth. Of these three, lowering the resistance is the least practical because the signal voltage will be reduced more than the noise voltage. For example, decreasing the resistance of a current shunt by a factor of 100 will reduce the signal voltage by a factor of 100 as well. The noise voltage, however, will be reduced only by a factor of 10.

Very often cooling the source is the only practical method available to reduce the noise. Here again, the reduction available is not as large as it might seem because the reduction is related to the square root of the change in temperature. For example, to cut the noise in half, the temperature must be decreased from 293°K to 73.25°K, a four-fold decrease.

As an example of determining the amount of noise present, assume that a source with an internal resistance of 10kΩ is being measured. At a room temperature of 293°K (20°C), the p-p noise developed over a bandwidth of 0.5Hz will be:

$$E_{p\text{-}p} = 6.35 \times 10^{-10} \sqrt{(10 \times 10^{3})(0.5)}$$

$$E_{p\text{-}p} = 45\text{nV}$$

2.6.2 Thermoelectric Potentials

Thermoelectric potentials (thermal EMFs) are small electric potentials generated by differences in the temperature at the junction of dissimilar metals. As shown in Table 2-1, the magnitude of the thermal EMFs depends on the particular materials involved. Although these thermal EMFs can affect measurements in the mV range if serious enough, they can be especially troublesome with the nV and μV signals levels encountered with the Model 7168.

To minimize thermal EMFs, use only copper wires and copper lugs for all input and output connections in the test system. Also, make certain that all connecting surfaces are clean and free of oxides. As noted in Table 2-1, copper-to-copper oxide connections can result in thermal EMFs as high as 1000μV/°C. For scanner card output to the Model 181, the supplied Model 1507 Low-Thermal Cable should always be used to minimize possible thermal EMF effects.

Table 2-1. Thermoelectric Coefficients

Materials	Thermoelectric Potential
Copper - Copper	≤0.2μV/°C
Copper - Silver	0.3μV/°C
Copper - Gold	0.3μV/°C
Copper - Cadmium/tin	0.3μV/°C
Copper - Lead/tin	1-3μV/°C
Copper - Kovar	40μV/°C
Copper - Silicon	400μV/°C
Copper - Copper Oxide	1000μV/°C

Even when low-thermal cables and connectors are used, thermal EMFs can still be a problem in some cases. It is especially important to keep the two materials forming the junction at the same temperature. Keeping the two junctions close together is one way to minimize such thermal problems.

In some cases, connecting the two thermal junctions together with good thermal contact to a common heat sink may be required. Unfortunately, most good electrical insulators have good thermal insulating characteristics as well. In cases where such low-thermal conductivity may be a problem, special insulators that combine high electrical insulating properties with high thermal conductivity may be used. Some examples of these materials include: hard anodized aluminum, beryllium oxide, specially filled epoxy resin, sapphire, and diamond.

Figure 2-9 shows a representation of how thermal EMFs are generated. The test leads are made of material A, while the source under test is the B material. The temperatures between the junctions are shown as T_1 and T_2. To determine the thermal EMF generated, the following relationship may be used:

$$E_T = Q_{AB} (T_1 - T_2)$$

Where: E_T = Generated thermal EMF

Q_{AB} = Thermoelectric coefficient of material A with respect to material B (μV/°C)

T_1 = Temperature of B to A junction (°K or °C)

T_2 = Temperature of A to B junction (°K or °C)

In the unlikely event the two junction temperatures are identical, the thermal EMFs will exactly cancel, since the generated potentials oppose one another. More often, the two junction temperatures will differ, and considerable thermal EMFs will be generated.

A typical test setup will probably have several copper-to-copper junctions. Typically, such a junction can have a thermoelectric coefficient as high as 0.2μV/°C. Since the two materials will frequently have a several degree temperature differential, it is easy to see how thermal potentials of several microvolts can be generated, even if reasonable precautions are taken.

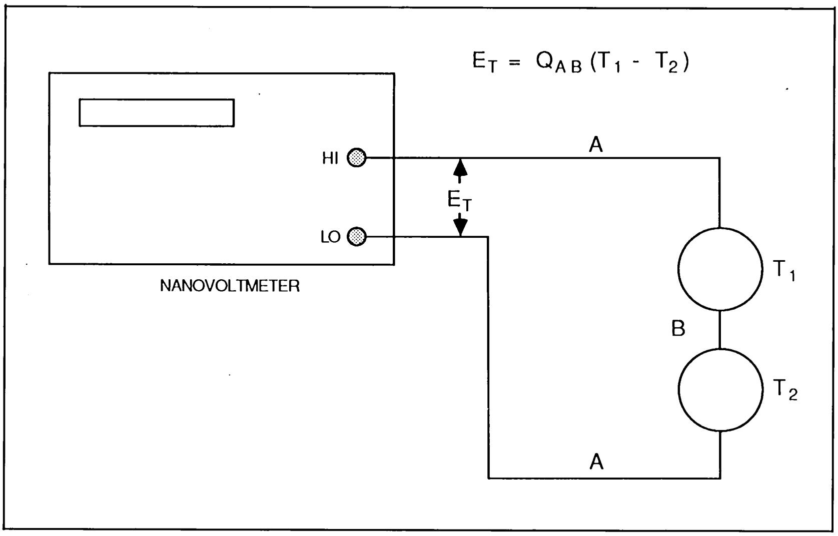


Figure 2-9. Thermal EMF Generation

2.6.3 Magnetic Fields

When a conductor cuts through magnetic lines of force, a very small current is generated. This phenomenon will frequently cause unwanted signals to occur in the test leads of a measuring instrument. If the conductor has sufficient length, even weak magnetic fields like those of the earth can create sufficient signals to upset measurements in the nV or μV range. Thus, several precautions may be taken if magnetic-field induced signals become a problem.

Reducing the the length of the leads and minimizing the exposed circuit area are two ways these effects can be minimized. In extreme cases, magnetic shielding may be required. Special metals with high permeability at low flux densities (such as mu metal) are effective in this application.

Even in cases where the conductor is stationary, magnetically-induced signals may still be a problem. Fields may be produced by various signals such as the AC power line voltage. Large inductors such as power transformers are very good magnetic field generators, so care must be taken to keep the measuring circuit 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. Using this method, the resulting fields will be largely cancelled out.

2.6.4 Ground Loops

When two or more devices 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. The resulting ground loop causes current to flow through the instrument LO signals leads and then back through power line ground (see Figure 2-10). Because of this circulating current, a small but undesirable voltage is developed between the LO terminals of the two instruments. This voltage will be added to the source voltage, upsetting the measurement.

To see how a ground loop can affect the voltage readings, refer to Figure 2-11. Here, the source to be measured is connected to the measuring device (a nanovoltmeter in this case) through the customary HI and LO signal leads, with the resistance of the LO terminal connection represented by R. This resistance is generally very low--typically about 0.1Ω, but even this low value can result in significant error voltages if the circulating current is high enough.

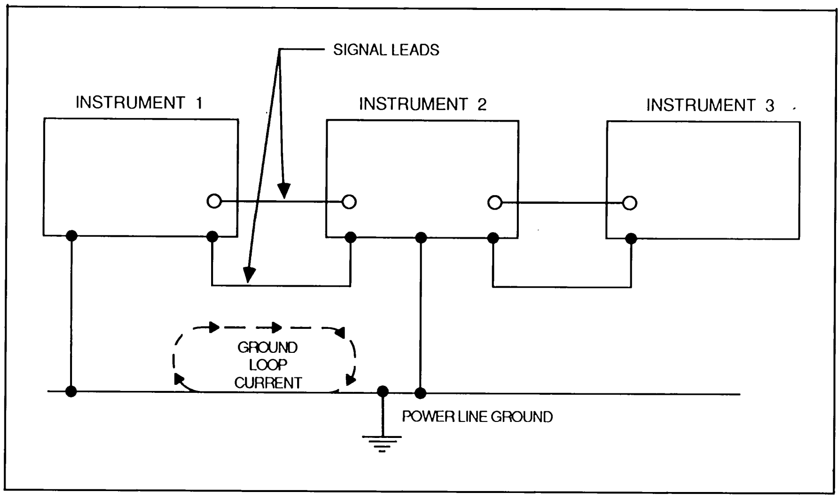


Figure 2-10. Power Line Ground Loops

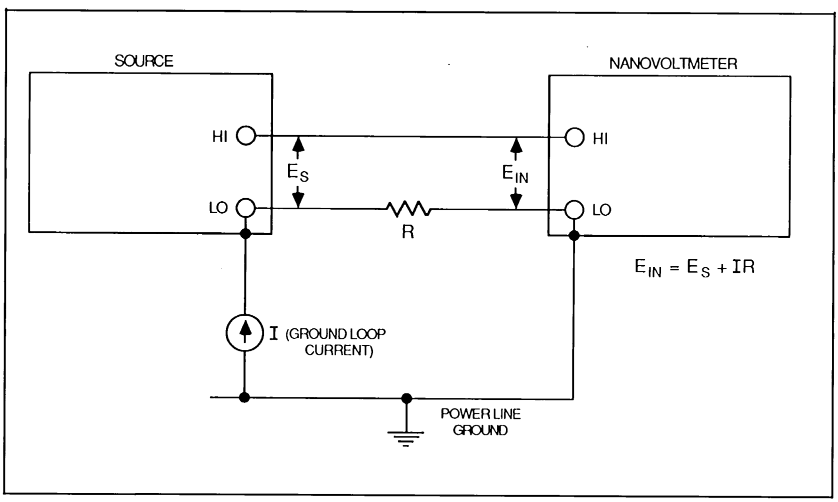


Figure 2-11. Generating Ground Loop Voltage

The source voltage is E_S, while the ground loop current is I. The actual voltage seen by the nanovoltmeter is the sum of the source voltage and the IR drop across the resistance R, and is given as follows:

$$E_{IN} = E_S + IR$$

Thus with a 100nV source voltage, an R value of 0.1Ω, and a 100nA ground loop current, the total voltage seen by the measuring instrument will be 110nV, resulting in an error of 10%.

Figure 2-12 shows a test configuration that will eliminate this type of ground loop problem. Here, only the center instrument is connected to power line ground. Ground loops are not normally a problem with instruments with isolated LO terminals (such as the Model 181 Nanovoltmeter), but other instruments in the test setup may not be designed in the same way. When in doubt, consult the manual for all instrumentation in the test setup.

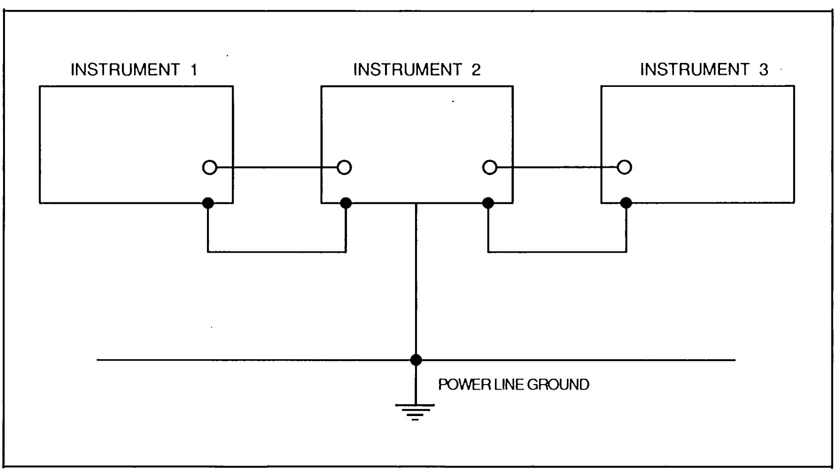


Figure 2-12. Eliminating Ground Loops

2.6.5 Radio Frequency Interference (RFI)

RFI (Radio Frequency Interference) is a general term used to describe electromagnetic interference over a wide range of frequencies across the spectrum. Such RFI can be especially troublesome at signal levels in the nV and and μV signal levels associated with the Model 7168.

RFI can be caused by steady-state sources such as radio, TV broadcast 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. With either type, the affect on the measurement can be considerable if enough of the unwanted signal is present.

RFI can be minimized by taking one or more of several precautions when making low-level voltage measurements in such environments. The most obvious method for minimizing these effects is to keep all equipment and signal leads as far away from the RFI source as possible. Shielding the scanner card, signal source, test leads, and measuring instrument 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 like the Model 181 Nanovoltmeter incorporate internal filtering that may help to reduce RFI effects in some situations. In some cases, additional external filtering may also be helpful.

2.6.6 Switching FET Thermals

The FETs that switch the channels have an on resistance of approximately 10Ω. As a result, any current that flows through the devices will cause some power dissipation in them. This power dissipation can cause significant thermal offset voltages in some situations, as we will now discuss.

In most applications, the current through the FETs is small enough so that power dissipation is negligible. For example, assume we are switching a 200mV signal with the Model 7168 and measuring the voltage through the mV input of a Model 181 Nanovoltmeter. Since the Model 181 has a nominal mV input resistance of >1GΩ, the current through the switching FETs of the selected channel (ignoring any card input bias current) is:

$$I = \frac{E}{R}$$

$$I = \frac{0.2}{1 \times 10^9}$$

$$I = 200pA$$

The power dissipation under these conditions is:

$$P = I^2 R$$

$$P < (2 \times 10^{-10})^2 \times 10$$

$$P < 4 \times 10^{-19}W$$

Here, we see that the power dissipation is so small that we can consider it to be zero for all practical purposes.

The situation changes if much larger currents are allowed to flow through the FETs. For example, assume the maximum rated current of 50mA flows through the FETs. In this case, the power dissipation for each FET becomes:

$$P = I^2 R$$

$$P = (0.05)^2 \times 10$$

$$P = 25mW$$

With this level of power dissipation, substantial thermal offset voltages can be generated by FET heating. These thermals can, of course, substantially reduce the quality of low-level voltage measurements. Thus, to minimize the effects of these thermals, you should allow at least one hour for the FETs to temperature stabilize before making sensitive voltage measurements after switching relatively large currents (>1mA).

2.6.7 Contact Potential Correction

The Model 7168 Nanovolt Scanner Card provides benefits in applications where low-level voltages must be switched. JFET switches eliminate self-heating offset errors associated with electromechanical relays. This design produces repeatable results with both fast and slow scanning. The thermal time constant and power dissipation of a mechanical relay would cause the offset error to vary with the duration of relay closure, but this problem is eliminated by the solid-state design of the Model 7168. Voltage offsets are further reduced by using copper-to-copper contacts on the board.

The apparent contact potential that may be observed when using the Model 7168 is a function of cable connections at the scanner and at the source, the type of cable conductor material, and the amount of oxidation at each junction. For that reason, the entire measurement system, including cables, connecting lugs, etc., must be taken into account when considering thermoelectric potential error sources.

To realize the full capability of the Model 7168 nV Scanner Card, the procedure below should be used to remove initial thermal EMFs.

There are several points to keep in mind when correcting readings with this procedure:

1. Correction is valid only at the temperature at which it was performed. The temperature coefficient (see specifications) should be used to compensate for variation due to temperature drift; or simply re-correct at the new temperature.

2. Nanovoltmeter drift is not corrected by this procedure. These error terms should also be factored into the final readings. See the specifications for the measuring instrument.
3. Correction becomes more critical for lower signal levels. For example, at 1mV an uncorrected accuracy of 0.01% will result with a signal voltage of 1mV. That figure rises to 10% uncorrected accuracy at a level of 1μV.

Manual Correction Procedure

The manual method for offset correction assumes that the supplied Model 7168-316 Input Cables and the Model 1507 are already connected to the scanner card, and that the card is installed and warmed up in the Model 705 Scanner.

Proceed as follows:

1. Short the source ends of the Model 7168-316 input cables HI to LO (red to black). If lugs are crimped on, use an alligator clip, or a nut and screw to short the lugs together. If no lugs are being used, carefully twist the center conductor and inner shield together. Keep shorted wires away from air currents.
2. Allow the Model 705/7168 to warm up for two hours, and the Model 181 to warm up for four hours before proceeding.
3. Connect the Model 1507 mV connector to the Model 181 mV INPUT jack. Allow 5 minutes minimum to thermally stabilize.
4. Close channel 1 on the scanner.
5. Select the 2mV range and 6½ digit resolution on the Model 181, and allow the reading to settle.
6. Record the channel 1 offset reading.
7. Close channel 2 and then open channel 1.
8. Allow the reading to settle, and then record the offset reading for channel 2.
9. Repeat steps 7 and 8 for channels 3 through 8, recording the offset for each channel. Be sure to close the next channel before opening the previous one, and also allow sufficient time for each reading to settle.
10. Remove the shorts from the Model 7168 input cables and connect the cables to the voltage sources to be measured.

11. Measure each source voltage by closing the appropriate channel and recording each reading. Be sure to place the Model 181 on the lowest range possible without overanging the unit; also allow sufficient time for each reading to settle before recording it.
12. Calculate the corrected readings by subtracting the offset values obtained in steps 6 through 9 from the voltage source readings measured in step 11. The resulting values represent the actual, corrected source voltages.

Example 1: Assume that the measured offset voltage is +30nV, and that the measured source voltage is +90nV. The corrected voltage is:
90nV −30nV = 60nV.

Example 2: If the offset voltage is −35nV, and the measured voltage is +110nV, the corrected voltage is:
110nV − (−35nV) = 145nV.

Computerized Correction

The fundamental correction procedure outlined above can also be incorporated into a computer program. An example is shown below; Figure 2-13 is a flowchart of the program.

There are several important points to remember when running this program:

1. The Model 705/7168 must be allowed to warm up for at least two hours, and the Model 181 must warm up for at least four hours.
2. The program assumes that the Model 7168-316 input cables are connected to the channel inputs, and that the Model 1507 cable is connected to the card output terminals.
3. For the zeroing process, each Model 7168-316 cable must be shorted HI to LO. The program will prompt you to do so at the appropriate point. The readings taken with the inputs shorted are offset values that are later subtracted from final readings to obtain corrected values.
4. After the zeroing process, you will be prompted to remove the channel shorts and connect the voltage sources to be measured. After

this step, the program will cycle through the eight channels, taking a reading from each, and correcting the value based on the earlier stored offset for that particular channel.

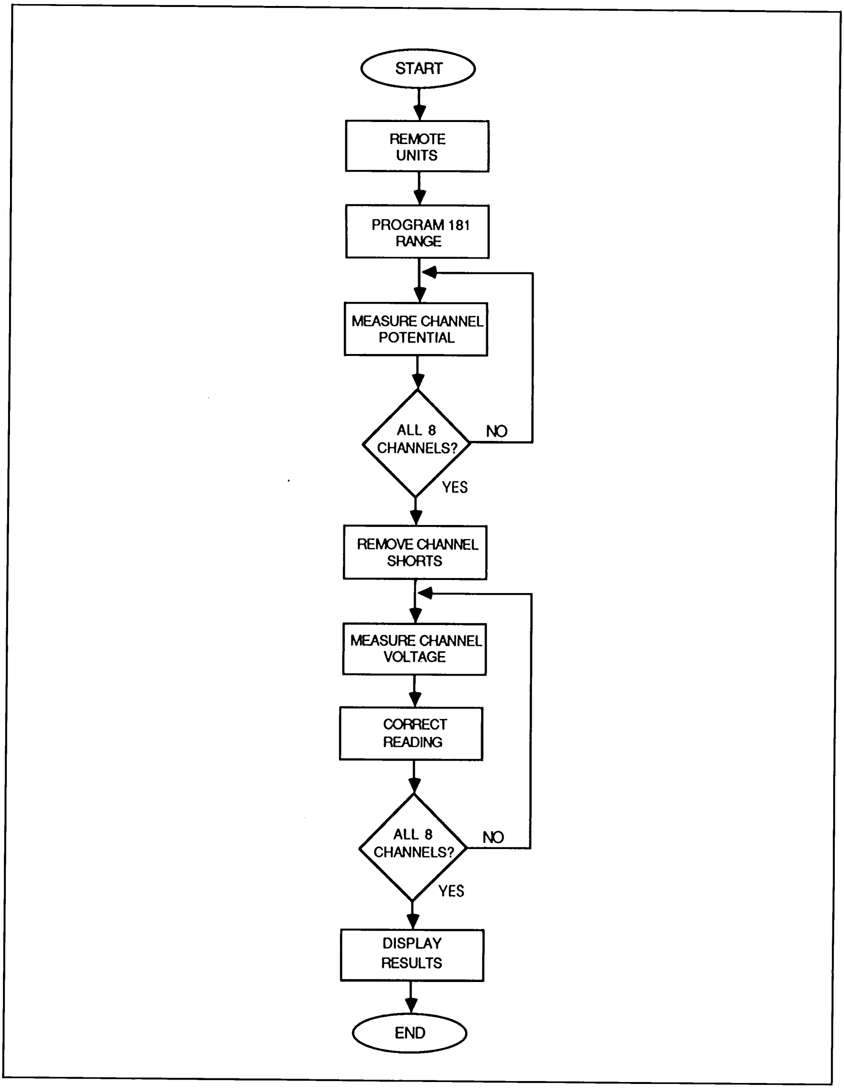


Figure 2-13. Contact Potential Correction Program Flowchart

Contact Potential Correction Program

```
10 P1=705 ! 181 ADDRESS IS 5
20 P2=717 ! 705 ADDRESS IS 17
30 DIM Z(8),V(8) ! DIMENSION ZERO,DATA ARRAYS
40 CLEAR ! CLEAR DISPLAY
50 REMOTE P1,P2 ! PUT UNITS IN REMOTE
60 CLEAR 7 ! SEND DEVICE CLEAR
70 OUTPUT P1 ;"B1P2X" ! 6-1/2 DIGITS,FILTER ON
80 DISP "THIS PROGRAM DEMONSTRATES"
90 DISP "CHANNEL OFFSET CORRECTION"
100 DISP "FOR THE MODELS 181 AND 7168"
110 DISP
120 DISP "SELECT RANGE"
130 DISP "1=2MV"
140 DISP "2=20MV"
150 DISP "3=200MV"
160 DISP
170 INPUT R ! INPUT 181 RANGE
180 IF R<1 OR R>3 THEN 120 ! CHECK RANGE LIMITS
190 DISP "MAKE SURE ALL CHANNEL INPUTS"
200 DISP "ARE SHORTED."
210 DISP
220 DISP "PRESS 'CONT'"
230 PAUSE
240 REM ***ROUTINE TO STORE CHANNEL ZERO VALUES ******
250 DISP
260 DISP "MEASURING CHANNEL OFFSETS"
270 FOR I=1 TO 8 ! LOOP FOR ALL 8 CHANNELS
280 OUTPUT P2 ;"C";I;"X" ! CLOSE CHANNEL I
290 OUTPUT P2 ;"B";I;"X" ! DISPLAY CHANNEL I
300 IF I>1 THEN 350 ! BYPASS UNLESS FIRST TIME THROUGH
310 OUTPUT P1 ;"R";R;"X" ! PROGRAM 181 RANGE
320 WAIT 30000 ! WAIT 30 SECONDS FOR SETTLING
330 GOTO 360
340 OUTPUT P2 ;"N";I-1;"X" ! OPEN CHANNEL I-1
350 WAIT 10000 ! WAIT 10 SECONDS
```

```
360 ENTER P1 ; A$ ! GET CHANNEL ZERO READING
370 Z(I)=VAL(A$[5,16]) ! STORE CHANNEL ZERO IN ARRAY
380 NEXT I ! LOOP BACK FOR NEXT CHANNEL
390 OUTPUT P2 ;"N8X" ! OPEN CHANNEL 8
400 DISP
410 DISP "REMOVE SHORTS FROM ALL"
420 DISP "CHANNELS, CONNECT TO SOURCES"
430 DISP "PRESS 'CONT'"
440 PAUSE
450 REM *** CORRECTED MEASUREMENT LOOP*****
460 DISP
470 DISP "MEASURING..."
480 FOR I=1 TO 8 ! LOOP FOR ALL 8 CHANNELS
490 OUTPUT P2 ;"C";I;"X" ! CLOSE CHANNEL I
500 OUTPUT P2 ;"B";I;"X" ! DISPLAY CHANNEL I
510 WAIT 10000 ! WAIT 10SEC TO SETTLE
520 ENTER P1 ; A$ ! GET 181 READING
530 V(I)=VAL(A$[5,16])-Z(I) ! CORRECT READING
540 OUTPUT P2 ;"N";I;"X" ! OPEN CHANNEL I
550 NEXT I ! LOOP BACK FOR NEXT CHANNEL
560 IMAGE "CH#",D,X,MD.DDDe,X,"VOLTS"
570 CLEAR ! CLEAR DISPLAY
580 CLEAR 7 ! SEND DEVICE CLEAR
590 FOR I=1 TO 8 ! LOOP FOR ALL CHANNELS
600 DISP USING 560 ; I,V(I) ! DISPLAY CORRECTED READING
610 NEXT I ! LOOP BACK FOR NEXT CHANNEL
620 END
```

2.7 FRONT PANEL SCANNER PROGRAMMING

The following paragraphs discuss in general terms front panel operation of the Model 705 Scanner when used with the Model 7168. For more detailed programming information, refer to the Model 705 Instruction Manual.

2.7.1 Entering the 2-Pole Mode

Because the Model 7168 is designed to operate with the Model 705 in the 2-pole mode, the scanner must be programmed as follows:

1. Press PRGM, 6 in that order to enter the pole selection program. The unit will then display the following:

   POLE

2. Press 2, ENTER to select the 2-pole mode.
3. The unit will then display the status of channel 1. Note that all channels will be open after using Program 6.

2.7.2 Scanner Display Format

In the 2-pole mode, the Model 705 display format appears as follows:

nn F or L O or C

Where: nn represents the channel number
F or L indicate first or last channel (blank for other channels)
O and C represent open and closed respectively.

Since the Model 705 can hold two cards, and up to five units can be daisy chained, the unit can control up to 100 2-pole channels. However, since the Model 7168 has only eight channels, a total of 80 Model 7168 channels can be controlled, as summarized in Table 2-2. Note that the channel to access depends on both the slot and unit involved. For example, to access channel 3 on a Model 7168 located in slot 2 of unit #1, you would select channel 13 on the Model 705.

Table 2-2. Model 7168/705 Channels

	Card	Model 7168 Channel							
Unit*	Slot**	1	2	3	4	5	6	7	8
1	1	1	2	3	4	5	6	7	8
1	2	11	12	13	14	15	16	17	18
2	1	21	22	23	24	25	26	27	28
2	2	31	32	33	34	35	36	37	38
3	1	41	42	43	44	45	46	47	48
3	2	51	52	53	54	55	56	57	58
4	1	61	62	63	64	65	66	67	68
4	2	71	72	73	74	75	76	77	78
5	1	81	82	83	84	85	86	87	88
5	2	91	92	93	94	95	96	97	98

*Unit 1 is master for daisy chained units.
**Slot 1 is marked CARD 1 ; slot 2 is marked CARD 2.

2.7.3 Scanner Switching Control

The Model 705 Scanner operates on a "break-before-make" basis when scanning. A delay of 1msec occurs between the time the current channel opens until the next channel closes to ensure that no two sources are connected together.

When switching channels manually, however, it is possible to have two or more channels on simultaneously. In this situation, it is important that the potential between channel inputs not exceed 1V, or you will risk damaging the scanner card. (10V may be applied if the current is limited to 50mA or less).

2.7.4 Manual Channel Control

Individual channels can be controlled as follows:

1. Use Program 6 to place the scanner in the 2-pole mode.
2. Display the desired channel either by using the CHANNEL button for sequential access, or by keying in the channel number with the DATA keys. For example, to access channel 8, key in 0 8.
3. Use the OPEN or CLOSE key to update the channel status, as desired.
4. To open any closed channels quickly, press the RESET key. The unit will also return to channel 1 display in addition to opening any closed channels.

2.7.5 Scan Operation Programming

The Model 7168 can be operated in the scan mode by appropriately programming the Model 705. The basic procedure is as follows:

1. Use Program 6 to select 2-pole operation.
2. Program the first and last channels, as required.
3. Select single or continuous scan mode using the appropriate SCAN key.
4. Select the desired interval per channel with the INTERVAL key.
5. Press START/STOP to initiate the scan. The instrument will cycle through all programmed channels at selected intervals.

2.8 IEEE-488 BUS PROGRAMMING

The Model 7168 may be controlled over the IEEE-488 bus through the Model 705, as described in the following paragraphs. For more detailed bus information, consult the Model 705 Instruction Manual.

2.8.1 Bus Commands

Table 2-3 summarizes the bus commands necessary to control the scanner card. Remember that each command or command string must be terminated with the X character before the scanner will execute them. Additional commands may be found in the Model 705 Instruction Manual.

Table 2-3. Abbreviated Model 705 Command Summary

Command	Description
A2	Select 2-pole operation
Bnnn	Display channel nnn
Cnnn	Close channel nnn
Fnnn	Set first channel nnn
Hnnn.nnn	Set settle time nnn.nnn
Lnnn	Set last channel nnn
Nnnn	Open channel nn
P0	Step
P1	Single
P2	Continuous
X	Execute commands

2.8.2 Program Example

The example program below will allow you to open or close a specific channel on the Model 7168. The programs are written in Hewlett-Packard Model 85 BASIC, but the syntax for other similar computers (such as the HP9816) is virtually identical. More detailed applications programs are located in Section 3.

Note that the card must be in the CARD 1 location of the scanner.

Program	Comments
`10 REMOTE 717`	! Put 705 in remote.
`20 OUTPUT 717; ''A2X''`	! Select 2-pole operation.
`30 CLEAR`	! Clear CRT.
`40 DISP''CHANNEL # (1-8)''`	! Prompt for channel.
`50 INPUT C`	! Input channel number.
`60 IF C < 1 OR C > 8 THEN 50`	! Check channel limits.
`70 OUTPUT 717;''B'';C;''X''`	! Display selected channel.
`80 DISP ''OPEN OR CLOSE (O OR C)''`	! Open or close prompt.
`90 INPUT C$`	! Input response.
`100 IF C$# ''O'' AND C$#''C'' THEN 80`	! Check for proper response.
`110 IF C$=''O'' THEN OUTPUT 717; ''N'';C;''X''`	! Output open command string.
`120 IF C$=''C'' THEN OUTPUT 717; ''C'';C;''X''`	! Output close command string.
`130 GOTO 40`	
`140 END`	

SECTION 3
APPLICATIONS

3.1 INTRODUCTION

This section gives typical applications for the Model 7168 nV Scanner Card and is arranged as follows:

3.2 Thermocouple Testing: Outlines a basic procedure, equipment configuration, and also gives a typical program for testing thermocouples.

3.3 Low-Resistance Testing: Summarizes procedures, equipment, and gives a sample program for testing low-resistance devices such as shunts and bus bars.

Note that the example programs are written in Hewlett-Packard Model 85 BASIC. Since these programs are intended as examples, they may require some modification to fit your particular measurement situations.

3.2 THERMOCOUPLE TESTING

The Model 7168 can be used in conjunction with a Keithley Model 181 Digital Nanovoltmeter to automatically test thermocouples. Since thermocouple output voltages are in the μV and mV range, the nV Scanner Card is necessary to avoid the offset effects of more ordinary switching circuits that could affect measurement accuracy.

3.2.1 System Configuration

Figure 3-1 shows the system configuration for this application. The components of the system perform the following functions:

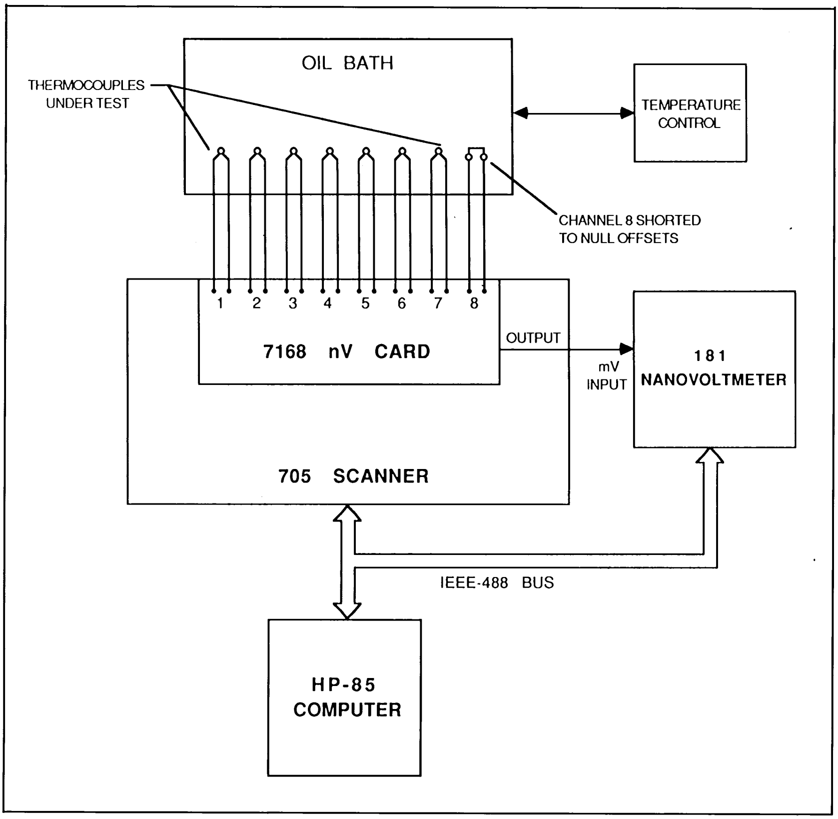


Figure 3-1. System Configuration for Thermocouple Testing

HP-85 computer: Controls the 705 Scanner and 181 Nanovoltmeter through the application program. Data sent back to the computer is then further processed and displayed.

Model 705 Scanner: Controls the Model 7168 nV Card in accordance with commands sent from the computer.

Model 7168 nV Scanner Card: Switches among the seven thermocouples under test and a low-thermal short used to null offsets. The output of the thermocouple being measured is connected through the scanner card to the mV input of the Model 181 for measurement.

Oil bath and temperature control: These components are intended to maintain the thermocouple junctions being tested at a constant temperature. Although not shown on the diagram, a temperature control computer interface could be used to provide automated control of temperature.

Model 181 Nanovoltmeter: Measures each thermocouple voltage and then sends the data to the computer for further processing.

3.2.2 Example Program

The program below will allow you to perform automated testing using the system configuration shown in Figure 3-1. Figure 3-2 is a general flowchart of this program.

At the start of the program, you will be prompted to select the Model 181 range and the time interval between measurements. Remember that the selected time interval should be sufficiently long to allow the circuit to settle. After these selections, the program will proceed to close channel eight and then zero the Model 181 to null offsets (a clean solid copper wire must be connected between the L and H channel 8 terminals of the scanner card to take advantage of this feature). Next, the seven thermocouples will be scanned at the selected interval with the voltage measured by the nanovoltmeter. Note that each measurement is checked for an overflow condition to determine if the proper Model 181 range is selected. If an overflow occurs, the program will branch back to allow you to select a new range.

Each voltage measurement is stored in a numeric array, and, at the conclusion of the test, all seven thermocouple measurements are displayed on the computer CRT. Finally, the average and standard deviation of the data are computed and displayed to determine thermocouple variations.

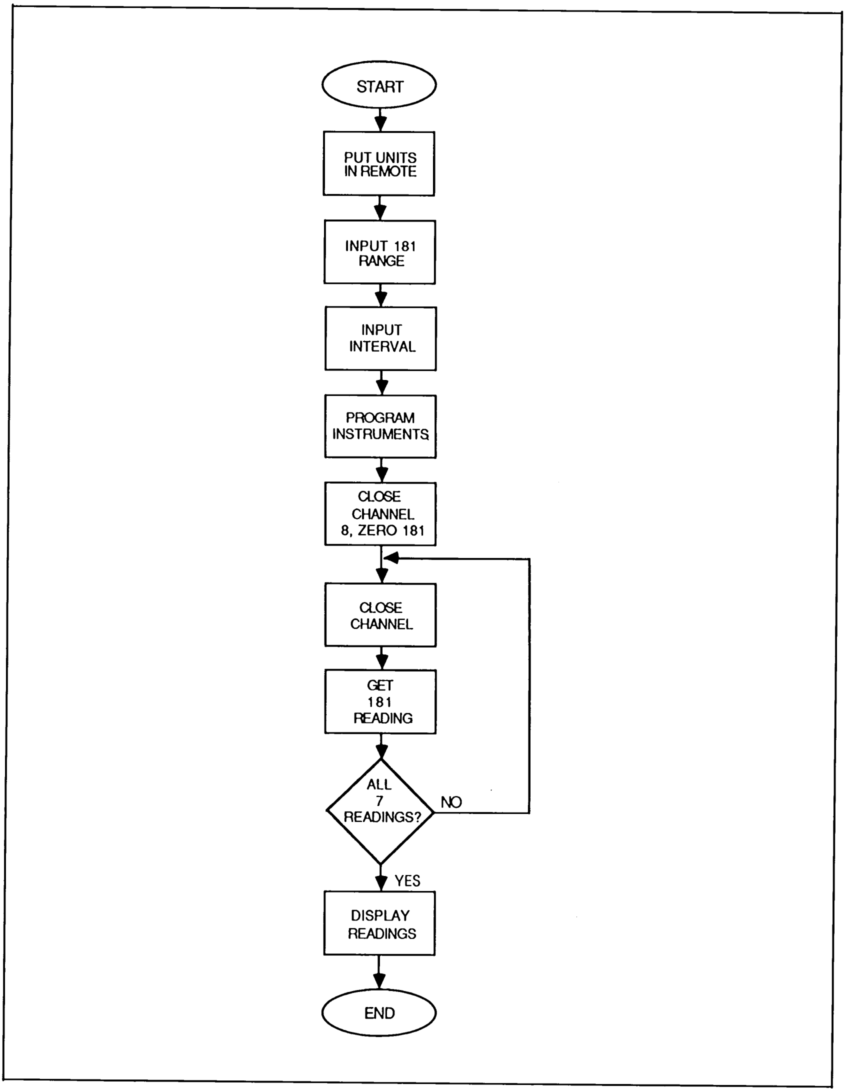


Figure 3-2. Thermocouple Program Flowchart

Program 1 Thermocouple Testing

```
10 P1=705 ! 181 ADDRESS IS 5
20 P2=717 ! 705 ADDRESS IS 17
30 DIM A$[25],A(7) ! DIMENSION STRING AND ARRAY
40 REMOTE P1,P2 ! PUT INSTRUMENTS IN REMOTE
50 CLEAR 7 ! SEND DEVICE CLEAR
60 CLEAR ! CLEAR SCREEN
70 DISP "THIS PROGRAM MEASURES"
80 DISP "THERMOCOUPLES CONNECTED"
90 DISP "TO CHANNELS 1-7."
100 DISP "A LOW-THERMAL SHORT MUST"
110 DISP "BE CONNECTED TO CHANNEL 8."
120 DISP
130 DISP "SELECT 181 RANGE"
140 DISP "1=2mV"
150 DISP "2=20mV"
160 DISP "3=200mV"
170 DISP
180 DISP "SELECTION"
190 INPUT R ! INPUT 181 RANGE
200 IF R<1 OR R>3 THEN 130
210 DISP "INTERVAL BETWEEN CHANNELS (MSEC)"
220 INPUT T
230 OUTPUT P1 ;"R";R;"X" ! PROGRAM 181 RANGE
240 OUTPUT P2 ;"A2X" ! SELECT 705 2 POLE MODE
250 CLEAR
260 DISP "PRESS 'CONT' TO MEASURE."
270 PAUSE
280 DISP "MEASURING..."
290 OUTPUT P2 ;"C8X" ! CLOSE CHANNEL 8
300 WAIT T ! SETTLING TIME
310 OUTPUT P1 ;"Z1X" ! ZERO 181
320 OUTPUT P2 ;"N8X" ! OPEN  CHANNEL 8
330 FOR I=1 TO 7 ! LOOP FOR ALL CHANNELS
340 OUTPUT P2 ;"C";I;"X" ! CLOSE CHANNEL I
350 OUTPUT P2 ;"B";I;"X" ! DISPLAY CHANNEL I
360 WAIT T ! SETTLING TIME
370 ENTER P1 ; A$ ! GET 181 READING
```

```
380 IF A$[1,1]#"O" THEN 400 ! CHECK FOR OFLO
390 DISP "181 OVERFLOW" @ CLEAR 7 @ GOTO 130
400 A(I)=VAL(A$[5,16]) ! CONVERT 181 READING
410 OUTPUT P2 ;"N";I;"X" ! OPEN CHANNEL I
420 NEXT I
430 BEEP @ DISP "MEASUREMENTS COMPLETE"
440 CLEAR 7 ! SEND DEVICE CLEAR
450 DISP
460 A=0 @ B=0
470 FOR I=1 TO 7 ! LOOP FOR ALL SEVEN CHANNELS
480 A=A+A(I) @ B=B+A(I)^2 ! COMPUTE SUMS
490 IMAGE "TC",D,"= ",MD.5De," VOLTS"
500 DISP USING 490 ; I,A(I) ! DISPLAY VOLTAGES
510 NEXT I ! LOOP BACK FOR NEXT CHANNEL
520 DISP
530 C=A/7 ! COMPUTE AVERAGE
540 D=SQR((B-7*C^2)/7) ! COMPUTE STANDARD DEVIATION
550 IMAGE "AVERAGE= ",D.5De," VOLTS"
560 IMAGE "STD DEV= ",D.5De," VOLTS"
570 DISP USING 550 ; C ! DISPLAY AVERAGE
580 DISP USING 560 ; D ! DISPLAY STANDARD DEVIATION
590 DISP
600 DISP "REPEAT TEST"
610 INPUT B$
620 IF B$[1,1]="Y" THEN 130
630 END
```

3.3 LOW-RESISTANCE TESTING

Low resistance testing of such devices as bus bars and low-resistance shunts can be performed by placing a current source and voltmeter across the resistance being measured, as shown in Figure 3-3. With this method, the resistance can be computed by dividing the measured voltage by the current source value. For example, with a voltage of 100μV, and a current of 10mA, the resistance is: 100μV/10mA = 0.01Ω.

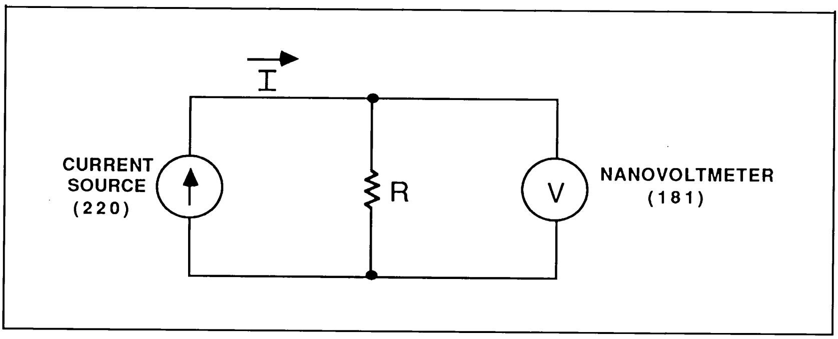


Figure 3-3. Sourcing Current Through Resistance to Develop Voltage

3.3.1 System Configuration

Figure 3-4 shows a typical system configuration for testing low resistances in this manner. System components have the following functions:

Computer: Controls the scanner, current source, and nanovoltmeter over the IEEE-488 bus. Data sent from the nanovoltmeter is in volts, so the computer must also calculate and display the resistance.

Model 705 Scanner: Controls the Model 7168 nV Card under supervision of the computer program.

Test fixture and resistors: The test fixture holds the eight resistances under test, which are designated R1 through R8. These resistances could be individual shunt resistors, or they may represent the equivalent resistances between individual nodes on a bus bar. Note that these resistors are wired in series so that a single current source can supply all eight resistors.

Model 181 Nanovoltmeter: Measures the voltage across each resistance as it is selected by the scanner. The resulting data is then sent over the IEEE-488 bus to the computer for further computation.

Model 220 Current Source: Sources the current through all eight resistances simultaneously. The current value is programmed over the IEEE-488 bus.

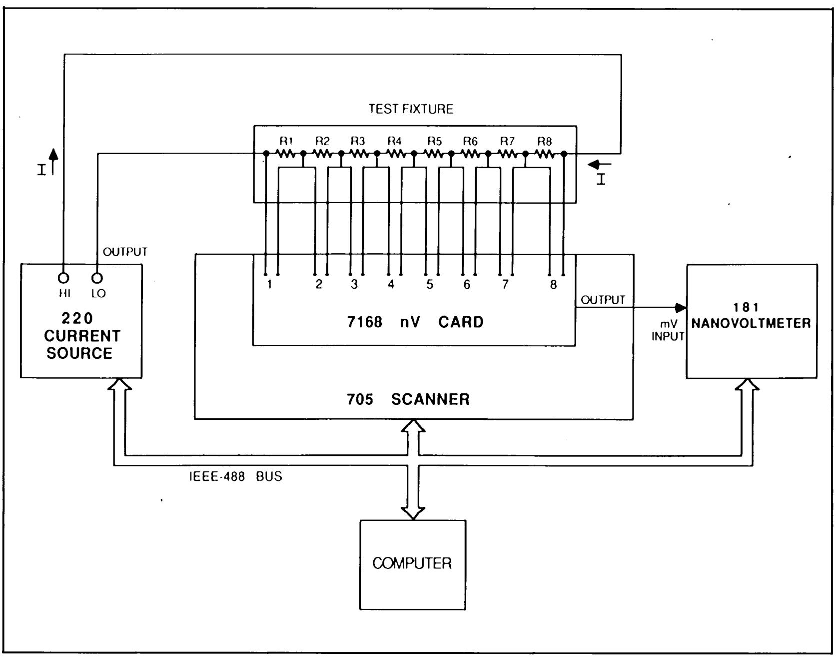


Figure 3-4. System Configuration for Low Resistance Measurements

3.3.2 Sample Program

The program below performs the low-resistance tests described above using the system configuration shown in Figure 3-4. A program flow-chart is shown in Figure 3-5.

At the beginning of the program, you will be prompted for the Model 181 range and the Model 220 current amplitude. When selecting these items, keep in mind the approximate resistances being measured so as not to overrange the Model 181. One additional prompt allows you to program the time interval between measurements. Note that each interval is divided into three segments: the first two delays are part of the zeroing process, while the third delay allows the circuit to properly settle before each measurement. Keep in mind that you must enter a sufficiently long time interval to allow the circuit to settle properly.

Following parameter initialization, the program will sequence the scanner through the eight channels, measuring the voltage across each resistor in sequence. Following the program, the current and voltages are used to calculate the resistances, which are then displayed on the computer CRT.

Program 2 Low Resistance Testing

```
10 P1=705 ! 181 ADDRESS IS 5
20 P2=717 ! 705 ADDRESS IS 17
30 P3=712 ! 220 ADDRESS IS 12
40 DIM A$[25],A(8) ! DIMENSION STRING AND ARRAY
50 REMOTE P1,P2,P3 ! PUT INSTRUMENTS IN REMOTE
60 CLEAR 7 ! SEND DEVICE CLEAR
70 CLEAR ! CLEAR SCREEN
80 DISP "THIS PROGRAM MEASURES"
90 DISP "VOLTAGES ACROSS RESISTORS"
100 DISP "CONNECTED TO CHANNELS 1-8"
110 DISP "AND THEN COMPUTES THE"
120 DISP "RESISTANCES"
130 DISP
140 DISP "220 CURRENT (500fA-101mA)"
150 INPUT I1 ! INPUT 220 CURRENT
160 IF I1<5.E-13 OR I1>.101 THEN 140 ! CHECK LIMI
170 DISP
180 DISP "SELECT 181 RANGE"
190 DISP "1=2mV"
200 DISP "2=20mV"
210 DISP "3=200mV"
220 DISP
230 DISP "SELECTION"
240 INPUT R ! INPUT 181 RANGE
250 IF R<1 OR R>3 THEN 180 ! CHECK RANGE LIMITS
260 DISP "INTERVAL BETWEEN CHANNELS (MSEC)"
270 INPUT T ! INPUT DELAY  INTERVAL
280 T=T/3 ! SEGMENT DELAY INTO THIRDS
290 OUTPUT P1 ;"R";R;"X" ! PROGRAM 181 RANGE
300 OUTPUT P2 ;"A2X"    ! SELECT 705 2 POLE MODE
310 OUTPUT P3 ;"I";I1;"X" ! PROGRAM 220 CURRENT
320 OUTPUT P3 ;"V20X" ! 220 20V COMPLIANCE
330 CLEAR
340 DISP "PRESS 'CONT' TO MEASURE."
350 PAUSE
360 DISP "MEASURING..."
370 FOR I=1 TO 8 ! LOOP FOR ALL 8 CHANNELS
```

```
380 OUTPUT P2 ;"C";I;"B";I;"X" ! CLOSE CHANNEL
390 WAIT T ! SETTLING TIME
400 OUTPUT P1 ;"Z1X" ! ZERO THE 181
410 WAIT T ! SETTLING TIME
420 OUTPUT P3 ;"F1X" ! TURN ON 220 OUTPUT
430 WAIT T ! WAIT FOR CIRCUIT TO SETTLE
440 ENTER P1 ; A$ ! GET READING FROM 181
450 IF A$[1,1]#"O" THEN 460
455 DISP "181 OVERFLOW" @ CLEAR 7 @ GOTO 130
460 A(I)=VAL(A$[5,16]) ! PUT READING IN ARRAY
470 OUTPUT P2 ;"N";I;"X" ! OPEN CHANNEL I
480 OUTPUT P3 ;"F0X" ! TURN OFF 220 OUTPUT
490 OUTPUT P1 ;"Z0X" ! TURN OFF 181 ZERO
500 NEXT I ! LOOP BACK FOR NEXT CHANNEL
510 BEEP @ DISP "MEASUREMENTS COMPLETE"
520 CLEAR 7 ! SEND DEVICE CLEAR
530 DISP
540 FOR I=1 TO 8 ! LOOP FOR ALL EIGHT CHANNELS
550 IMAGE "R",D,"= ",MD.5De," OHMS"
560 DISP USING 550 ; I,A(I)/I1 ! DISPLAY RESISTANCE
570 NEXT I ! LOOP BACK FOR NEXT DATA POINT
580 DISP
590 DISP "REPEAT TEST"
600 INPUT B$
610 IF B$[1,1]="Y" THEN 130
620 END
```

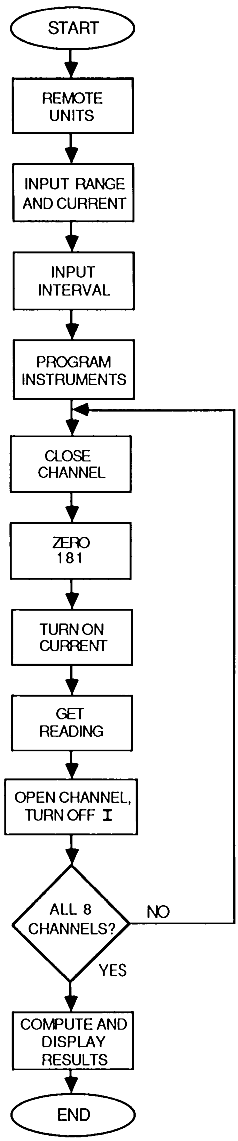


Figure 3-5. Low Resistance Program Flow Chart

SECTION 4
SERVICE INFORMATION

4.1 INTRODUCTION

This section contains information necessary to service the Model 7168 nV Scanner Card and is arranged as follows:

4.2 **Handling and Cleaning Precautions:** Discusses handling precautions and cleaning methods for the scanner card.

4.3 **Performance Verification:** Covers the procedures necessary to determine if the card is operating properly.

4.4 **Battery Replacement:** Details replacement and disposal of the lithium batteries.

4.5 **Principles of Operation:** Briefly discusses circuit operation from a simplified schematic diagram viewpoint.

4.6 **Special Handling of Static-Sensitive Devices:** Reviews precautions necessary when handling static-sensitive devices.

4.7 **Troubleshooting:** Presents some troubleshooting tips for the Model 7168.

4.2 HANDLING AND CLEANING PRECAUTIONS

Because of the high impedance circuits on the Model 7168, 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 handling the scanner card.

1. Handle the card only at the edges whenever possible. Do not touch any board surfaces or components not associated with the repair.
2. 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 card if necessary.

3. If it is necessary to use solder on the circuit board, remove the flux from these areas when the repair is complete. Use Freon® TMS or TE or the equivalent along with 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 blow dry the board with dry nitrogen gas.
4. After cleaning, the card should be placed in a 50°C low-humidity environment for several hours before use.

4.3 PERFORMANCE VERIFICATION

The following paragraphs discuss performance verification procedures for the Model 7168, including contact resistance, input offset leakage current, and contact potential.

4.3.1 Environmental Conditions

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

4.3.2 Warm Up Period

The Model 7168 should be turned on (in the host scanner) and allowed to warm up for at least two hours before beginning the verification procedures. Also, the test equipment should be warmed up for the period stated in the instruction manuals for that equipment.

4.3.3 Recommended Equipment

Table 4-1 summarizes the equipment necessary for performance verification, along with the application for each unit.

4.3.4 Contact Resistance

The contact resistance test outlined below should be performed to verify

Table 4-1. Verification Equipment

Description	Manufacturer and Model	Specifications	Application
Digital Multimeter	Keithley 196	300Ω range, ±0.01% accuracy	Contact resistance
Electrometer	Keithley 617	200pA DC range, ±1.6% accuracy	Leakage current
Scanner	Keithley 705		Control 7168 for all tests
Extender card	Keithley 7061		Contact resistance
Nanovoltmeter	Keithley 181	1nV resolution	Contact potential
Kelvin clip leads	Keithley 5806		Contact resistance
#18 AWG copper wire			Contact resistance
Computer	HP-85		Contact resistance
Input cable	Keithley 1507		Contact potential
Triax cable	Keithley 6011		Offset leakage current

that each channel is closing properly, and that the resistance is within specification.

Required Equipment

The following equipment is required to measure contact resistance (see Table 4-1 for more detailed information):

- Model 196 DMM
- Model 705 Scanner
- Model 7061 Universal Adapter Card (used as an extender card)
- Model 5806 Kelvin clip leads

Procedure

1. Remove the top shield from the Model 7168, as shown in Figure 4-1.
2. Configure the Model 7061 as an extender card, as discussed in the Model 7061 Instruction Manual. Insert the Model 7061 into slot 1 of the Model 705 Scanner.
3. Connect the Model 7168 to the Model 7061, as shown in Figure 4-2.
4. Turn on the Model 196 DMM and allow it to warm up for two hours before beginning the test.
5. Select the 300Ω range on the Model 196.
6. Temporarily short the Model 5806 test leads and zero the instrument. Leave zero enabled for the duration of the test.
7. Connect the DMM to the Model 7168, as shown in Figure 4-3. The Model 196 input LO and ohms sense LO should be connected to the H (high) terminal of the channel being tested. Connect the Model 196 input HI and ohms sense HI to the HI output terminal of the Model 7168.
8. Program the Model 705 to close the channel being tested.
9. Verify that the DMM reading is less than 12Ω.
10. Repeat steps 7 through 9 for the remaining seven channels. Be sure you connect the DMM to the channel being tested, and that you program the Model 705 to close the correct channel.
11. Repeat steps 7-10 for output LO and channel LO. In this instance, the DMM leads must be connected to the LO channel and output terminals.

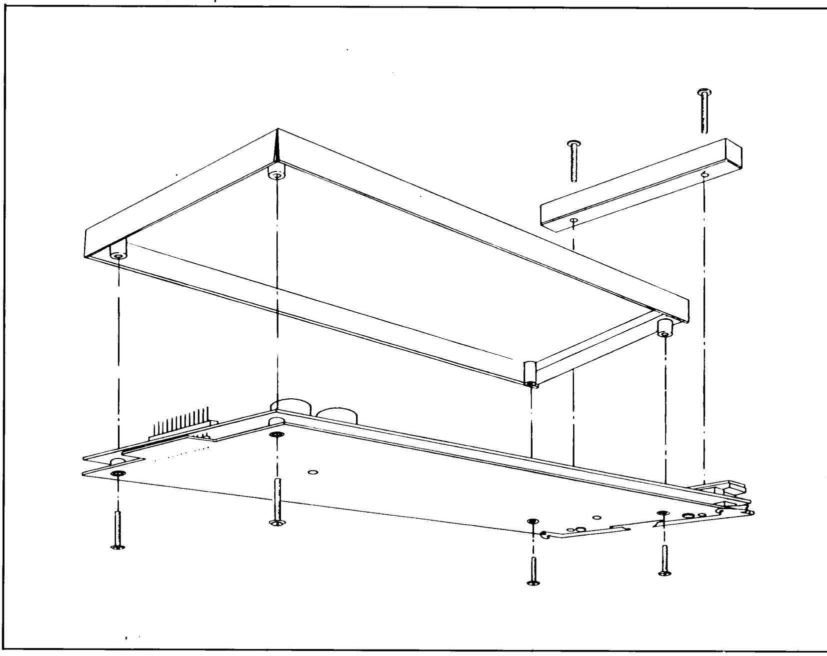


Figure 4-1. Shield Removal

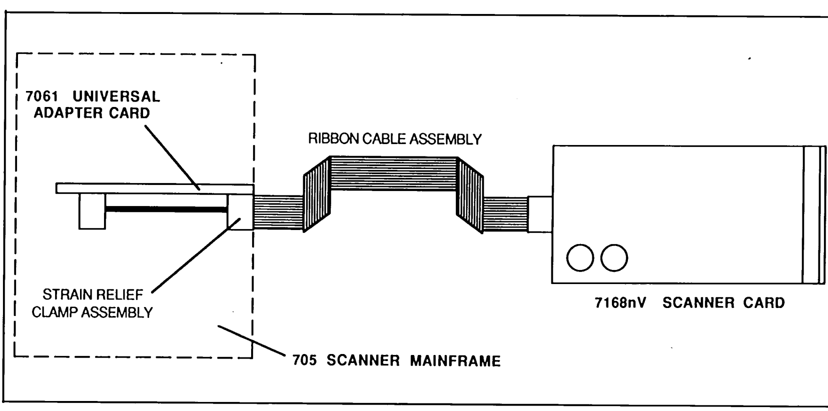


Figure 4-2. Connecting Model 7168 to Extender Card

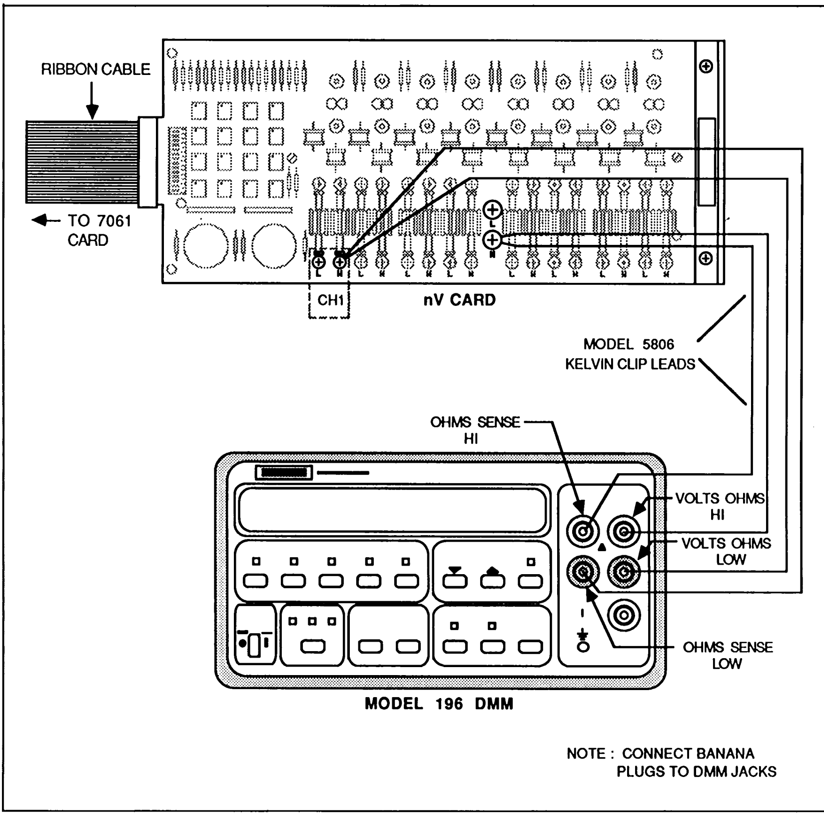


Figure 4-3. Connections for Contact Resistance Verification (Channel 1 shown)

4.3.5 Contact Potential

Use the procedure below to test contact potential of each channel. A computer is used for the procedure in order to apply an averaging algorithm necessary to minimize noise.

Required Equipment

Equipment from Table 4-1 required for this test includes:

- Model 705 Scanner
- Model 181 Nanovoltmeter
- Model 1507 Cable
- #18 AWG bare copper wire
- HP-85 (or similar) computer.

Procedure

NOTE

The following procedure must be performed at an ambient temperature of 23° ±1°C.

1. With the power off, connect the Model 705 Scanner and Model 181 Nanovoltmeter to the IEEE-488 bus of the computer.
2. Turn on the Model 181 Nanovoltmeter and allow the unit to warm up for at least four hours.
3. Connect the Model 1507 Cable to the mV INPUT of the Model 181.
4. Clean the lugs on the opposite end of the cable with Scotchbrite® .
5. Remove the shield from the Model 7168, as shown in Figure 4-1.
6. Clean the copper pads on the card input and output terminals with Scotchbrite® .
7. Cut eight ¾″ lengths of #18 bare copper wire, and clean off any oxidation from both ends of each piece.
8. Form a small loop at each wire end with a pair of needle nose pliers.
9. Short each channel input by connecting the HI and LO input terminals together with the short lengths of copper wire.
10. Route the Model 1507 cable through the cable clamp on the Model 7168, as shown in Figure 4-4.
11. Connect the Model 1507 cable to the card output terminals (see Figure 4-4).
12. Replace the scanner card shield and secure it with the screws re-

13. Install the Model 7168 in the Model 705 Scanner and turn on the scanner power. Allow the scanner and card to warm up for two hours before continuing the test.
14. Enter the program below into the computer and check it for errors. Note that the program assumes that the primary address of the Model 181 is 5, and that the primary address of the Model 705 is 17.
15. Run the program and follow the prompts.
16. Press the computer CONT key to continue the program. The program will then take 100 readings on each channel, average them (to reduce noise), and display the results. The complete test will take about 10 minutes because of the large number of readings involved.
17. Finally, the computer will compute and display the maximum difference in contact potential between channels. Verify that this value is <30nV.

Contact Potential Test Program

```
10 P1=705 ! 181 ADDRESS IS 5
20 P2=717 ! 705 ADDRESS IS 17
30 DIM A(8) ! DIMENSION INPUT ARRAY
40 REMOTE P1,P2 ! PUT INSTRUMENTS IN REMOTE
50 CLEAR 7 ! SEND DEVICE CLEAR
60 OUTPUT P1 ;"B1X" ! 181 6-1/2 DIGIT RESOLUTION
70 OUTPUT P2 ;"A2X" ! 705 2 POLE MODE
80 CLEAR
90 DISP "THIS PROGRAM MEASURES THE"
100 DISP "CONTACT POTENTIAL OF A"
110 DISP "7168 CARD IN SLOT 1"
120 DISP
130 DISP "CONNECT 1507 TO CARD OUTPUT"
140 DISP "HI AND LO TERMINALS"
150 DISP "PRESS 'CONT'"
160 PAUSE
170 DISP "MEASURING..."
180 FOR I=1 TO 8 ! LOOP FOR 8 CHANNELS
190 OUTPUT P2 ;"C";I;"B";I;"X" ! CLOSE CHANNEL
```

```
200 IF I=1 THEN 230
210 OUTPUT P2 ;"N";I-1;"X" ! OPEN CHANNEL
220 OUTPUT P1 ;"P0D0X" ! FILTER,DAMPING OFF
230 A=0
240 IF I>1 THEN 280
250 OUTPUT P1 ;"R1X" ! 2MV RANGE
260 WAIT 30000 ! WAIT TO SETTLE
270 OUTPUT P1 ;"Z1X" ! ZERO 181
280 WAIT 10000 ! 10 SEC DELAY
290 OUTPUT P1 ;"P2D1X" ! FILTER,DAMPING ON
300 FOR J=1 TO 100 ! LOOP FOR 100 READINGS
310 ENTER P1 ; A$ ! GET 181 READING
320 A=A+VAL(A$[5,16]) ! SUM READINGS
330 NEXT J ! LOOP BACK FOR NEXT READING
340 A(I)=A/100 ! STORE CHANNEL AVERAGE
350 DISP USING 370 ; I,A(I) ! CHANNEL AVERAGE
360 NEXT I
370 IMAGE "CH #",D,XX,MD.3De," VOLTS"
380 CLEAR 7 ! SEND DEVICE CLEAR
390 A=A(1) @ B=A(1)
400 FOR I=2 TO 8 ! COMPUTE MIN/MAX
410 IF A(I)>A THEN A=A(I) ! MAXIMUM
420 IF A(I)<B THEN B=A(I) ! MINIMUM
430 NEXT I
440 DISP
450 DISP "MAXIMUM CHANNEL DIFFERENCE="
460 IMAGE D.3De," VOLTS"
470 DISP USING 460 ; ABS(A-B)
480 END
```

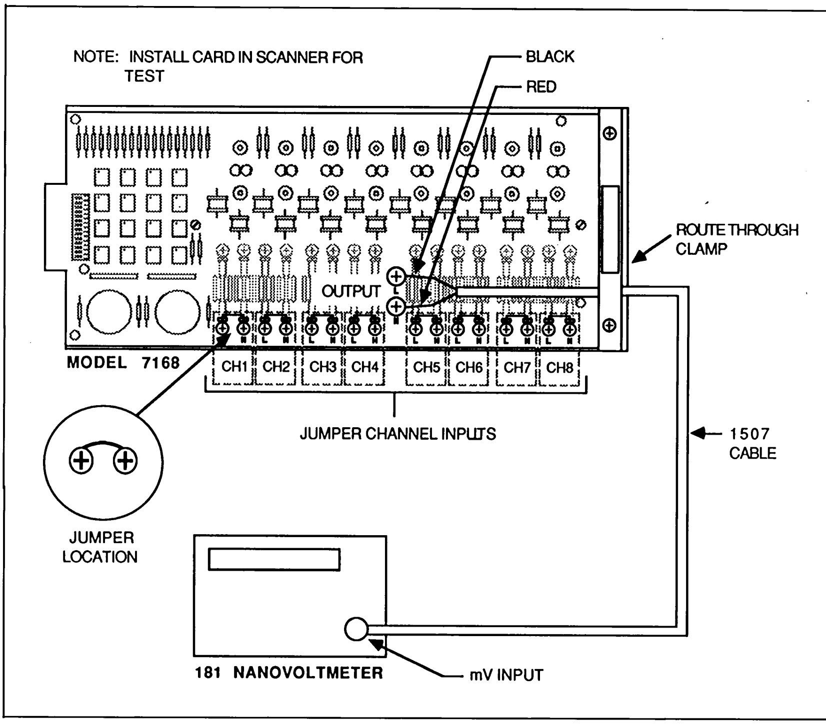


Figure 4-4. Connections for Differential Contact Potential Verification

4.3.6 Offset Leakage Current

Required Equipment

The following equipment from Table 4-1 will be necessary to verify leakage current:

- Model 617 Electrometer
- Model 6011 Triax Cable

Procedure

Test leakage current as follows. Note that it is not necessary to install the scanner card in the Model 705 for these tests.

NOTE

The following procedure must be performed at an ambient temperature of 23° ±1°C.

1. Remove the top shield and cable clamp from the Model 7168.
2. Connect the Model 6011 cable to the INPUT jack of the Model 617.
3. Turn on the Model 617; select the 200pA range and enable zero check. Allow the unit to warm up for one hour before proceeding.
4. Connect the Model 6011 triax cable HI (red) lead to channel 1 INPUT HI (see Figure 4-5).
5. Connect the Model 6011 cable LO (black) lead to OUTPUT HI, as shown in Figure 4-5.
6. Zero correct the Model 617, and then release zero check.
7. Allow the Model 617 reading to settle, and verify that the reading is <50pA exclusive of noise.
8. Repeat steps 4 through 7 for channels 2 through 8 input HI. The Model 6011 cable red lead should be connected to INPUT HI of the channel being tested.
9. Connect the Model 6011 black lead to OUTPUT LO and repeat steps 4 through 8. The Model 6011 red lead should be connected to INPUT LO for the channel being tested.

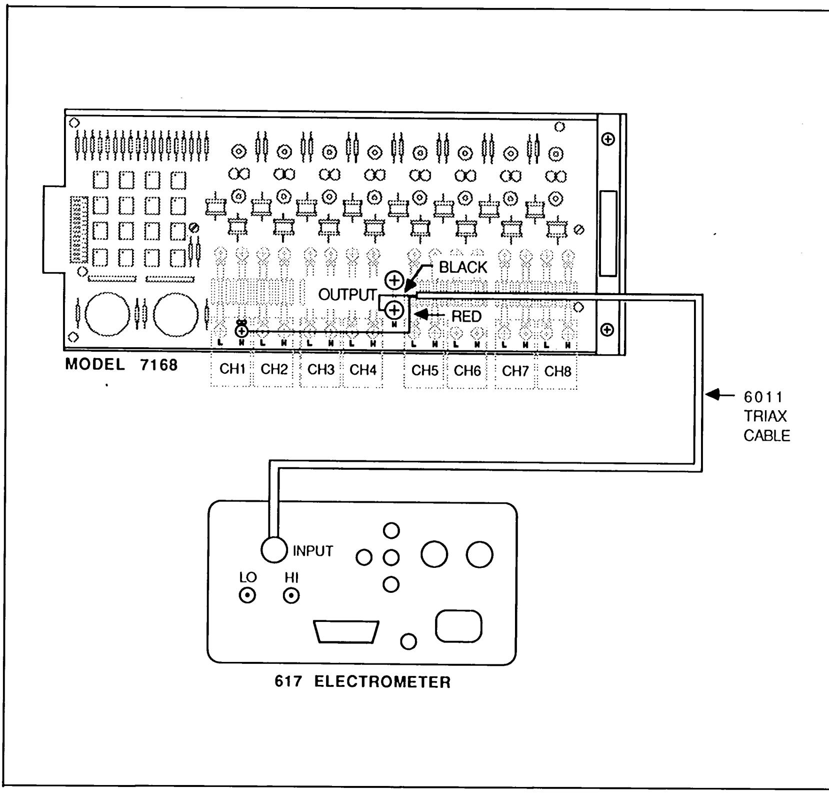


Figure 4-5. Connections for Leakage Current Verification

4.4 BATTERY REPLACEMENT

The two lithium batteries which bias switching JFETs should last for about five years of normal use (battery life can be prolonged by leaving all channels turned off when not in use). The following paragraphs discuss battery replacement procedures and disposal precautions.

4.4.1 Recommended Replacement Batteries

The batteries should be replaced only with the following:

Keithley part number BA-41

These batteries may be ordered directly from Keithley Instruments, as discussed in Section 5 of this manual.

4.4.2 Battery Replacement and Disposal Precautions

Replacement of the two lithium batteries is normally a safe procedure as long as these safety precautions are followed.

WARNING
The precautions below must be followed to avoid possible personal injury.

1. Wear safety glasses or goggles when working with the lithium batteries.
2. Do not short the battery terminals together.
3. Do not incinerate or otherwise expose the batteries to excessive heat (>60°C).
4. Keep lithium batteries away from all liquids.

4.4.3 Replacement Procedure

Replace the batteries as follows:

1. Turn off the power and then remove the card from the scanner, if installed.
2. Remove the four screws that secure the top shield then remove the shield (see Figure 4-1).
3. Pinch the Teflon® standoff ends that protrude through the shield board. Carefully separate the two circuit boards to allow access to the battery solder pads.
4. Carefully unsolder the batteries.

WARNING
Be careful not to short the battery terminals while unsoldering or soldering them.

5. Clean the solder pads and holes free of solder using a de-soldering tool or wick.
6. Install the new battery, taking care to observe proper polarity, then solder the leads to the circuit board, and cut exposed leads flush with the board.
7. Connect the two circuit boards together, then install the shield and screws that were removed earlier. Be sure to align the molex connectors and Teflon® standoffs properly.

4.5 PRINCIPLES OF OPERATION

The paragraphs below discuss the basic operating principles for the Model 7168. A simplified schematic of one-half of one of the channels is shown in Figure 4-6. Since all switching circuits are identical, only one is shown here. A complete schematic diagram is shown on drawing number 7168-106, located at the end of Section 5.

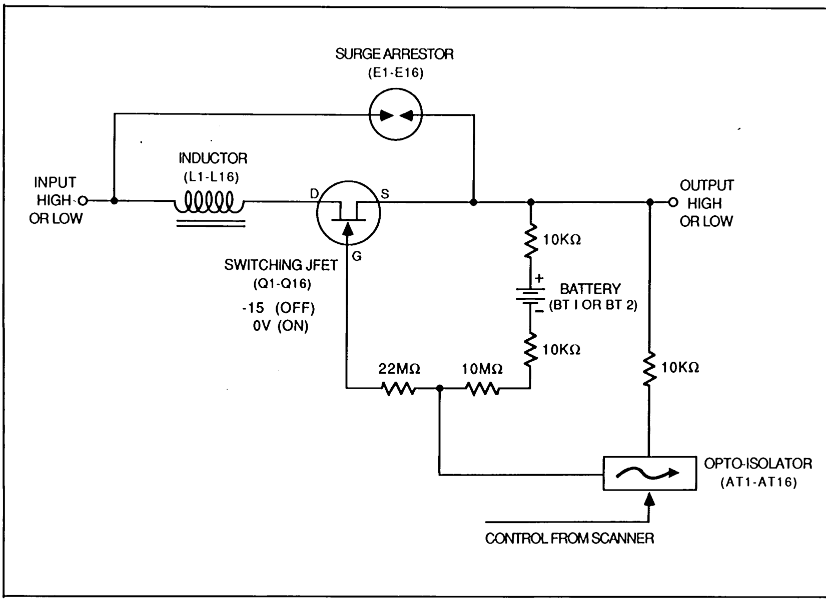


Figure 4-6. Simplified Schematic (1/2 of one channel shown)

4.5.1 Switching Circuits

The high and low inputs of the eight input channels are switched by JFETs Q1 through Q16. Since each of these devices is an N-channel JFET, the channel is opened by placing the gates of the associated JFETs at −15V potential, and a channel is closed by placing the gates at approximately 0V, referenced to the source.

4.5.2 Battery Biasing

Biasing for the switching JFETs is provided by two 15V lithium batteries. BT1 supplies gate bias for the JFETs associated with the high channel inputs, and BT2 biases the low side JFETs. This two-battery setup is used to assure proper isolation between the high and low signals paths of the scanner card.

4.5.3 JFET Control

The control signals that switch the JFETs are transmitted from the scanner mainframe through optoisolators AT1-AT16. This scheme is used to ensure proper isolation between the sensitive analog circuits on the Model 7168 and the digital circuits located in the host scanner. The JFETs are turned on or off by placing the gates at 0V or −15V (referenced to the source), as discussed above.

4.5.4 Circuit Protection

Circuit protection consists of an inductor (L1-L16) in series with each input, as well as a surge arrestor (E1-E16) between the drain and source of each JFET. These circuits work together to protect the JFETs from possible damage due to static discharge.

4.6 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 (indicated by * in the parts list), use the following precautions:

1. Such devices should be transported and handled only in containers specially designed to prevent or dissipate static build-up. Typically, these devices will be received in anti-static containers made of plastic or foam. Keep these parts in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap while working with these devices.
3. Handle the devices only by the body; do not touch the pins.
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.

4.7 TROUBLESHOOTING

4.7.1 Recommended Equipment

Table 4-2 summarizes the equipment necessary for general troubleshooting.

4.7.2 Troubleshooting Procedure

Table 4-3 outlines the troubleshooting procedure for the nV Scanner Card.

Table 4-2. Recommended Troubleshooting Equipment

Description	Manufacturer and Model	Application
DMM	Keithley 196	Measure DC voltages
Voltage source	Keithley 230	Apply DC voltage
Extender card	Keithley 7061	Allow circuit access

Table 4-3. Troubleshooting Summary

Step	Item/Component	Required Condition	Comments
1	BT1, BT2	15V, ±5%	Measure at battery terminals
2	Voltage source	Connect to channel 1	Input connections
3	DMM	Connect to card output	Output connection
4	Voltage source	Set to +5V	Apply +5V to input
5	Close channel		
6	DMM	+5V, ±0.1%	Verify card output
7	Voltage source	Set to −5V	Apply −5V to input
8	DMM	−5V, ±0.1%	Verify card output
9	Repeat steps 4-7 for all channels		
10	Q1-Q16 gates	−15V, channel open; ≅0V, channel closed	Referenced to source of JFET

SECTION 5
REPLACEABLE PARTS

5.1 INTRODUCTION

This section contains a list of replaceable electrical and mechanical parts for the Model 7168, as well as a component layout drawing and schematic diagram of the scanner card.

5.2 PARTS LISTS

Electrical parts are listed in order of circuit designation in Table 5-1. Table 5-2 summarizes mechanical parts.

5.3 ORDERING INFORMATION

To place a parts order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see the inside front cover for addresses). When ordering parts, be sure to include the following information:

1. Scanner card model number (7168)
2. Card serial number
3. Part description
4. Circuit description, if applicable
5. Keithley part number

5.4 FACTORY SERVICE

If the scanner 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 DEPARTMENT on the shipping label.

Note that it is not necessary to return the scanner mainframe with the card.

5.5 COMPONENT LAYOUT AND SCHEMATIC DIAGRAM

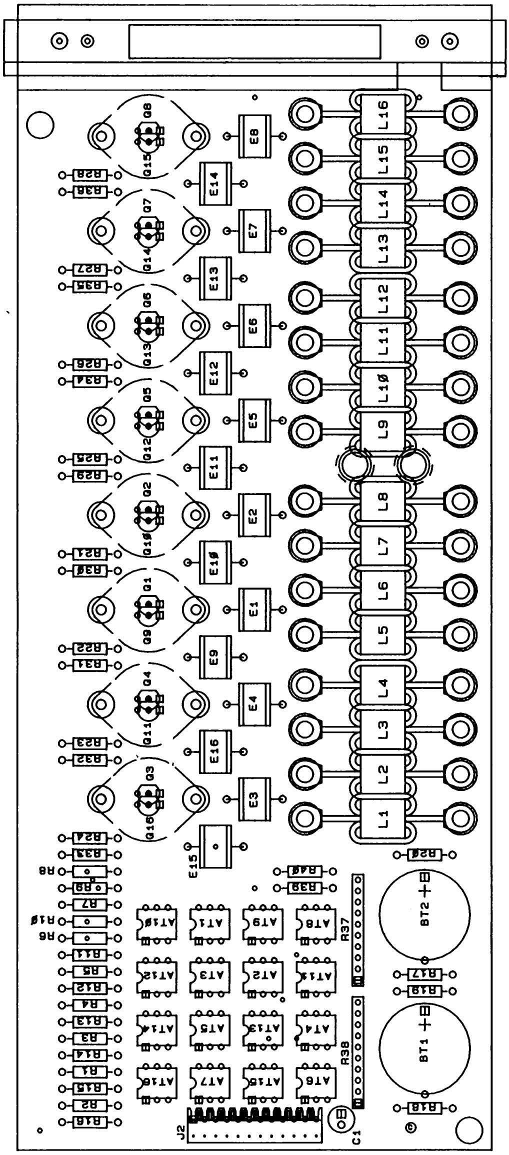
Figure 5-1 shows a component layout of the Model 7168. Figure 5-2 shows a schematic diagram of the Model 7168.

Table 5-1. Electrical Parts List

Circuit Desig.	Description	Keithley Part No.
AT1-AT16	IC, Opto-isolator	IC-524
BT1, BT2	Battery, 15V Lithium	BA-41
C1	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
E1-E16	Surge Arrestor	SA-1
J2	Connector, 12 pin	CS-583-1
L1-L16	Choke	CH-40
P2	Connector, 12 pin	CS-584-1
Q1-Q16	Transistor	617-600
R1-R16	Resistor, 10MΩ, 10%, ¼W, Composition	R-76-10M
R17-R20	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k
R21-R36	Resistor, 22MΩ, 10%, ¼W, Composition	R-76-22M
R37, R38	Resistor, Network	TF-90
R-39, R40	Resistor, 10kΩ, 5%, ¼W, Composition	R-76-10k

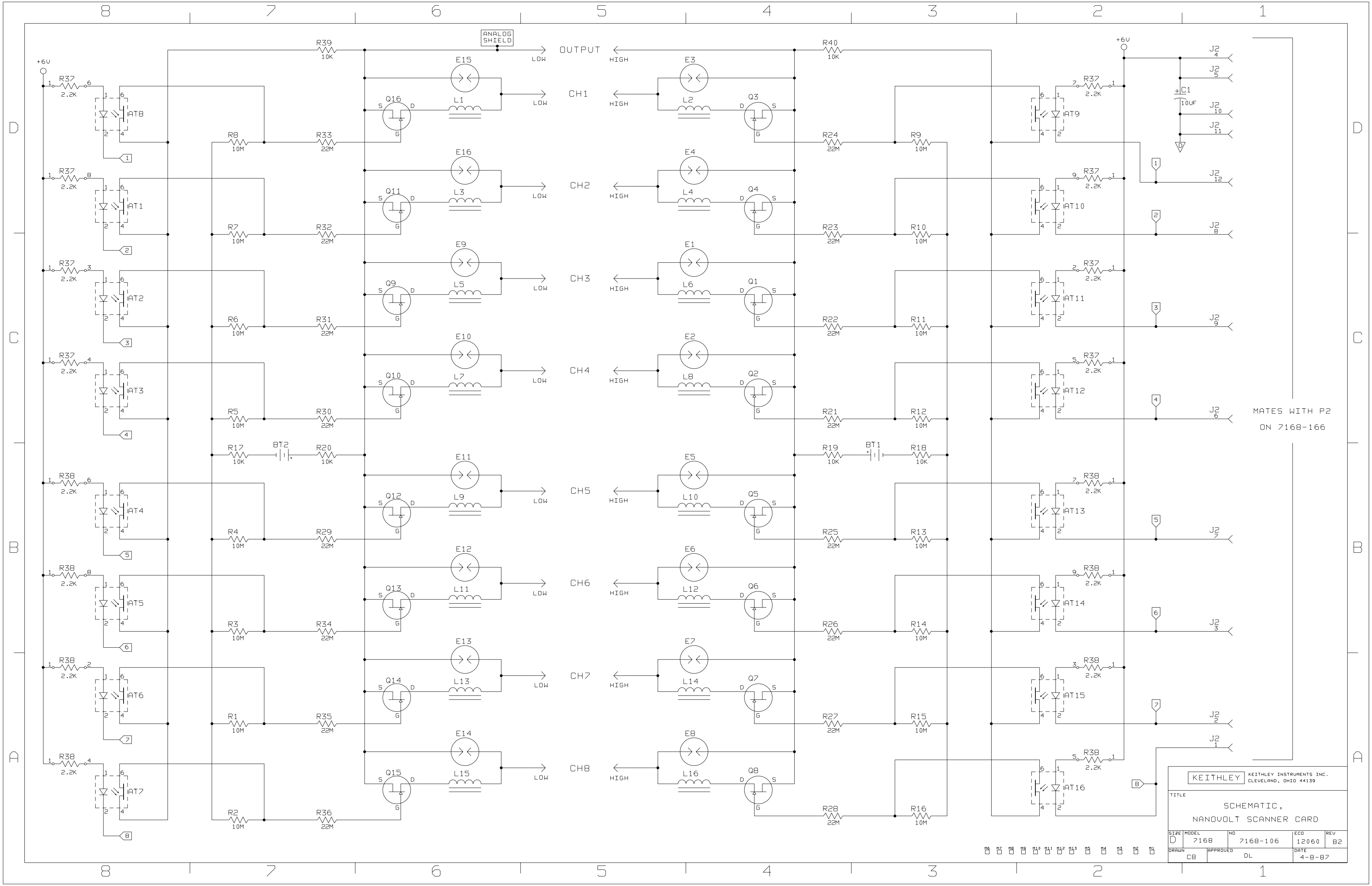
Table 5-2. Mechanical Parts List

Quantity	Description	Keithley Part No.
8	Thermal cup (for Q1-Q16)	30582
8	Gasket (for thermal cup)	GA-20
1	Clamp, upper (cable clamp)	7168-312
1	Clamp, lower (cable clamp)	7055-307
1	Strip, rubber	7168-315
1	Strip, rubber	7168-314
1	Shield	7168-305
1	Strip, rubber (inside of shield)	7168-308
1	Strip, rubber (between mother board and shield board)	7168-306



LTR.	ECO NO.	REVISION	ENG.	DATE
B	11918	RELEASED	MS	1/3Ø/87
B1	11996	REVISED	SZ	3/6/87
B2	12Ø6Ø	REVISED	[signature]	4/8/87
B3	14446	DELETED (8) GA-20, GASKET	[signature]	5/3/91

Figure 5-1. Model 7168 Component Location Drawing



8 7 6 5 4 3 2 1
D C B A
ANALOG SHIELD
OUTPUT
LOW
HIGH
CH1
CH2
CH3
CH4
CH5
CH6
CH7
CH8
+6V
R39 10K
R40 10K
R37 2.2K
R38 2.2K
AT1 AT2 AT3 AT4 AT5 AT6 AT7 AT8
AT9 AT10 AT11 AT12 AT13 AT14 AT15 AT16
Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16
L1 L2 L3 L4 L5 L6 L7 L8 L9 L10 L11 L12 L13 L14 L15 L16
R1 R2 R3 R4 R5 R6 R7 R8 10M
R9 R10 R11 R12 R13 R14 R15 R16 10M
R21 R22 R23 R24 R25 R26 R27 R28 22M
R29 R30 R31 R32 R33 R34 R35 R36 22M
R17 10K
R18 10K
R19 10K
R20 10K
BT1
BT2
C1 10UF
J2
MATES WITH P2
ON 7168-166
KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139
TITLE
SCHEMATIC,
NANOVOLT SCANNER CARD
SIZE D
MODEL 7168
NO 7168-106
ECO 12060
REV B2
DRAWN CB
APPROVED DL
DATE 4-8-87

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

Display or output (check one)

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

- ❑ Calibration only
- ❑ Certificate of calibration required
- ❑ Data required

(attach any additional sheets as necessary)

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

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

____

____

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

Relative humidity? ____________________ Other? ____________________

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

____

____

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

Keithley Instruments, Inc. 28775 Aurora Road • Cleveland, Ohio 44139
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1-888-KEITHLEY (534-8453) www.keithley.com

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