Errata

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Manual Part Number: 03852-90002P1

Revision Date: October 1985

HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this manual copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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HEWLETT PACKARD

HP 3852A DATA ACQUISITION/CONTROL UNIT

Volume 2

Plug-in Accessories Configuration & Programming Manual

Part 1
Chapters 1 - 11

Manual Part No. 03852-90002

Microfiche Part No. 03852-90052

Loveland Instrument Division
P.O. Box 301, Loveland, Colorado, 80539

Printed: October 1985

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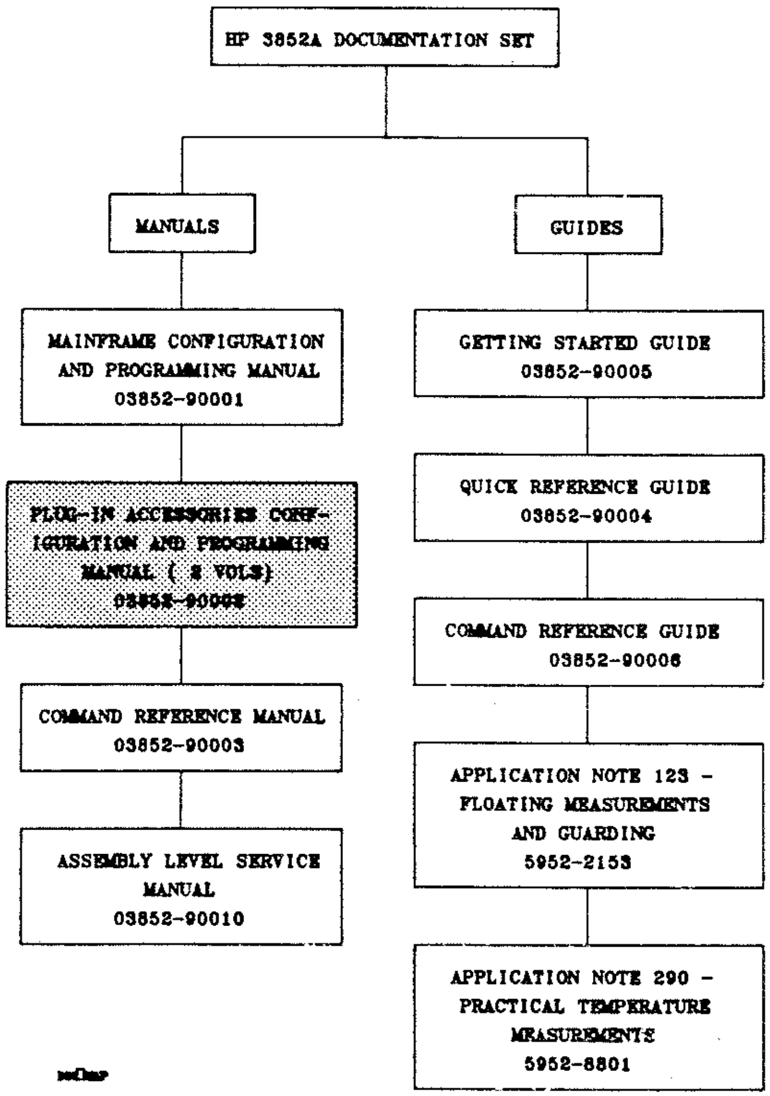
HP 3852A DOCUMENTATION MAP

This figure shows the documentation set for the HP 3852A Data Acquisition/Control Unit. The shaded box identifies this manual or guide.



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1. Analog and digital sections are interconnected.
2. HP 3852A/HP 3853A power supply limitations are exceeded.
3. Component height/protrusion restrictions are violated.
4. Maximum input on the digital lines is exceeded.

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SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

GROUND THE INSTRUMENT

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Under certain conditions, dangerous voltages may exist even with the instrument switched off. To avoid injuries, always disconnect input voltages and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

DO NOT OPERATE A DAMAGED INSTRUMENT

Whenever it is possible that the safety protection features built into this instrument have been impaired, either through physical damage, excessive moisture, or any other reason, REMOVE POWER and do not use the instrument until safe operation can be verified by service-trained personnel. If necessary, return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

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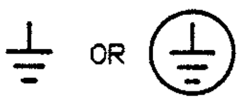
Operating and Safety Symbols

Symbols Used On Products And In Manuals

~ LINE — AC line voltage input receptacle.

Instruction manual symbol affixed to product. Warns and cautions the user to refer to respective instruction manual procedures to avoid personal injury or possible damage to the product.

Indicates dangerous voltage – terminals connected to interior voltage exceeding 1000 volts.



Protective conductor terminal. Indicates the field wiring terminal that must be connected to earth ground before operating equipment – protects against electrical shock in case of fault.

Clean ground (low-noise). Indicates terminal that must be connected to earth ground before operating equipment – for single common connections and protection against electrical shock in case of fault.

Frame or chassis ground. Indicates equipment chassis ground terminal – normally connects to equipment frame and all metal parts.

Affixed to product containing static sensitive devices – use anti-static handling procedures to prevent electrostatic discharge damage to components.

NOTE

NOTE

Calls attention to a procedure, practice, or condition that requires special attention by the reader.

CAUTION

CAUTION

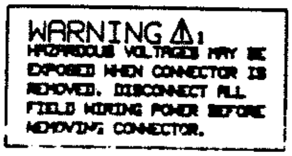
Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

WARNING

WARNING

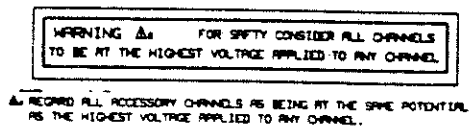
Calls attention to a procedure, practice, or condition that could possibly cause bodily injury or death.

HP 3852A Caution and Warning Labels

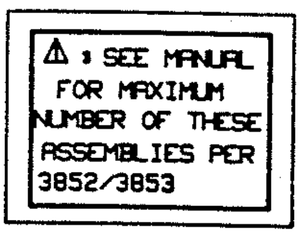


This symbol and warning statement is found beside the Analog Extender port on the HP 3852A and HP 3853A. The analog extender port enables the HP 3852A backplane analog bus to be expanded to an extender. The analog bus routes signals from channels on multiplexer accessories to the voltmeter accessories. Depending on the multiplexer combinations installed and the application wired to the accessories, up to 350V peak (equivalent to 250V AC rms or 250V DC) can be present on the bus and, therefore, on the terminals of the port.

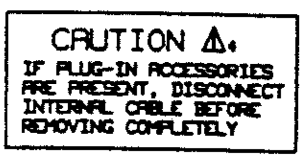
The symbol and these statements are found below the locking ring on the terminal module and on the metal cover fastened to the component module of the plug-in accessories. Since all field wiring and most of the configuration involves the terminal module, the warnings serve as a reminder that even when the terminal module is separated from the component module, hazardous voltages can still be present on the terminal module due to the field wiring connected.



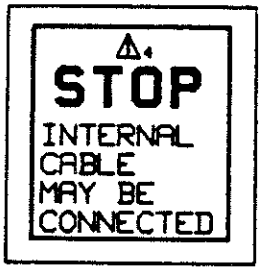
The symbol and these statements are found inside the terminal module and on the metal cover fastened to the component module of the plug-in accessories. The statements serve as a reminder to be careful when wiring in close proximity to other channels in which field wiring is already connected. Recall that hazardous voltages can still be present on the wiring terminals even though the accessory has been removed from the instrument. Note that all field wiring and configuration should be performed with the accessory removed from the instrument and with the terminal module separated from the component module.



This symbol and statement is found above the locking ring on the terminal module of the HP 44727A, HP 44727B, and HP 44727C DAC (Digital-to-Analog Converter) accessories and on the side of the HP 44701A and HP 44702A/B voltmeter accessories. The symbol and statement refer to the fact that when a specific number of these accessories are installed in the same instrument, they place an excessive drain on the HP 3852A and HP 3853A power supply which in turn, causes degraded and often unpredictable system performance.



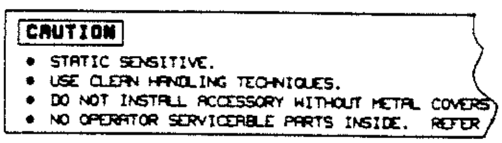
This symbol and statement is found on the name plate of the HP 44702A/B 13 bit High Speed Voltmeter accessory. The statement serves as a reminder that before removing the accessory, check to see that an HP 44711A, HP 44712A, or HP44713A High Speed FET multiplexer accessory is not connected to the voltmeter by the ribbon cable.



This symbol and statement is found on the bottom "rail" of the HP 44711A, HP 44712A, and HP 44713A High Speed FET multiplexer accessories and is exposed when the accessory's terminal module is removed. The "internal cable" is the ribbon cable that connects the FET multiplexer to the HP 44702A 13 bit High Speed Voltmeter accessory.

This statement appears at the bottom of the HP 3852A and HP 3853A power modules and under the CAUTION label on the metal cover of an accessory's component module. All equipment configuration and repair should be performed by service-trained personnel only.

This statement appears by the fuse socket on the HP 3852A and HP 3853A power modules. The HP 3852A and HP 3853A are shipped without the fuse installed. A 1.5 AT and 750 mAT fuse and a fuse cap are packaged together in a small static shielding bag which accompanies the instruments. A service-trained individual should install the correct fuse and set the LINE SELECTOR switches to the proper position before power is applied to the instrument.



These statements are found under the CAUTION label on the metal cover of an accessory's component module. The statements serve as a reminder to avoid touching the connector contacts and to use care when handling the accessory. Note that the protective cover should be attached following any necessary configuration in order to prevent damage to the components resulting from static discharge or when other accessories are installed.

CONTENTS

Chapter 1 -- Using This Manual

Chapter 2 -- HP 44701A Integrating Voltmeter

Chapter 3 -- HP 44702A/B 13-Bit High-Speed Voltmeter

Chapter 4 -- HP 44705A 20-Channel Relay MUX

Chapter 5 -- HP 44706A 60-Channel Relay MUX

Chapter 6 -- HP 44708A 20-Channel Relay MUX/TC

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Chapter 7 -- HP 44709A 20-Channel FET MUX

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Chapter 11 -- HP 44713A 24-Channel High-Speed FET MUX/TC

Chapter 1
Using This Manual

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Chapter 1
Using This Manual

Chapter 1

Using This Manual

Introduction

The HP 3852A Plug-In Accessories Configuration and Programming Manual has been designed to serve as a reference document for using the HP 3852A plug-in accessories. It contains functional information, configuration (wiring) information, and programming information for each plug-in accessory.

Familiarize yourself with the manual and the plug-in accessories by looking through this chapter. The best way to feel at ease with the plug-in accessories is to sit down with the manual and perform the examples that we have provided for you. The Plug-In Accessories Manual has been designed to enable you to use the plug-in accessories in the most effective manner for your data acquisition and control applications.

NOTE

If you have just received your new HP 3852A, you should refer to the Mainframe Configuration and Programming Manual before proceeding with this manual. The Mainframe Configuration and Programming Manual contains important set-up instructions and operating procedures.

Related Manuals

In addition to the Plug-In Accessories Manual, the HP 3852A documentation set includes the Mainframe Configuration and Programming Manual and the HP 3852A Command Reference Manual.

Mainframe Configuration and Programming Manual (Volume 1)

The Mainframe Configuration and Programming Manual is a getting started guide and a detailed reference manual for using the HP 3852A. It discusses the following topics:

- Initial Unpacking/Inspection.
- HP 3852A mainframe/HP 3853A Extender features.
- Mainframe and accessory installation procedures.
- HP 3852A front panel operation.
- Remote (HP-IB)* operation.
- Programming the data acquisition system.

* The Hewlett-Packard Interface Bus (HP-IB) is Hewlett-Packard's implementation of IEEE Standard 488-1978 and ANSI MC1.1.

HP 3852A Command Reference Manual (Volume 3)

The Command Reference Manual contains an alphabetical listing of the programming commands used by the HP 3852A and the plug-in accessories. The following information is included for each command in the Command Reference Manual:

- Command description.
- Prerequisites.
- Command syntax (with syntax diagram).
- Command parameters.
- Remarks.
- Example programs.

Manual Organization

The Plug-In Accessories Manual consists of 19 chapters including this "getting started" chapter. Chapters 2 through 19 contain functional information, configuration (wiring) information, and programming information for each plug-in accessory. The documentation for the plug-in accessories is contained in two binders: Part 1 and Part 2. Chapters 1 through 11 are the analog accessories and can be found in Part 1. Chapters 12 through 19 are the digital accessories and can be found in Part 2.

A table of contents is included at the beginning of each chapter to help you locate specific information. An index is included behind the Index tab page in each binder. The indexes have been organized by chapter for ease of use.

Each chapter contains information on one accessory (or related accessories) and is essentially independent of the rest of the manual. This organization enables you to read only those chapters that you need. A typical chapter in the Plug-In Accessories Manual consists of four primary sections: Introduction, Specifications, Configuration, and Programming. A brief description of each section follows.

Introduction

This section contains an overview of what information is covered in the chapter, a brief discussion of the accessory and its features, and a discussion of the functions (applications) of the accessory. This section also contains a getting started section which will help you through the chapter.

Specifications

This section lists the specifications for the accessory. The specifications are the performance standards or limits against which the accessory was tested.

Configuration

This section contains hardware configuration information for the accessory. Information such as setting jumpers, setting switches, and connecting field wiring from your application is covered in this section.

WARNING

In this section, examples and illustrations show connections between the accessory and external circuitry. Because of the potentially high voltages which may be present when an external circuit is connected, only qualified, service-trained personnel should install or configure the HP 3852A plug-in accessories.

Programming

This section contains example programs that show how to program the accessory for each of its functions. This section also includes a command summary which gives the command syntax and a brief description of each command used by the accessory in that chapter.

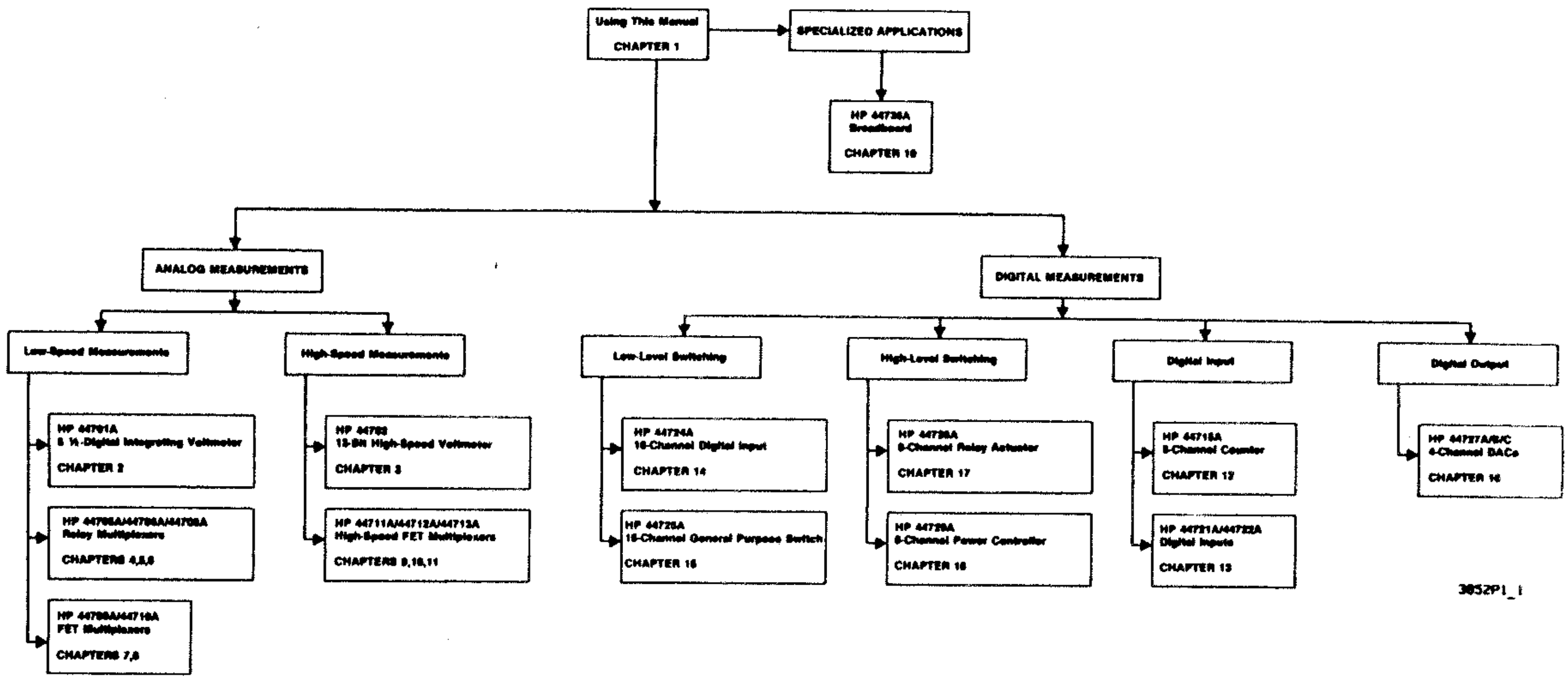
NOTE

The example programs in this section are intended to show how to use the accessory for typical measurements and applications. The examples do not show all of the details for using the programming commands or programming techniques. Refer to the HP 3852A Command Reference Manual for a more detailed discussion of the programming commands.

How To Use This Manual

If you have just received your new HP 3852A, refer to the flowchart in Figure 1-1 for a quick overview of the Plug-In Accessories Manual organization. This flowchart lists the accessory product numbers, the titles of the plug-in accessories, and in what chapter each accessory is covered. Note that the plug-in accessories can be grouped into three categories according to the types of measurements or control that each can perform: Analog Measurements, Digital Measurements, and Specialized Applications.

Figure 1-1. Plug-In Accessories Manual Organization



NOTE: Part 1 consists of Chapters 1 through 11.
Part 2 consists of Chapters 12 through 19.

Figure 1-1. Plug-In Accessories Manual Organization

Table 1-1 lists the chapters in the Plug-In Accessories Manual, the application categories, and typical applications for each plug-in accessory. Use this table in conjunction with the flowchart in Figure 1-1 to select the accessories for your application.

Table 1-1. Typical Applications

Example: Using the Plug-In Accessories Manual

This example shows a suggested getting started sequence that will help you begin using the Plug-In Accessories Manual. The example uses Figure 1-1 and Table 1-1 from this chapter.

Suppose that your firm manufacturers high-performance, long-life, lead-acid batteries. Your quality assurance department wants to use the HP 3852A to test the quality and life-cycle characteristics of the batteries. Twenty batteries will be tested every 30 seconds.

The first step to get started is to refer to the flowchart in Figure 1-1. Find the application category which suits your application (for example, Analog Measurements). The Analog Measurements group is broken down into two categories: Low-Speed Measurements and High-Speed Measurements. Under each of the categories you will find the plug-in accessories that can be used for that type of measurement. From the plug-in accessories listed, choose those that can be used for your application (for this example, the HP 44701A Integrating Voltmeter and one of the multiplexer accessories).

The next step is to refer to Table 1-1 for a listing of the typical applications for the plug-in accessories that you have chosen using Figure 1-1. The column entitled "Typical Applications" shows that the HP 44701A Integrating Voltmeter and any of the multiplexer accessories can be used to make low-speed DC voltage measurements.

The final step is to refer to those chapters that you have selected using Figure 1-1 and Table 1-1. Each chapter has its own getting started section and a brief description of each function to help you to begin using the accessory for your application.

Table 1-1. Typical Applications

	Chapter	Chapter Title	Application Category	Typical Applications
ANALOG	2	HP 44701A 5½-Digit Integrating Voltmeter	Low-Speed Measurements	DC/AC Voltage DC/AC Current (with shunt) 2-Wire/4-Wire Ohms
	3	HP 44702 13-Bit High-Speed Voltmeter	High-Speed Measurements	DC Voltage DC Current (with shunt) 2-Wire/4-Wire Ohms
	4	HP 44705A 20-Channel Relay MUX	Low-Speed Measurements	DC/AC Voltage DC/AC Current (with shunt) 2-Wire/4-Wire Ohms
	5	HP 44706A 60-Channel Relay MUX	Low-Speed Measurements	DC/AC Voltage 2-Wire Ohms
	6	HP 44708A 20-Channel Relay MUX/TC	Low-Speed Measurements	DC/AC Voltage DC/AC Current (with shunt) 2-Wire Ohms Thermocouple Compensation
	7	HP 44709A 20-Channel FET MUX	Low-Speed Measurements	DC/AC Voltage 2-Wire Ohms
	8	HP 44710A 20-Channel FET MUX/TC	Low-Speed Measurements	DC/AC Voltage DC/AC Current (with shunt) 2-Wire/4-Wire Ohms Thermocouple Compensation
	9	HP 44711A 24-Channel High-Speed FET MUX	High-Speed Measurements	DC/AC Voltage DC/AC Current (with shunt) 2-Wire Ohms
	10	HP 44712A 48-Channel High-Speed FET MUX	High-Speed Measurements	DC/AC Voltage 2-Wire Ohms
	11	HP 44713A 24-Channel High-Speed FET MUX/TC	High-Speed Measurements	DC/AC Voltage DC/AC Current (with shunt) 2-Wire Ohms Thermocouple Compensation
DIGITAL	12	HP 44715A 5-Channel Counter	Digital Inputs	Frequency Measurements Period Measurements Ratio Measurements Count Direction Up/Down Counting Total Counts
	13	HP 44721A/44722A Digital Inputs	Digital Inputs	Read Input States Count Input Events Enable Event Interrupts Enable Counter Interrupts
	14	HP 44724A 16-Channel Digital Output	Low-Level Switching	Control DC Devices Drive Logic Levels
	15	HP 44725A 16-Channel General Purpose Switch	Low-Level Switching	Switch Voltages Switch Current
	16	HP 44727A/B/C 4-Channel DACs	Digital Output	Programmable Voltage Sources Programmable Current Sources
	17	HP 44728A 8-Channel Relay Actuator	High-Level Switching	DC/AC Power Switching
	18	HP 44729A 8-Channel Power Controller	High-Level Switching	AC Power Switching
Special Applications	19	HP 44736A Breadboard	Specialized Applications	User-Defined Applications

Chapter 2
HP 44701A
Integrating Voltmeter

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Chapter 2
HP 44701A Integrating Voltmeter

Chapter 2
Integrating Voltmeter
HP 44701A

Introduction

This chapter contains a description, specifications, configuration information, and programming instructions for the HP 44701A Integrating Voltmeter. It is made up of the following five sections:

- **Introduction** contains an overview of the chapter and a description of the voltmeter.
- **Specifications** lists the voltmeter's performance characteristics.
- **Installation and Checkout** describes how to verify proper installation of the voltmeter.
- **Programming** shows you how to make measurements with the voltmeter alone and with the voltmeter coupled to a multiplexer accessory (scanning).
- **Command Summary** summarizes the voltmeter commands.

The examples used in this chapter are primarily for Hewlett-Packard Series 80 or Series 200 computers using HP BASIC language. They assume an HP-IB interface select code of 7 and a device address of 09 (factory address setting) resulting in a combined HP-IB address of 709. We recommend you retain this address to simplify programming.

Description

You can use the HP 44701A Integrating Voltmeter's external (rear) terminals for AC or DC voltage measurements and 4-wire ohms measurements. You can also make current measurements, indirectly, using an external shunt (current sensing resistor). The HP 44701A has offset compensation for most resistance ranges and autozero for all types of measurements. A guard terminal provides added common mode noise rejection
mon mode noise rejection* and the HP 44701A's method of analog to digital conversion (integration) provides normal mode noise rejection. The integration time can be varied from 0.0005 to 16 power line cycles (PLCs) yielding 3 1/2 to 6 1/2 digits of resolution.

Figure 2-1 shows the backpanel of the HP 44701A Integrating Voltmeter. The upper three terminals (HI, LO and GUARD) are the input terminals for both voltage and resistance measurements. The lower two terminals (HI and LO CURRENT SOURCE) are the current source terminals for resistance measurements. The lever on the bottom of the backpanel allows the HP 44701A to be released from its slot. To remove the HP 44701A from a slot, lift the lever and pull the voltmeter outward.

When using the HP 44701A Integrating Voltmeter in conjunction with one of

*For more information on guarded measurements, refer to HP Application Note Number 123 *Floating Measurements and Guarding* available through your nearest HP Sales and Service Office.

the various multiplexer accessories (through the mainframe's or extender's analog backplane), you can also make a number of additional measurements not possible with the HP 44701A alone. These include automatic 2-wire ohms measurements, 4-wire ohms measurements with automatic Source channel designation, and automatic temperature measurements from thermistors, thermocouples, and RTDs.

CAUTION

The maximum voltage between any of the input terminals (HI, LO, GUARD) is +/-300V peak AC or DC. Do not exceed this voltage–the HP 44701A and possibly the mainframe or extender will be damaged. This voltage exceeds the voltage limits for many of the other plug-in accessories that may be in the mainframe or extender. Whenever measuring high voltage levels, make sure the TERM command is set to EXT (selects the HP 44701A rear terminals). If the TERM command is set to BOTH, the voltage will be connected to the mainframe's or extender's analog bus.

The maximum voltage between the LO input terminal and the HI or LO CURRENT SOURCE terminal is +/-3V peak AC or DC. Do not exceed this voltage–the HP 44701A and possibly the mainframe or extender will be damaged.

WARNING

The mainframe and extender internal analog buses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the mainframe, extenders, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum Allowable Peak Voltage
HP 3852A Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	300V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexer	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extender(s), the mainframe and extender(s) are each considered as a separate circuit.

When the HP 44701A's TERM command is set to BOTH, or in case of equipment failure, any high voltage present on the analog backplane will be connected to the HP 44701A's rear terminals. Always regard the HP 44701A's rear terminals as being at a high voltage level.

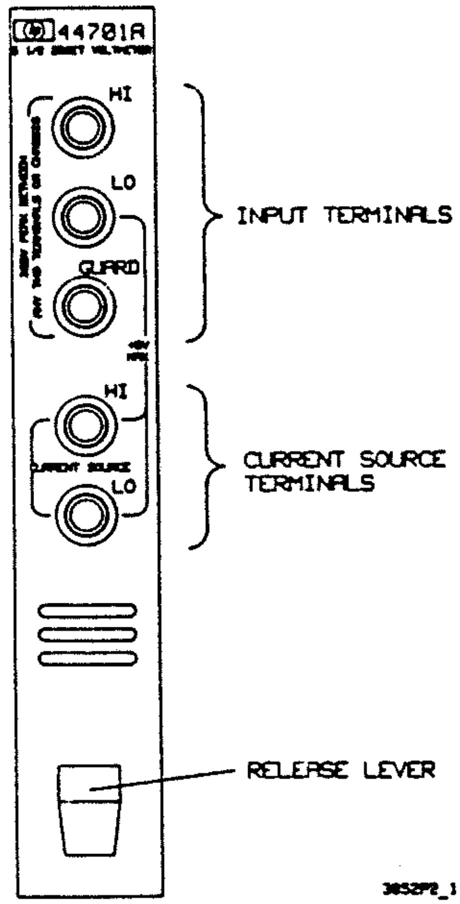

Figure 2-1. HP 44701A Backpanel

How the HP 44701A Works

The HP 44701A measures an analog signal by converting it to a digital value. Once the signal is in digital form, it can be displayed, sent over the HP-IB bus, inserted into a mathematical algorithm and so on. Input signals are converted to digital values by the HP 44701A's A/D (analog to digital) converter.

The A/D Converter

The A/D converter is responsible for many of the HP 44701A's operating characteristics. These characteristics include normal mode rejection (ability to reject signals at the power line frequency from measurements), measurement speed, resolution, and accuracy. The magnitude of these characteristics is, in turn, determined by the A/D converter's integration time.

Integration Time

Integration time is the amount of time that the A/D converter samples the input signal. You specify integration time as a certain number of power line cycles (PLCs) with the NPLC command. The HP 44701A then multiplies the specified number of PLCs times the power line period to determine the integration time. For example, the period of a 50Hz power line is 1/50 = 20 msec. If you specify 0.1 PLCs, the integration time is 20 msec x 0.1 = 2 msec. The 0.0005 and 0.005 PLC settings, however, are fixed regardless of the line frequency at 10 µsec and 100 µsec, respectively.

NOTE

When power is applied, the HP 44701A bases its integration time on a line frequency of 60Hz regardless of the actual power line frequency. If your line frequency is 50 or 400Hz you must execute the NPLC command prior to making measurements. Executing the NPLC command selects the proper line frequency reference for the A/D converter. Refer to "Setting the Integration Time", later in this chapter, for more information.

With longer integration times, the measurement resolution, accuracy, and normal mode rejection increases, but measurement speed decreases. Table 2-1 shows the relationship between the number of PLCs, the maximum number of digits available, and the normal mode rejection. The Specifications Table (Table 2-2) shows the accuracy and maximum measurement speed for each measurement function (AC voltage, DC voltage, and 4-wire ohms) based on the integration time.

Table 2-1. A/D Converter Relationships

Power Line Cycles	Integration Time 60Hz	Integration Time 50Hz	Maximum Number of Digits	Normal Mode Rejection
0.0005	10µs	10µs	3.5	0dB
0.005	100µs	100µs	4.5	0dB
0.1	1.67ms	2.0ms	5.5	0dB
1	16.7ms	20.0ms	6.5	60dB
16	267ms	320ms	6.5	60dB

Specifications

Table 2-2 lists the specifications for the HP 44701A Integrating Voltmeter. The specifications are the performance standards or limits against which the voltmeter is tested.

Any changes in the specifications due to manufacturing changes, design, or traceability to the National Bureau of Standards will be covered in a manual change supplement.

Table 2-2. Specifications

NOTE

For accurate measurements, allow the HP 44701A to warm-up for at least one hour after power is applied.

DC Voltage Ranges/Resolution

Range	Maximum Display	6 1/2 Digit Resolution	5 1/2 Digit Resolution	4 1/2 Digit Resolution	3 1/2 Digit Resolution
30mV	+/-30.30000	10nV	100nV	1µV	10µV
300mV	+/-303.0000	100nV	1µV	10µV	100µV
3V	+/-3.030000	1µV	10µV	100µV	1mV
30V	+/-30.30000	10µV	100µV	1mV	10mV
300V	+/-300.0000	100µV	1mV	10mV	100mV

DC Voltage Accuracy

+/-(% of reading + number of counts)
(autozero on, rear terminals or backplane)
90 days, 23°C +/-5°C, RH < 85%

Range	Percent of Reading	Number of Counts* (Volts) 1,16 PLC	0.1 PLC	0.005 PLC	0.0005 PLC
30mV	0.010	600 (6µ)	80 (8µ)	20 (20µ)	6 (60µ)
300mV	0.008	60 (6µ)	10 (10µ)	4 (40µ)	4 (400µ)
3V	0.008	8 (8µ)	4 (40µ)	4 (400µ)	4 (4m)
30V	0.008	30 (300µ)	7 (700µ)	4 (4m)	4 (40m)
300V	0.008	7 (700µ)	4 (4m)	4 (40m)	4 (400m)

For 1 year, 23° C +/-5°C, add 0.01% to the 90 day accuracies.

(specifications continued on next page)

Table 2-2. Specifications (cont.)

DC Voltage Temperature Coefficient

Add as an additional accuracy error if outside of 18-28°C.
+/-(% of reading + number of counts)/°C
(NPLC = 1)

Autozero on:

Range	30mV	300mV	3V	30V	300V
Coefficient*	0.0006+30	0.0006+3.0	0.0006+0.3	0.0006+0.3	0.0006+0.3

* For NPLC = 0.0005, multiply counts times 0.001
For NPLC = 0.005, multiply counts times 0.01
For NPLC = 0.1, multiply counts times 0.1

Autozero off:

Add as an additional accuracy error if autozero is off. Assumes stable environment (+/-1°C) for 24 hours and NPLC = 1 (6 1/2 digits).

Range	30mV	300mV	3V	30V	300V
Counts*	1000	100	10	10	10

* For NPLC = 0.0005, multiply counts times 0.001
For NPLC = 0.005, multiply counts times 0.01
For NPLC = 0.1, multiply counts times 0.1

DC Voltage Measurement Characteristics

NMR = Normal mode rejection (line frequency = 50 or 60 Hz +/- 0.09%)
ECMR = Effective common mode rejection (1000 ohm unbalance in low lead)

NPLC*	Integration Time 60Hz (50Hz)	Max. Number of Displayed Digits	Max. Reading Rate 60Hz (50Hz)	Noise Rejection (dB) AC NMR	AC ECMR	DC CMR
0.0005	10µS (10µs)	3 1/2	1600 (1600)	0	90	120
0.005	100µs (100µs)	4 1/2	1350 (1350)	0	90	120
0.1	1.67mS (2.0mS)	5 1/2	415 (360)	0	90	120
1.0	16.7mS (20.0mS)	6 1/2	57 (48)	60	150	120
16.0	267mS (320mS)	6 1/2	2.7 (2.3)	60	150	120

* NPLC = Number of Power Line Cycles

(specifications continued on next page)

Table 2-2. Specifications (cont.)

DC Voltage Input/Isolation Resistance

25°C </= 85% RH or 40°C </= 60% RH

Range	High to Low	Low to Guard or Guard to Chassis
30mV to 3V	$>10^{9}$	$>10^{8}$
30V, 300V	10^{7} +/-5%	$>10^{8}$

DC Voltage Maximum Bias Current

+/- 1nA (from high to low), RH < 85% @ 28°C;RH < 60% @ 40°C

	Hi to Low	Low to Guard	Guard to Chassis
Input Capacitance (pF)	≤120	≤2700	≤2500

Resistance Ranges/Resolution (all values in ohms)

Range	Maximum Display	Resolution 6 1/2 Digit	5 1/2 Digit	4 1/2 Digit	3 1/2 Digit	Current Through Unknown
30	+/-30.30000	10µ	100µ	1mV	10m	1mA
300	+/-303.0000	100µ	1m	10m	100m	1mA
3k	+/-3.030000	1m	10m	100m	1	100µA
30k	+/-30.30000	10m	100m	1	10	100µA
300k	+/-303.0000	100m	1	10	100	10µA
3M	+/-3.030000	1	10	100	1k	1µA

(specifications continued on next page)

Resistance Accuracy* (all values in ohms)

+/-(% of reading + number of counts)
(autozero on, 4-wire ohms, rear terminals or backplane)
90 days, 23°C +/-5°C

Range	Percent of Reading	Number of Counts (Ohms) NPLC= 1,16	0.1	0.005	0.0005	Max. Lead Resistance
30	0.015	600(6m)	80(8m)	20(20m)	6(60m)	3k
300	0.015	60(6m)	10(10m)	4(40m)	4(400m)	3k
3k	0.015	60(60m)	10(100m)	4(400m)	4(4)	3k
30k	0.015	8(80m)	4(400m)	4(4)	4(40)	30k
300k	0.015	10(1)	4(4)	4(40)	4(400)	30k
3M	0.015	17(17)	7(70)	5(500)	5(5k)	30k

For 1 year, 23° C +/-5°C, add 0.001% of reading to the 90 day accuracies

*For lead resistances in current source or voltage sense leads </= 3k ohms or full scale of range, not to exceed 30k ohms.

Resistance Temperature Coefficient

Add as an additional accuracy error if outside of 18 - 28°C.

+/-(% of reading + number of counts)/°C

NPLC = 1 (6 1/2 digits)

Autozero on:

Range	30	300	3k	30k	300k	3M
Coefficient*	0.0006+500	0.0006+50	0.0006+5	0.006+5	0.001+5	0.001+5

* For NPLC = 0.0005, multiply counts times 0.001
For NPLC = 0.005, multiply counts times 0.01
For NPLC = 0.1, multiply counts times 0.1

(specifications continued on next page)

Autozero off:

(Changes in lead resistance are not corrected in 4-wire ohms with autozero off).

Add as an additional accuracy error if autozero is off. Assumes stable environment (+/-1°C) for 24 hours.

NPLC = 1 (6 1/2 digits).

Range	30	300	3k	30k	300k	3M
Number of Counts of Zero Offset*	1000	100	10	10	10	10

* For NPLC = 0.0005, multiply counts times 0.001
For NPLC = 0.005, multiply counts times 0.01
For NPLC = 0.1, multiply counts times 0.1

Resistance Reading Rates

Same as for DC measurements. Offset compensated ohms requires two readings and therefore slows the reading rate by a factor of two.

AC Voltage Ranges/Resolution

Range	Maximum Display	3 1/2 Digit Resolution
200mV	+/-202.0000	100μV
2V	+/-2.020000	1mV
20V	+/-20.20000	10mV
200V	+/-202.0000	100mV

AC Voltage Accuracy

AC measurements are made with a peak detector calibrated in RMS and is intended to measure sine waves. The voltmeter is accurate only when the input voltage is greater the 10% of full scale.

90 days, 23°C +/- 5°C, 45 - 500Hz NPLC = 1 (6 1/2 digits) All ranges (0.2, 2, 20, 200V) +/- 0.5% of reading + 600 counts

(specifications continued on next page)

Table 2-2. Specifications (cont.)

AC Voltage Temperature Coefficient

Add as an additional error for temperatures outside of 18 - 28°C. All ranges (0.2, 2, 20, 200V) +/- (0.01% of reading + 70 counts)/°C

AC Voltage Reading Rate

1.5 seconds/reading

Note: changing to the AC volts function requires approximately 2 seconds.

AC Voltage Input/Isolation Resistance

Same as for DC

Installation and Checkout

Installation of the HP 44701A Integrating Voltmeter is described in Chapter 3 of the HP 3852A Mainframe Configuration and Programming Manual. After installing the HP 44701A, you can use the following programs to verify that the installation is correct and that the HP 44701A is operational.

Warnings and Cautions

Two Warning statements and one Caution statement appear on the HP 44701A's case. They are indicated by the symbol ! followed by a numeric subscript. These statements are described below referenced by their numeric subscript. For more complete information refer to the HP 3852A Mainframe Configuration and Programming Manual.

⚠ 1 This Warning reminds you that even when the HP 44701A is removed from the mainframe or extender, hazardous voltages may still be present due to external wiring.

⚠ 2 This Warning reminds you that hazardous voltages (from another channel) may be present on any accessory channel.

⚠ 3 This Caution states that, because of power consumption constraints, only a limited number of voltmeter accessories can be installed in the same mainframe or extender. Refer to "Accessory Power Consumption" in chapter 3 of the Mainframe Configuration and Programming Manual for more information.

Installation Verification

The following program verifies that the HP 44701A has been installed correctly. The program assumes that the voltmeter is installed in slot 1. If your voltmeter is in an extender or a different slot, the slot number in line 20 (100) and in line 40 (SLOT 1) must be modified accordingly.

```
10  PRINTER IS 1
20  OUTPUT 709;"ID? 100"
30  ENTER 709; IDENT$
40  PRINT "ACCESSORY IN SLOT 1 =";IDENT$
50  END
```

NOTE

The command "ID? 100" *can also be entered from the mainframe's front panel and the response will be returned to the display.*

If the voltmeter has been correctly installed in slot 1 of the mainframe, the message *ACCESSORY IN SLOT 1= 44701A* is displayed on the system computer's CRT.

Addressing an empty slot returns a value of *000000* to the controller.

Self-Test

The HP 44701A's self-test consists of the following five tests:

1. Communications check between mainframe/extender & HP 44701A.
2. A/D converter test.
3. Input amplifier offset test.
4. RAM and ROM checksum verification.
5. Calibration constants verification.

NOTE

The calibration constants verification does not guarantee that the voltmeter is adequately calibrated. It only verifies that the calibration constants exist. It is possible to calibrate the voltmeter to an inaccurate standard.

Before executing self-test, you must first ensure that the HP 44701A is not busy performing a measurement or processing a command. If the HP 44701A is busy when you execute self-test, it will cause a self-test failure. You can set the HP 44701A to a non-busy state by executing:

```
OUTPUT 709;"RST 100"
```

You can now execute self-test by sending:

```
OUTPUT 709;"TEST 100"
```

NOTE

You can execute self-test from the front panel by executing RST 100 *followed by* TEST 100.

- If the self-test passes, the HP 3852A displays *SELF TEST OK*. When the self-test passes, you have a high confidence level that the HP 44701A is operational and measurements will be accurate.

- If self-test fails, a hardware or software failure exists and the HP 3852A displays *ERROR -340: TEST: SELF TEST FAILED.* Refer to the HP 44701A Service Manual for repair information.

Following the self-test, the HP 44701A reverts to the power-on state.

Programming the HP 44701A

This section contains step-by-step procedures that teach you the fundamentals of programming your HP 44701A and how to make measurements. It is divided into three major subsections: (1) Configuring the Voltmeter, (2) Making Measurements, and (3) Scanning. The first subsection discusses how to configure the HP 44701A for making measurements such as selecting the function, range, and input terminals. The second subsection shows you how to trigger the voltmeter, make measurements, and read the results. The third subsection shows how to make measurements using the HP 44701A coupled to a multiplexer accessory. To gain a complete understanding of the HP 44701A, we recommend that you perform the procedures in all three subsections.

NOTE

To maintain the highest accuracy, your HP 44701A should be calibrated regularly. For complete calibration information refer to the service manual. Also, for accurate measurements, allow the HP 44701A to warm-up for at least onehour after power is applied.

Configuring the Voltmeter

This subsection shows you how to prepare the HP 44701A for making measurements. For more information about the individual commands referenced in this subsection, refer to the Command Reference Manual.

Power-On State

When you apply power, the HP 44701A sets itself to predefined power-on values. This is called the *power-on state*. Table 2-3 shows the HP 44701A's power-on state.

Table 2-3. Power-On State

Item	State
Function	DC Voltage
Range	Autorange
Terminals	External (Rear)
Trigger Mode	Hold
Offset Compensation	Off (disabled)
Autozero	On (enabled)
Integration Time	1 PLC @ 60Hz
Readings per Trigger	1
Delay Time	Default (see Table 2-6)

Each item in the above table is discussed later in this subsection. The command descriptions in the Command Reference Manual also list the power-on and default values. (A default value is the value selected if you execute a command but do not specify a value).

Reset

Many times during operation, you may wish to return to the power-on state. The reason may be an error in entering commands, or you just want to return the voltmeter to a known state. The reset function returns the HP 44701A to its power-on state without cycling power. However, the reset function aborts any measurements in progress and destroys any readings in the HP 44701A's internal reading buffer. To reset the voltmeter, send:

```
OUTPUT 709;"RESET 100"
```

or

```
OUTPUT 709;"RST 100"
```

Selecting the Voltmeter

More than one voltmeter accessory can be installed in the mainframe or the extender(s). This means that, before sending a voltmeter command, you must designate which voltmeter (by slot number) is to receive the command. This can be done with the USE command. After executing the USE command, all subsequent commands will be sent to the slot defined in the USE command. The slot number is a four digit number in the form ES00, where E is the extender number (mainframe = 0, extenders = 1 - 7) and S is the slot number.

For example, to designate the voltmeter in slot 1 of the mainframe, send:

```
OUTPUT 709;"USE 100"
```

The USE command is remembered by the system mainframe and remains active until another USE command is executed, the mainframe is reset (RST command), or power is cycled. In addition to the USE command, many commands have a USE parameter. For example, the last parameter in the FUNC command is a USE parameter:

```
OUTPUT 709;"FUNC DCV,AUTO,USE 100"
```

In this example, the USE parameter defines the destination (slot) for the FUNC command only. Subsequent commands go to the slot previously defined by the USE command.

The remaining examples in this chapter assume that you have executed the USE command, in advance, to select the appropriate voltmeter slot for the commands.

USE Query

The USE query command (USE?) returns the number of the slot defined by the USE channel or USE parameter. For example, the following program returns and displays the slot number:

```
10 OUTPUT 709; "USE?"
20 ENTER 709; A
30 PRINT "Slot number ";A;" is USE channel"
40 END
```

Selecting the Input Source

The HP 44701A can make measurements from the voltmeter's external (rear) terminals or from a multiplexer module through the mainframe's internal analog bus. The TERM command allows you to select one or both of these input sources. In the power-on state, the voltmeter's external terminals are selected. To make measurements from a multiplexer module, send:

```
OUTPUT 709;"TERM BOTH"
```

Notice that the parameter *BOTH* selects both the backplane analog bus and the external terminals. There is no way to select the backplane analog bus alone. Make sure you disconnect any input signals from the HP 44701A's external terminals before making a measurement from a multiplexer accessory.

WARNING

When the terminals are set to BOTH, or in case of equipment failure, any high voltages present on the analog backplane will be connected to the HP 44701A's rear terminals. Always regard the HP 44701A's rear terminals as possibly being at a high voltage level.

To return to the external terminals, send:

```
OUTPUT 709;"TERM EXT"
```

Voltage Measurements

The HP 44701A has five DC voltage ranges and can measure DC voltages from 10nVDC to 300VDC. The DC Voltage Ranges/Resolution Table (part of Table 2-2) lists the maximum readings for each range and the resolution available for the various integration times.

The HP 44701A has four AC voltage ranges and can measure AC voltages from 100uVAC to 200VAC. The AC voltage Ranges/Resolution Table (part of Table 2-2) lists the maximum readings for each range and the resolution available (the only resolution available for AC voltage measurements is 3 1/2 digits).

The connections for making either AC or DC voltage measurements using the HP 44701A's external (rear) terminals are shown in Figure 2-2.

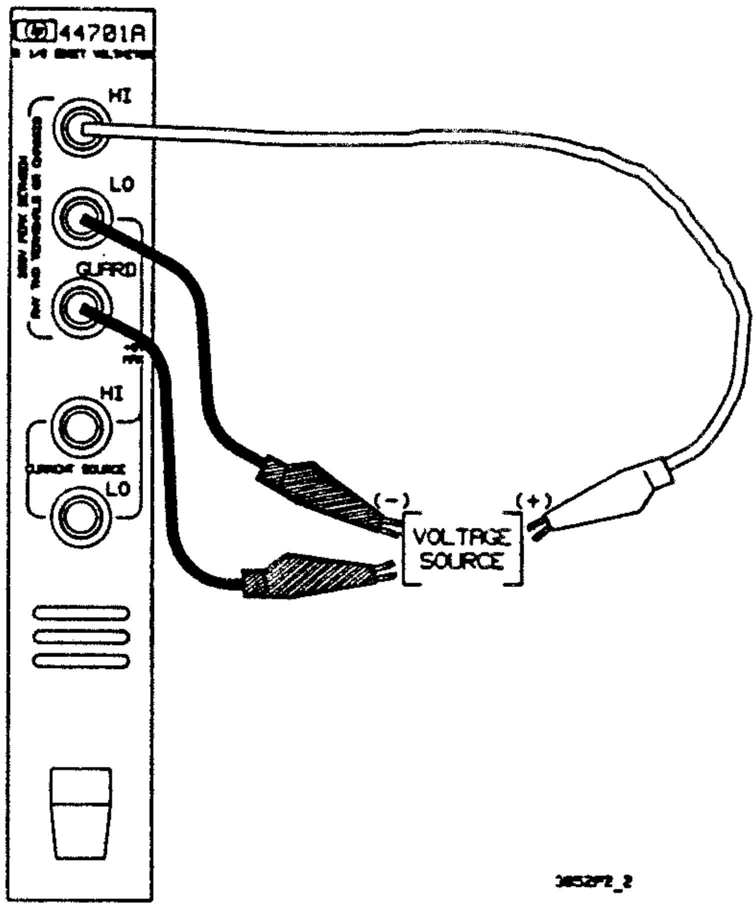

Figure 2-2. Voltage Measurement Connections

Use the voltmeter FUNC command to select the measurement function. For example, to measure DC voltage, send:

```
OUTPUT 709;"FUNC DCV"
```

To measure AC voltage, send:

```
OUTPUT 709;"FUNC ACV"
```

You can add a parameter to the FUNC command to select the measurement range. You specify this parameter as the input signal's maximum expected amplitude (or the maximum resistance for 4-wire ohms measurements). The HP 44701A then chooses the correct range. For example, if you are measuring DC voltage with a maximum voltage of 1.5 volts, send:

```
OUTPUT 709;"FUNC DCV,1.5"
```

In this situation, the HP 44701A chooses the 3V range. Additionally, you can select the autorange mode by defaulting or by specifying *AUTO* or 0 for the second parameter. Refer to "Autorange", later in this subsection for more information on autoranging.

4-Wire Ohms Measurements

The HP 44701A has six resistance ranges and can measure resistances from 10uΩ to 3MΩ. The HP 44701A measures resistance by sourcing a known current through the unknown resistance being measured. The current passing through the resistance generates a voltage across it. The HP 44701A measures this voltage and calculates the unknown resistance (resistance = voltage/current).

Refer to Resistance Ranges/Resolution in Table 2-2 for a listing of the ranges, the maximum reading for each range, the current sourced, and the resolution available for the various integration times.

The connections for making 4-wire ohms measurements using the HP 44701A's external (rear) terminals are shown in Figure 2-3.

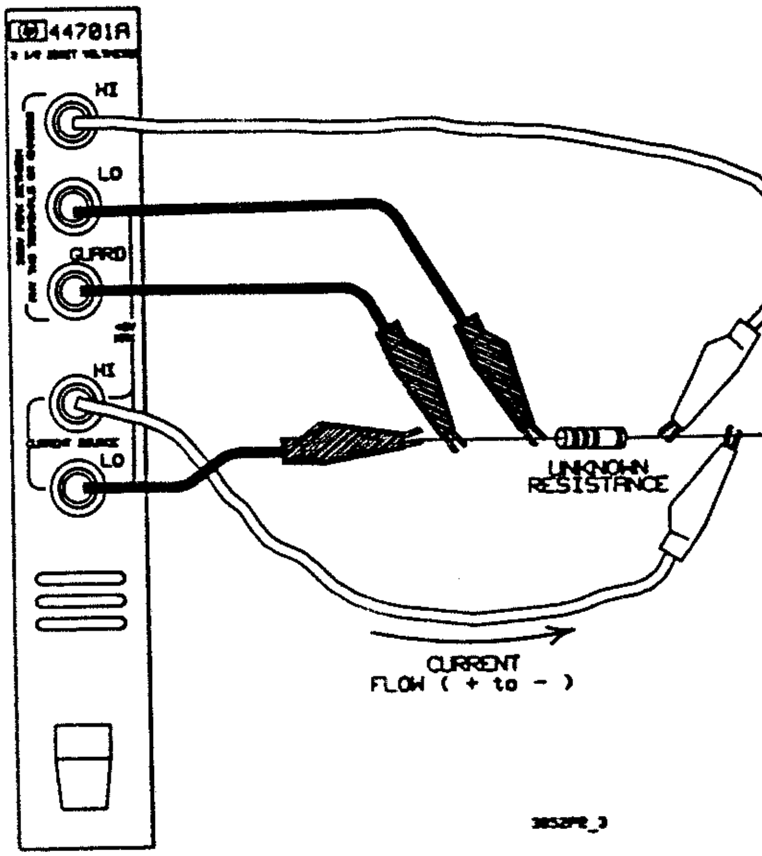

Figure 2-3. 4-Wire Ohms Measurement Connections

Use the FUNC command to select the 4-wire resistance measurement function. For example:

```
OUTPUT 709;"FUNC OHMF"
```

Offset Compensation

Offset compensation allows the HP 44701A to correct for small *external* offset voltages on the 30Ω through 30kΩ ranges. Offset compensation does not function on the 300kΩ and 3 MΩ ranges.

With offset compensation enabled, the HP 44701A measures the offset voltage prior to each resistance measurement. Next, it sources current and measures the combination of induced voltage and offset voltage. The HP 44701A subtracts the offset voltage from the combined voltage leaving only the induced voltage. The HP 44701A then uses this induced voltage to determine the resistance (resistance = voltage/current). Table 2-4 shows the maximum combined voltages that can be present for each range.

Table 2-4. Maximum Combined Voltages

Resistance Range	Maximum Combined Voltage
30 ohm	30 mV
300 ohm	300 mV
3k ohm	300 mV
30k ohm	3 V

NOTE

Since offset compensation requires sampling the input, it takes more time per reading than measurements made with offset compensation disabled.

The OCOMP command turns offset compensation on or off. For example, to turn offset compensation on, send:

```
OUTPUT 709;"OCOMP ON"
```

Current Measurements

The HP 44701A can measure current indirectly by measuring the voltage drop across a small, known resistance (shunt) placed in the current path. The connections for making both AC and DC current measurements using the HP 44701A's external (rear) terminals are shown in Figure 2-4.

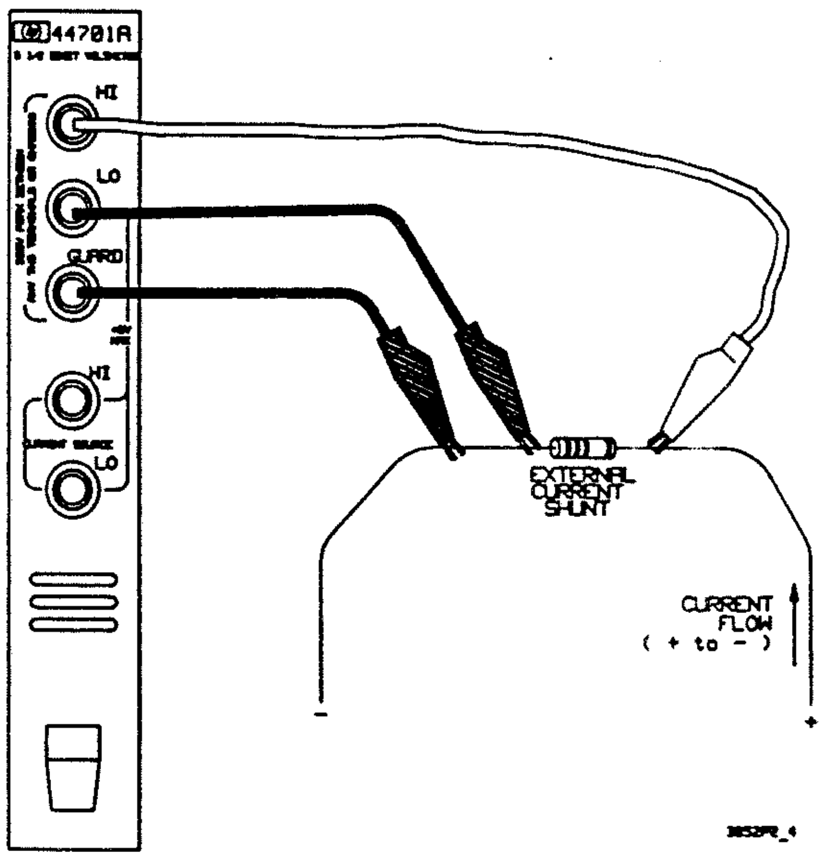

Figure 2-4. Current Measurement Connections

To measure DC current, select DC voltage measurements as previously described. To measure AC current, select AC voltage measurements. You calculate the current flowing through the shunt as follows:

Current = Voltage Reading/Known Resistance

For example, if a 2Ω resistor is used, and the measured voltage is 350 mVDC, the current is 350 mVDC/2 = 175 mADC.

Setting the Integration Time

The HP 44701A samples the signal being measured for a period of time (integration time) based on the power line frequency. You specify this integration time as a certain number of power line cycles (PLCs) of the line frequency. The integration time is responsible for the measurement speed, accuracy, maximum digits of resolution, and the amount of normal mode rejection (ability to reject the line frequency from the measurement). Refer to "How the HP 44701A Works" (near the beginning of this chapter) for more information on integration time. The power-on integration time is 1 PLC at a line frequency of 60Hz.

NOTE

When power is applied, the HP 44701A bases its integration time on a line frequency of 60Hz regardless of the actual power line frequency. If your line frequency is 50Hz you must execute the NPLC or CONF command prior to making measurements. This selects the proper line frequency reference for the A/D converter.

To set the integration time for the fastest measurements (with the lowest accuracy and no normal mode rejection), send:

```
OUTPUT 709;"NPLC .0005"
```

or:

```
OUTPUT 709;"NPLC 0"
```

To specify the most accurate measurements (with the slowest measurement speed and 60dB of normal mode rejection), send:

```
OUTPUT 709;"NPLC 16"
```

There are three settings between these high and low limits that provide varying degrees of measurement speed vs. accuracy. Typically, you should select the integration time that provides adequate speed while maintaining an acceptable amount of accuracy. The specifications table (Table 2-2) shows the speed/accuracy tradeoffs, based on the integration time, for each measurement function. (For AC voltage measurements, because of settling time constraints, the reading rate is 1.5 readings per second regardless of the amount of integration time).

Autorange

When autorange is enabled, the HP 44701A samples the input prior to each measurement and automatically selects the correct range. The ARANGE (autorange) command enables or disables the autorange mode.

NOTE

Since autoranging requires sampling the input, it takes more time per reading than measurements made with autorange disabled.

When power is applied autorange is enabled. Therefore, if you are measuring a fairly steady input signal or resistance, you can allow autorange to select the correct range and then disable autorange. This allows you to get the automatic range selection advantage of autorange and also the speed advantage of readings made with autorange disabled. For example, to allow autorange to select the range, trigger a reading by sending:

```
OUTPUT 709;"TRIG SGL"
```

The HP 44701A has now gone to the correct range. Now, to disable autorange, send:

```
OUTPUT 709;"ARANGE OFF"
```

The HP 44701A now stays on the range selected by autorange. Later, if you need to enable autorange, send:

```
OUTPUT 709;"ARANGE ON"
```

Specifying the Range

You can specify the voltmeter's measurement range either as a parameter of the FUNC command or separately with the RANGE command. You specify the range as the input signal's maximum expected amplitude (or the maximum resistance for resistance measurements). The HP 44701A then chooses the correct range. for example, if you are measuring DC voltages with a maximum input of 5.5 volts, send either:

```
OUTPUT 709;"FUNC DCV,5.5"
```

or

```
OUTPUT 709;"RANGE 5.5"
```

In both of the above cases, the HP 44701A selects the 30V range.

You may also specify *AUTO* or 0 as the range parameter and the voltmeter will autorange all measurements.

Overload Indication

The HP 44701A indicates an overload condition (input greater than present range can measure) by sending 1E38 to the output buffer/display instead of a reading.

The Autozero Function

The autozero function ensures that any offset errors internal to the voltmeter are nulled from subsequent readings. The autozero function is controlled using the AZERO command. With AZERO ON, the HP 44701A internally disconnects the input signal and makes a zero reading following every measurement. It then subtracts the zero reading from the preceding measurement. This prevents offset voltages on the HP 44701A's *internal* circuitry from affecting measurements.

With AZERO OFF or ONCE, the HP 44701A takes one zero reading (upon receipt of the command) and subtracts it from all subsequent measurements. It takes a new zero reading whenever the function or range changes.

NOTE

When the HP 44701A makes a zero reading with AZERO OFF or ONCE, it actually averages 16 zero readings made using the present integration time setting. This is done to ensure the zero reading has maximum line frequency rejection. Depending on the integration time setting, this zero reading may take 500msec or longer. When AZERO is ON, the HP 44701A makes a zero reading after each measurement that is a single reading (not the average of 16 readings). In most cases, AZERO ON requires more time per reading than AZERO OFF or ONCE. However, if you are making a series of measurements where the range or function will be changing, you may get faster readings with AZERO ON instead of AZERO OFF or ONCE.

In the power-on mode, AZERO is set to ON. You can change it by sending:

```
OUTPUT 709;"AZERO ONCE"
```

NOTE

You cannot set AZERO ON for AC voltage measurements. The AZERO mode is always OFF for AC voltage measurements.

The CONF Command

The CONF command selects the measurement function and sets the other functions (range, autozero, etc.) to their preset values. Table 2-5 shows the preset values.

Table 2-5. Default Values

Item	State
Range	Autorange*
Terminals	Both (Backplane & Rear)
Trigger Mode	Hold
Offset Compensation	Off (disabled)
Autozero	On
Integration Time	1 Power Line Cycle
Readings per Trigger	1
Delay Time	Unchanged

*For all measurement functions except TEMP. For TEMPtype B, R, S, T, and N28 the 30mV range is selected. For TEMPtype E, J, K, and N14 the 300mV range is selected.

NOTE

The CONF command is considered a high level command since it performs more than one operation. The other high level commands are MEAS, CONFMEAS, and MONMEAS. The commands discussed earlier in this subsection perform single operations (such as selecting range or number of power line cycles) and are considered low level commands.

Typically, you will want to send the CONF command first and then change some of the default selections using low level commands. For example, to set the Integrating Voltmeter to the DC volts function and select the default settings for the other functions, send:

```
OUTPUT 709;"CONF DCV"
```

Now you can change some of the default settings (to suit your application) using the low level commands discussed earlier in this subsection. For example, to change the autozero mode from ON to OFF, send:

```
OUTPUT 709;"AZERO OFF"
```

NOTE

When scanning on a multiplexer accessory using high level commands (CONF & MEAS together, CONFMEAS, or MONMEAS), you can make a number of additional measurements not possible using the low level commands alone. These include 2-wire ohms measurements, 4-wire ohms measurements with automatic Source channel designation, and automatic temperature measurements from thermistors, thermocouples, and RTDs. These additional measurement functions are discussed in detail under "The CONFMEAS Command" later in this chapter.

Making Measurements

When power is applied (power-on mode), the HP 44701A's trigger mode is set to HOLD which prevents it from making measurements. All you must do to make a reading is trigger the HP 44701A. This subsection shows you a variety of ways to trigger the voltmeter and read the results. It also shows you how to store readings in mainframe memory and how to interrupt when readings are available.

Continuous Readings

In the continuous trigger mode (TRIG AUTO) the voltmeter triggers whenever it is not making a measurement or processing a command. This is the easiest way to make measurements. To specify continuous triggering, send:

```
OUTPUT 709;"TRIG AUTO"
```

The voltmeter is now continuously making measurements one after the other. The HP 44701A's internal reading buffer, however, can store only 1 reading. When making automatic measurements, you should transfer the previous reading to the HP-IB output buffer before the new reading is ready. If not, the HP 44701A *overwrites* the previous reading with the new reading.

By now, the HP 44701A has made (and written over) many readings. To transfer the present reading from the voltmeter's reading buffer (voltmeter in slot 1) to the HP-IB output buffer, send:

```
OUTPUT 709;"CHREAD 100"
```

NOTE

If the CHREAD command is entered from remote (HP-IB), the reading goes to the HP-IB output buffer and, in the mainframe's power-on mode, to the display. If entered from the front panel, the reading goes to the display only.

For a single reading, you can use the following program to enter and display the reading on your computer:

```
10  ENTER 709;A
20  DISP A
30  END
```

To transfer a series of readings, you could repeatedly send the CHREAD command. A better method, however, is to use the XRDGS command. The XRDGS command transfers a series of readings (one reading at a time) to the HP-IB output buffer. For example, the following program line transfers a total of 10 readings (specified by the 2nd parameter) from the voltmeter in slot 1 (specified by the 1st parameter) to the HP-IB output buffer:

```
OUTPUT 709;"XRDGS 100,10"
```

NOTE

If the XRDGS command is entered from remote (HP-IB), the readings go to the HP-IB output buffer and, in the mainframe's power-on mode, to the display. If entered from the front panel, the readings go to the display only.

You can use the following program to enter all 10 readings (one reading at a time) into a computer array called *Data* and display the readings.

```
10  DIM Data(1:10)
20  ENTER 709; Data(*)
30  PRINT USING"K,/";Data(*)
40  END
```

Suspending Measurements

You can stop making measurements by setting the trigger mode to HOLD (the power-on mode):

```
OUTPUT 709;"TRIG HOLD"
```

Measurements are now suspended. The HP 44701A will not make another measurement until you select another trigger mode.

Single Readings

You can trigger the HP 44701A once by setting the trigger mode to single, send:

```
OUTPUT 709;"TRIG SGL"
```

The HP 44701A has just made a single reading and placed it in its internal reading buffer.

To transfer the reading from the voltmeter's reading buffer (voltmeter in slot 1) to the HP-IB output buffer, send:

```
OUTPUT 709;"CHREAD 100"
```

Multiple Readings

You can use the NRDGS (number of readings) command to specify more than one reading for each trigger received. For example, to set the number of readings to 10, send:

```
OUTPUT 709;"NRDGS 10"
```

Now for each trigger (e.g., TRIG SGL) the HP 44701A will make 10 measurements. To trigger the measurements, send:

```
OUTPUT 709;"TRIG SGL"
```

NOTE

The HP 44701A's internal reading buffer can store only 1 reading. When making multiple readings per trigger (in any trigger mode except AUTO), the HP 44701A takes one reading (after being triggered) and places it into its reading buffer. It then waits until the reading is transferred (by the XRDGS command for example) before it makes the next reading. This provides a type of synchronization between the HP 44701A and the mainframe/extender which prevents readings from being lost.

When transferring readings over the HP-IB, the mainframe allows the HP 44701A to make measurements until the HP-IB output buffer is full (approximately 68 readings using the default format). When the HP-IB output buffer is full, the mainframe causes the HP 44701A to wait until the controller removes a reading. After the controller removes a reading, the voltmeter can send another reading to the HP-IB output buffer. So in effect, the voltmeter and the mainframe are handshaking the readings and preventing them from being lost. It also means the computer must transfer readings from the output buffer to prevent stacking-up readings and suspending the measurements.

The following program transfers 10 readings to the HP-IB output buffer. It then transfers each reading from the output buffer to a computer array (*Data*) and displays the readings.

```
10  DIM Data(1:10)
20  OUTPUT 709;"XRDGS 100,10"
30  ENTER 709; Data(*)
40  PRINT USING"K,/";Data(*)
50  END
```

Trigger Delay

You can insert a time interval to delay readings using the DELAY command. When making a single reading per trigger, (NRDGS = 1), the time interval occurs between the trigger and the reading. For example, the following program specifies one reading per trigger and inserts a one second delay between the trigger and the first reading:

```
10  OUTPUT 709;"NRDGS 1"
20  OUTPUT 709;"DELAY 1"
30  OUTPUT 709;"TRIG SGL"
40  OUTPUT 709;"CHREAD 100"
50  END
```

When making multiple readings per trigger (NRDGS > 1) the delay interval occurs between the trigger and the first reading and also before each successive reading. For example, the following program specifies ten readings per trigger, inserts a one second delay between the trigger and the first reading and before each successive reading. In other words, a total of 10 seconds is inserted into the measurement cycle.

```
10  OUTPUT 709;"NRDGS 10"
20  OUTPUT 709;"DELAY 1"
30  OUTPUT 709;"TRIG SGL"
40  OUTPUT 709;"XRDGS 100,10"
50  END
```

Default Delays

The HP 44701A automatically selects a default delay time for each measurement function, range, and resolution. This delay time is actually the settling time allowed before each measurement which ensures accurate measurements. For AC voltage measurements, the default delay time is 1.5 seconds regardless of the range or resolution. The default delay times for DC voltage and 4-wire ohms measurements are shown in Table 2-6.

Table 2-6. Default Delay Times

Measurement Function	Range	Default Delay in µseconds Digits: 3.5	4.5	5.5 & 6.5
DCV	30mV	380	496	600
	300mv	200	260	320
	3V	200	260	320
	30V	36	46	57
	300V	11	14	17
OHMF	30 ohm	320	390	460
	300 ohm	200	240	290
	3 kohm	200	240	290
	30 kohm	200	240	290
	300 kohm	720	880	1000
	3 Mohm	7200	8800	10000

The default delay time is updated automatically whenever the function or range changes. Once you specify a delay time value, however, the value does not change until you specify another value or reset the HP 44701A.

NOTE

You can specify a shorter delay time than the default value. However, the resulting settling time may not produce accurate measurements.

Because of hardware constraints, specified delay times of less than 50 µsec. produce an actual delay time of 35 µsec.

The System Trigger

The system trigger function allows the HP 44701A to be triggered from other sources such as an external trigger or the HP-IB Group Execute Trigger. To select the system trigger, send:

```
OUTPUT 709;"TRIG SYS"
```

You can now specify the system trigger source using the TRG command. For example, to specify the external trigger, send:

```
OUTPUT 709;"TRG EXT"
```

The HP 44701A will now be triggered by a low-going pulse on the mainframe's Trigger-In BNC connector.

NOTE

When triggering the HP 44701A from an external source, it is possible for successive trigger(s) to occur before the HP 44701A has finished the present measurement. When this occurs, no error is generated and the first of the successive triggers is stored. When the measurement is completed, the stored trigger initiates another measurement.

To configure the HP 44701A to trigger from the HP-IB Group Execute Trigger signal, send:

```
OUTPUT 709;"TRG GET"
```

The HP 44701A now triggers whenever the HP-IB Group Execute Trigger (GET) is sent. For example, to send GET using HP BASIC language, send:

```
TRIGGER 709
```

Scan Triggering

The voltmeter can be set up to trigger immediately after a multiplexer channel is closed. To do this send:

```
OUTPUT 709;"TRIG SCAN"
```

Now, whenever a multiplexer channel is closed, the voltmeter is automatically triggered once. For example, to trigger the voltmeter send:

```
OUTPUT 709;"CLOSE 0201"
```

Scan triggering is very useful when using the HP 44701A coupled with a multiplexer accessory (scanning). This is discussed in detail later in this chapter under "Scanning".

Using Variables

Instead of sending a reading to the HP-IB output buffer, you can use the CHREAD command to send the reading to a mainframe variable. For example, the following program triggers the voltmeter in slot 1 and transfers the reading to the mainframe variable R.

```
10  OUTPUT 709;"REAL R"
20  OUTPUT 709;"USE 100"
30  OUTPUT 709;"TRIG SGL"
40  OUTPUT 709;"CHREAD 100,INTO R"
50  END
```

The VREAD command allows you to access readings stored in a mainframe variable. The following program transfers one reading from variable R, enters and displays the reading.

```
10  OUTPUT 709;"VREAD R"
20  ENTER 709; A
30  DISP A
40  END
```

Using Arrays

When making multiple readings, you can define a mainframe memory array that will hold all the readings and transfer the readings into this array automatically as they become available. For example, to dimension an array to hold 10 readings, send:

```
OUTPUT 709;"REAL RGS(9)"
```

You have now created an array called *RGS* large enough to hold 10 readings.

NOTE

The numbering system for arrays starts with the number zero. So by specifying 9 in the preceding statement, you created an array with 10 elements numbered from 0 to 9.

Now, to select 10 readings per trigger send:

```
OUTPUT 709;"NRDGS 10"
```

To trigger the measurements, send:

```
OUTPUT 709;"TRIG SGL"
```

To automatically transfer the readings to the array, send:

```
OUTPUT 709;"XRDGS 100,10,INTO RGS"
```

Now as each reading becomes available, it is placed into the RGS array and the next reading is made. You can access readings in the array using the VREAD command as follows:

```
OUTPUT 709;"VREAD RGS"
```

Again, to transfer readings to the computer, use the program:

```
10  DIM Data(1:10)
20  ENTER 709; Data(*)
30  PRINT USING"K,/";Data(*)
40  END
```

Interrupts

The ENABLE INTR command programs the HP 44701A to interrupt the mainframe processor when data becomes available or an overrange condition occurs. The system interrupt capability must be enabled (ENABLE INTR SYS command) before the ENABLE INTR command can be used to generate an interrupt. (In the power-on state, the system interrupt is enabled. An HP-IB device clear, however, disables the system interrupt).

Two conditions must be met to have the interrupt signal the system controller:

- To have an interrupt set the HP-IB SRQ line true, the status register's INTR bit (weight = 512) must be enabled (RQS 512 command) and cleared (STA? command) and the SRQ must be enabled (RQS ON command). (In the power-on state, the SRQ is enabled).
- Your system controller must be programmed to respond to the interrupt.

The interrupt is disabled when serviced, and cleared when the data is read.

The following program enables the voltmeter in mainframe slot 1 to interrupt when a reading is available or an overrange condition occurs.

```
10  OUTPUT 709;"USE 100"
20  OUTPUT 709;"RQS ON"
30  OUTPUT 709;"RQS 512"
40  OUTPUT 709;"STA?"
50  OUTPUT 709;"ENABLE INTR SYS"
60  OUTPUT 709;"ENABLE INTR"
70  END
```

Interrupt Query

The interrupt query command (INTR?) returns the number of the lowest slot generating an interrupt. If no slot is generating an interrupt, the number -1 is returned. The following program returns and displays the lowest interrupting slot number:

```
10 OUTPUT 709; "INTR?"
20 ENTER 709; A
30 PRINT "Slot number ";A;" is interrupting."
40 END
```

Disabling Interrupts

As stated above, a voltmeter interrupt is disabled when serviced. You can, however, use the DISABLE INTR command to disable an interrupt without having to service it. For example, to disable an interrupt, send:

```
OUTPUT 709;"DISABLE INTR"
```

For more information on interrupts, refer to chapter 8 of the Mainframe Configuration and Programming Manual.

Scanning

Scanning is the process of stepping to one or more multiplexer channels (channel list) and having the voltmeter make one or more measurements on each channel. Connections between the multiplexer accessory and the voltmeter are made through the mainframe or extender's analog backplane. Scanning can be done using the HP 44701A and any of the multiplexer accessories.

The scanning process is made up of (1) the configuration phase and, (2) the measurement phase.

Configuration Phase

You configure the voltmeter for scanning just as you did earlier (by executing the individual commands such as FUNC, RANGE, and NRDGS; by executing CONF; or by executing CONF followed by some of the individual commands).

Measurement Phase

In the measurement phase, the channel list is defined, and those channels are scanned and measured.

Scanning with Low Level Commands

The following program shows how to perform the configuration phase using the CONF command followed by certain low level commands and the measurement phase using low level commands. In this program, the voltmeter makes 10 readings on each multiplexer channel before proceeding to the next channel. The voltmeter is installed in slot 1 of the mainframe and the multiplexer accessory is installed in slot 2 of the mainframe. The readings are stored in the mainframe array RGS.

```
10     !Configuration Phase:
20  OUTPUT 709;"REAL RGS (99)"
30  OUTPUT 709;"USE 100"
40  OUTPUT 709;"TRIG HOLD"
50  OUTPUT 709;"CONF DCV"
60  OUTPUT 709;"NRDGS 10"
70  OUTPUT 709;"CLOSE 291"
80  OUTPUT 709;"TRIG SCAN"
90     !Measurement Phase:
100 FOR I= 200 TO 209 STEP 1
110 OUTPUT 709;"CLOSE ";I
120 OUTPUT 709;"XRDGS 100,10,INTO RGS"
130 OUTPUT 709;"OPEN ";I
140 NEXT I
150 OUTPUT 709;"VREAD RGS"
160 FOR I = 1 TO 100
170 ENTER 709; A
180 PRINT A
190 NEXT I
200 END
```

NOTE

After using a voltmeter to make measurements through a multiplexer accessory, the voltmeters's input terminals remain connected to the backplane analog bus. When another voltmeter is used to make measurements in the same mainframe or extender, the input terminals of both voltmeters are connected in parallel which lowers the effective input impedance of each. To prevent this, disconnect the unused voltmeter's input terminals from the backplane by selecting its rear terminals (TERM EXT command) or by resetting the voltmeter.

The MEAS Command

You can use the high level MEAS command to simplify the "Measurement Phase" in the above program. The MEAS command selects the measurement function and causes the voltmeter to scan and measure the specified multiplexer channels. It also automatically closes the appropriate tree relays (line 70 in the preceding program) when scanning. The characteristics of the MEAS command are:

- If the present voltmeter measurement function *is* compatible with the function specified in the MEAS command, the present state of the other functions (autozero, range etc.) are not changed. (To set these other functions to their default states, execute the CONF command prior to the MEAS command or use the CONFMEAS command.)
- If the present voltmeter function *is not* compatible with the function specified in the MEAS command, the function is changed and autorange is selected.
- If the present voltmeter trigger mode is set to HOLD or AUTO, executing the MEAS command changes the trigger mode to SCAN. If the trigger mode was previously set to SYS, it is not changed by the MEAS command.

NOTE

If the MEAS command is entered from remote (HP-IB), the readings go to the HP-IB output buffer and, in the mainframe's power-on mode, to the display. If entered from the front panel, the readings go to the display only.

The following program performs the same functions as the preceding program but uses the MEAS command. The voltmeter measures each channel on the multiplexer accessory 10 times before stepping to the next channel.

```
10 OUTPUT 709;"REAL RGS(99)"
20 OUTPUT 709;"USE 100"
30 OUTPUT 709;"CONF DCV"
40 OUTPUT 709;"NRDGS 10"
50 OUTPUT 709;"MEAS DCV,200-209,INTO RGS"
60 OUTPUT 709;"VREAD RGS"
70 FOR I=1 TO 100
80 ENTER 709; A
90 PRINT A
100 NEXT I
110 END
```

In line 20, the CONF command selects the default values, such as autorange, for the voltmeter. Since the DCV parameter for the MEAS command (line 30) is compatible with the present measurement function, all other functions, such as ranging and number of readings per trigger, are not changed by executing MEAS.

NOTE

When scanning with high level commands (CONF & MEAS together, CONFMEAS, or MONMEAS), you can make a number of additional measurements not possible using the low level commands alone. These include 2-wire ohms measurements, 4-wire ohms measurements with automatic Source channel designation, and automatic temperature measurements from thermistors, thermocouples, and RTDs. These additional measurements are not possible when using only low level commands or when using the HP 44701A without a multiplexer accessory. Refer to "The CONFMEAS Command" below for more information.

Notice that when using the CONF and MEAS commands that other events or programming steps can occur between the Configuration and Measurement Phase (such as the NRDGS command, line 40). It is also possible for interrupts, alarm conditions or limit tests to occur between the CONF and MEAS command which could reconfigure the voltmeter (if so programmed). If you do not need to change any of the voltmeter defaults and/or you want nothing to intervene between the two phases, both commands can be executed simultaneously with the CONFMEAS command.

The CONFMEAS Command

The CONFMEAS command configures the voltmeter to the specified measurement function (ACV, DCV, etc.) and selects the default values for the other functions (autozero, range, etc.). This command also causes the specified multiplexer channel(s) to be scanned, measured, and the data conversions for resistance and temperature to be performed on the results. The CONFMEAS command also scans and measures unspecified reference channels when making thermocouple temperature measurements. The CONFMEAS command is equivalent to the CONF command immediately followed by the MEAS command.

NOTE

If the CONFMEAS command is entered from remote (HP-IB), the readings go to the HP-IB output buffer and, in the mainframe's power-on mode, to the display. If entered from the front panel, the readings go to the display only.

The following program performs *most* of the same functions as the preceding program but uses the CONFMEAS command to replace the individual commands CONF and MEAS. Notice, however, when using CONFMEAS, you cannot change any of the preset settings between the Configuration and Measurement Phases. This means you cannot execute the NRDGS command to take 10 readings per trigger. In this program, the preset value of 1 reading per trigger must be used.

```
10  OUTPUT 709;"REAL RGS(20)"
20  OUTPUT 709;"USE 100"
30  OUTPUT 709;"CONFMEAS DCV,200-219,INTO RGS"
40  OUTPUT 709;"VREAD RGS"
50  FOR I=1 TO 20
60  ENTER 709; A
70  PRINT A
80  NEXT I
90  END
```

The CONFMEAS command or the separate CONF and MEAS commands, allow you to make the standard measurements discussed earlier (ACV, DCV, OHMF) and a number of additional measurements not possible using the low level commands alone. Table 2-7 shows the measurements possible using CONFMEAS, MEAS, or MONMEAS.

Table 2-7. High Level Command Measurement Functions

Measurement Function	Description
ACV	Measure AC voltage
DCV	Measure DC voltage
OHM	Measure 2-wire ohms*
OHMF	Measure 4-wire ohms**
TEMPtype	Measure the reference temperature then measure the thermocouple voltage. Convert measured voltage (compensated by the ref. temp.) to degrees C. Thermocouple types: J, K, T, S, R, B, E, N14, and N28.
REFT	Measure the reference temperature of thermistor on isothermal block.
THMtype	Configure for a 2-wire ohms measurement on a thermistor.* Convert the resistance to degrees C. Thermistor types: 2252 (for 2252 ohm thermistor) 5K (for 5k ohm thermistor) 10K (for 10k ohm thermistor)
THMFtype	Configure for 4-wire ohms measurement on a thermistor.** Convert the resistance to degrees C. Thermistor types: same as THMtype above.
RTDtype	Configure for 2-wire ohms measurement on an RTD.* The mainframe converts the resistance to a temperature in degrees C. RTD types: 85 (for RTDs with alpha = 0.00385 ohms/ohm/degree C) 92 (for RTDs with alpha = 0.003916 ohms/ohm/degree C)
RTDFtype	Configure for a 4-wire ohms measurement on an RTD.** The mainframe converts the resistance to a temperature in degrees C. RTD types: same as RTDtype above.

* For 2-wire ohms measurements (OHM), the multiplexer accessory connects the Source terminals to the Sense terminals which effectively causes the HP 44701A to make 2-wire ohms measurements.

** For 4-wire ohms measurements (OHMF), the Source terminals connect to Bank B of the multiplexer and the Sense terminals connect to Bank A.

4-Wire Ohms Measurements

When using high level commands, you can make 4-wire ohms measurements using the HP 44701A coupled with any multiplexer accessory capable of switching 4-wire ohms (such as the HP 44705A 20 Channel Relay Multiplexer). Each 4-wire ohms measurement uses two multiplexer channels. You specify the Sense channel(s) and the HP 3852A automatically defines the corresponding Source channel(s). For example, on a 20-channel multiplexer accessory, the Sense and Source channels are separated by 10. That is, if using channel 0 for the Sense, channel 10 is defined as the Source, 1 = Sense, 11 = Source, and so on. Refer to the chapter concerning your particular multiplexer accessory for more information.

NOTE

After making resistance measurements using a multiplexer accessory, the voltmeters's current source remains connected to the backplane analog bus. If another voltmeter is used to make resistance measurements in the same mainframe or extender, both current sources are connected in parallel which causes erroneous measurements. After using the HP 44701A for backplane resistance measurements, disconnect the current source from the backplane by selecting the rear terminals (TERM EXT command), by changing the measurement function, or by resetting the HP 44701A.

The following program performs a 4-wire ohms measurement using the HP 44701A voltmeter (slot 1) and a multiplexer accessory (slot 2). Notice that the channel specified in the CONFMEAS command (slot 2, channel 0) is the Sense channel (the HP 3852A automatically defines the Source channel). The resistance is scanned and measured once by the voltmeter and the result (in ohms) is returned to the controller.

```
10  OUTPUT 709;"CONFMEAS OHMF,200,USE 100"
20  ENTER 709; Ohms
30  PRINT Ohms
40  END
```

Making Current Measurements

When using the CONFMEAS command or the separate CONF and MEAS commands, you can make current measurements, indirectly, using the HP 44701A coupled with any multiplexer accessory with current shunt capabilities (for example, the HP 44705A 20 Channel Relay Multiplexer). When making a current measurement, the voltage across a shunt resistor (installed on a multiplexer accessory) is measured. You then calculate the current using the equation *current = measured voltage/shunt resistance*.

The following program uses the CONFMEAS command to scan and measure a 250Ω shunt resistor installed on channel 0. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the channel once. The voltage value is returned to the controller which then calculates the current in DC amps.

```
10  OUTPUT 709;"CONFMEAS DCV,200,USE 100"
20  ENTER 709; Volts
30  PRINT Volts/250
40  END
```

To use the above program to make AC current measurements, substitute the following line:

```
10 OUTPUT 709;"CONFMEAS ACV,200,USE 100"
```

Making Temperature Measurements

When using the CONFMEAS command or the separate CONF and MEAS commands, you can make automatic temperature measurements from thermistors and RTDs using the HP 44701A coupled with any multiplexer accessory.

NOTE

After making thermistor or RTD temperature measurements, the voltmeters's current source remains connected to the backplane analog bus. If another voltmeter is used to make resistance or thermistor/RTD measurements in the same mainframe or extender, both current sources are connected in parallel which causes erroneous measurements. After using the HP 44701A for backplane temperature measurements, disconnect the current source from the backplane by selecting the rear terminals (TERM EXT command), by changing the measurement function, or by resetting the HP 44701A.

You can also make automatic temperature measurements from thermocouples using a multiplexer accessory having thermocouple compensation (such as the HP 44708A 20-Channel Relay Multiplexer/TC). For all types of temperature measurements, the HP 3852A automatically converts the measured resistance (for thermistors and RTDs) or voltage (for thermocouples) into a temperature reading. For thermocouple temperature measurements, the HP 3852A also automatically measures the reference temperature at the connector block, and corrects the temperature reading accordingly.

Using Thermocouples

A thermocouple is a junction of two unlike metals that produces a voltage proportional to the junction temperature. The HP 3852A temperature conversions support B, E, J, K, N14, N28, R, S, and T type thermocouples.

The voltmeter measures the voltage generated by a thermocouple. Wiring junctions on the isothermal connector block, however, also act like thermocouples and can cause errors in the measurement. When using a multiplexer accessory that contains thermocouple compensation and when using the CONFMEAS command or the separate CONF and MEAS commands, the HP 3852A corrects for junction voltages as follows:

1. The resistance of the thermistor mounted on the

isothermal connector block is measured and the reference temperature is calculated.

2. The thermocouple voltage is measured.

3. The reference temperature is converted to a reference voltage. Since the compensation depends upon the type of thermocouple, this allows different types of thermocouples to be used.

4. The thermocouple voltage measured in step 2 is added to the voltage computed in step 3.

5. The total voltage from step 4 is converted to a temperature in Celsius.

The following program uses the CONFMEAS command to measure 20 J-type thermocouples connected to multiplexer channels 0 through 19. The program scans and measures the 20 channels once and returns the results (in °C) to the controller.

```
10  REAL Temp(19)
20  OUTPUT 709;"CONFMEAS TEMPJ,200-219,USE 100"
30  FOR I = 0 TO 19
40  ENTER 709; Temp(I)
50  PRINT "Ch.";I, Temp(I)
60  NEXT I
70  END
```

You can also measure the reference temperature separately. The following program uses the CONFMEAS command to measure the reference temperature and also the compensated temperature of a B-type thermocouple mounted on channel 0 (slot 2).

```
10  OUTPUT 709;"CONFMEAS REFT,200,USE 100"
20  ENTER 709; Reftemp
30  OUTPUT 709;"CONFMEAS TEMPB,200,USE 100"
40  ENTER 709; Temp
50  PRINT "Isothermal Reference Temperature = ";Reftemp
60  PRINT "Compensated Temperature = ";Temp
70  END
```

Using RTDs

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ and resistance values of 100Ω at 0°C.

The following program uses the CONFMEAS command to scan and measure 10 RTDs (with $\alpha = 0.00385\ \Omega/\Omega\,^{\circ}C$) using the 4-wire function. The multiplexer must be capable of making 4-wire ohms measurements (such as the HP 44705A 20-Channel Relay Multiplexer). The following program scans channels 0 through 9 (the Source channels are determined automatically) and returns the results (in °C) to the controller.

```
10  REAL Temp(9)
20  OUTPUT 709;"CONFMEAS RTDF85,200-209,USE 100"
30  FOR I = 0 TO 9
40  ENTER 709; Temp(I)
50  PRINT "Ch.";I, Temp(I)
60  NEXT I
70  END
```

Using Thermistors

Thermistors can detect small changes in temperature and are used in applications where the temperature extremes are not too high. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5kΩ, and 10kΩ.

The following program uses the CONFMEAS command to measure 20 thermistors using the 2-wire ohms function. The program scans and measures channels 0 through 19 once and returns the results (in °C) to the controller.

```
10  REAL Temp(19)
20  OUTPUT 709;"CONFMEAS THM5K,200-219,USE 100"
30  FOR I = 0 TO 19
40  ENTER 709; Temp(I)
50  PRINT "Ch.";I, Temp(I)
60  NEXT I
70  END
```

Monitoring the Scan

The MONMEAS command causes the HP 44701A to repeatedly measure each channel in the scan list and is useful for verifying external connections and debugging your scan routines. It is similar to the MEAS command in that you must configure the voltmeter for scanning beforehand (using the CONF command for example). You then use MONMEAS to specify the scan list and step to the first multiplexer channel in the list. The MONMEAS command causes the HP 44701A to repeatedly make measurements on the first channel and send the results to the display only (in RASC format). When you press the front panel SADV KEY, an advance is made to the second channel in the list. The HP 44701A will then repeatedly make measurements on the second channel until you press the SADV KEY again.

For example, assuming the voltmeter is installed in slot 1 of the mainframe and a multiplexer accessory is installed in slot 2, send:

```
OUTPUT 709;"MONMEAS DCV,200-219,USE 100"
```

The HP 3852A displays the channel number in its left display and the voltage measurement in its right display. Now press the front panel's SADV KEY. The scanner advances to the next channel. Continue pressing the SADV key and the scanner increments through the scan list. When it reaches the last channel in the list it remains there--pressing the SADV KEY no longer causes an advance.

Command Summary

This section summarizes all applicable commands for the HP 44701A. It is composed of two subsections: Low Level Commands, and High Level Commands. For an in-depth discussion of each command and its parameters, refer to the Command Reference Manual.

Low Level Commands

A low level command performs only one or two simple functions such as changing the range, enabling autozero, or transferring readings.

ARANGE Enables or disables the autorange function.

AZERO Controls the autozero function.

CHREAD Transfers one reading from the specified voltmeter channel to the HP-IB output buffer/display, or to reading memory.

DELAY Designates a time interval that is inserted into the measurement cycle. If you are making one reading per trigger, the delay is inserted between the trigger event and the reading. If you are making multiple readings per trigger, the delay is inserted between the trigger event and the first reading and between successive readings.

DISABLE INTR Prevents the voltmeter from generating an interrupt when a reading becomes available.

ENABLE INTR Enables the voltmeter to generate an interrupt when a reading becomes available.

FUNC Selects the voltmeter's measurement function (DCV, ACV etc.) and the measurement range.

ID? Queries the specified slot for the accessory number installed in that slot. The HP 44701A returns "44701A".

INTR? Returns the last channel number to cause an interrupt. If no channel has caused an interrupt, -1 (minus 1) is returned.

NPLC Specifies the integration time for the Integrating Voltmeter. Integration time is the time, measured in power line cycles (PLCs), during which the voltmeter samples the input signal.

NRDGS Sets the number of readings made per trigger.

OCOMP Enables or disables the offset compensated ohms function on the 30Ω through 30kΩ ranges. Offset compensation does not function on the 300kΩ and 3MΩ ranges.

RANGE Allows you to select the voltmeter's measurement range or the autorange mode.

RESET Resets the voltmeter to its power-on state.

TERM Selects the voltmeter input terminals for making measurements.

TEST Performs the HP 44701A's self-test.

TRIG Selects the voltmeter's trigger mode/source.

TRG Selects the trigger source when using the system trigger (TRIG SYS command).

USE Since more than one voltmeter can be installed in the mainframe or an extender, the USE command designates which voltmeter will receive the subsequent command(s).

USE? Returns the present USE channel address.

XRDGS Transfers one or more readings from a voltmeter channel.

High Level Commands

The high level commands perform a series of functions and, when scanning, provide additional measurement functions. These additional measurement functions are automatic 2-wire ohms, 4-wire ohms with automatic Source channel designation, and automatic temperature measurements from RTDs, thermistors, and thermocouples.

CONF Configures the voltmeter to the specified measurement function (DCV, OHMF, etc.) and selects the preset values for the other functions (autozero, range, etc.).

CONFMEAS Configures the voltmeter to the specified measurement function (ACV, DCV, etc.) and selects the preset values for the other functions (autozero, range, etc.). This command also causes the specified multiplexer channel(s) to be scanned, measured, and the associated data conversions (ohms, temperature) to be performed on the results. The CONFMEAS command also scans and measures unspecified reference channels when making thermocouple temperature measurements. The CONFMEAS command is equivalent to the CONF command immediately followed by the MEAS command.

MEAS Causes the specified multiplexer channels to be scanned and measured; and, if applicable, the associated data conversions (ohms, temperature) to be performed on the results. The MEAS command also scans and measures unspecified reference channels when making thermocouple temperature measurements. You must set the voltmeter's terminals to BOTH (using the TERM or CONF command) before sending the MEAS command.

- If the function of the measurement device *is* compatible with the function specified in the MEAS command, the present state of the other functions (autozero, range etc.) are not changed. (To set these other functions to their preset values, execute the CONF command prior to the MEAS command or use the CONFMEAS command.)

- If the function of the measurement device *is not* compatible with the function specified in the MEAS command, the function is changed and autorange is selected.

• If the trigger mode of the measurement device is previously set to HOLD or AUTO,executing the MEAS command changes the trigger mode to SCAN. If the trigger mode is previously set to SYS, it is not changed by the MEAS command.

MONMEAS Similar to the MEAS command except the MONMEAS command advances to the first multiplexer channel in the scan list, repeatedly makes measurements, and sends the results to the display only (in RASC format). Pressing the SADV KEY advances to the next channel in the list. You must set the voltmeter's terminals to BOTH (using the TERM or CONF command) before sending the MONMEAS command.

Chapter 3
HP 44702A/B
High-Speed Voltmeter

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HP 44702A 13-Bit High-Speed Voltmeter

Chapter 3

13-Bit High-Speed Voltmeter

HP 44702A/B

Introduction

This chapter provides a description, the specifications, configuration information, and programming instructions for the HP 44702 High-Speed Voltmeter. For information on the HP 3852A Data Acquisition/Control Unit mainframe and other accessories, refer to the HP 3852A DA/C Mainframe Configuration and Programming Manual.

Two models of the High-Speed Voltmeter are available: the HP44702A and the HP 44702B. They differ only in the amount of on-board reading storage memory. This chapter covers both models and, except where noted, will use only the numeric portion of the model number to refer to both voltmeters.

Seven sections are included in this chapter.

- **Introduction** contains an overview of the chapter and describes the voltmeter.
- **Specifications** lists the performance characteristics of the voltmeter.
- **Installation and Checkout** describes additional reading storage memory, installing the voltmeter GPIO interface, testing the voltmeter, and more.
- **Programming the Voltmeter** discusses general operation of the voltmeter, and one of its two primary modes of operation, the Systems Mode.
- **General Backplane Scanning** shows how to use the High Speed Voltmeter in general scanning operations.
- **High-Speed Scanning** discusses the second primary mode of operation, the Scanner Mode. High-Speed scanning over the dedicated interface cable is explained.
- **Advanced Programming and the GPIO** describes advanced features of the voltmeter and how to use them for greater measurement capability.

Description

Figure 3-1 shows the backpanel of the HP 44702 High-Speed Voltmeter. Note especially the Voltmeter Input Terminals, the Current Source Terminals, and the External Trigger BNC Connectors. The chassis terminal connects to earth ground inside the mainframe or extender. Lift the Release Lever to remove the voltmeter accessory from the mainframe.

You can use the HP 44702 Voltmeter for high speed DC voltage or current (with external shunt resistor) measurements, or 2 and 4-wire ohms measurements using the built-in current source. Resolution is 13 bits (12 bits plus sign bit). The voltmeter can autorange static signals at up to 100,000 readings per second. Successive Approximation is used in the analog-to-digital conversion.

Each High-Speed Voltmeter uses two slots in a frame (all other accessories use only one slot).

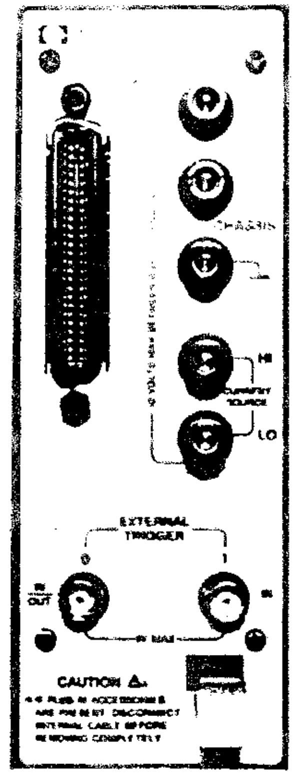


Figure 3-1. HP 44702A/B Back Panel

Analog input is via the rear panel terminals, any multiplexer accessory through the mainframe's (or extender's) analog backplane bus or via a dedicated high speed interface cable connecting up to six (eight in an extender) FET multiplexer accessories (either HP 44711A, 44712A, or 44713A).

Readings can be stored in mainframe memory, in the voltmeter on-board reading storage memory buffer, or sent to the GPIO port sending measurements directly to the system computer. Over eight thousand readings can be stored in the standard voltmeter buffer (HP 44702A) or more than 64 thousand readings with enhanced memory (HP 444702B).* When readings are stored in the on-board buffer, multiple High Speed Voltmeters can be triggered simultaneously.

The High-Speed Voltmeter has balanced inputs. This means that each input has an equal impedance to ground so that a common mode noise signal is seen equally by both high and low inputs. Since the voltmeter measures only the difference voltage between high and low, this provides good common mode noise rejection.

Modes of Operation

Two modes of operation are available with the High-Speed Voltmeter: Systems Mode and Scan Mode. In the Systems Mode, the High-Speed Voltmeter operates similar to the HP 44701A Integrating Voltmeter and can be used for general voltage measurements and general backplane scanning. In the Scanner Mode, the High-Speed Voltmeter can do high speed (up to 100,000) readings per second) scan measurements independent of other mainframe operations. This is accomplished by the voltmeter directly controlling FET multiplexer accessories through a dedicated high speed interface cable.

*The HP 44703C High-Speed Voltmeter Extender Memory Card may be added to the HP 44702A voltmeter to extend its reading memory to 64k readings. See the Installation and Checkout section in this chapter.

Applications

Typical applications for the High-Speed Voltmeter include shock and vibration analysis and high speed multiplexing. Programming the voltmeter to digitize accelerometer impulses is one example of shock/vibration analysis. Seismic echo analysis is another example.

CAUTION

The voltmeter's analog input is protected to ±12 volts peak. between any of the input terminals (HI, LO, CHASSIS). With the relay to backplane open (TERM set to EXT) the input is protected to ±42 volts peak. Do not exceed this voltage – the HP 4470 will be damaged.

The maximum compliance voltage for the ohms current source is ±10.24 volts. Do not exceed this voltage – the HP 44702A/B will be damaged.

WARNING

The mainframe and extender internal analog busses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against possible personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the mainframe, extenders, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum allowable Peak Voltage
HP 3852AA Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	300V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexers	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extender(s), the mainframe and extender(s) are each considered as a separate circuit.

Consider wiring all high voltages together on one frame with one voltmeter and all low voltages together on another frame with a second voltmeter. Do not connect the frames together with the analog bus. If high and low voltages must be mixed on one frame, keep the high voltages together in sequence and the low voltages together in sequence. Use a "dummy" channel between the high and low voltages to allow the internal capacitance to discharge.

Successive Approximation

Successive approximation is a method of digitally approximating an analog voltage. Figure 3-2 shows a simplified twelve-bit successive approximation converter. The illustration does not show that negative voltages are inverted and measured as positive voltages.

Figure 3-2. Successive Approximation Example

The control logic closes each of the twelve bits in the D/A, one at a time, starting with the MSB. As each switch is closed , the comparator gives an output indicating whether the input signal is greater or smaller in amplitude than the D/A. If the D/A amplitude is greater than the input signal, the switch is opened, otherwise, the switch remains closed. The control logic does this the next most significant bit, then the next, and so on. After all twelve bits of the D/A have been tried, the conversion is complete. If all twelve bits in the D/A converter are set, the voltmeter considers the reading to be an overload and therefore invalid.

For example, we want to measure a voltage source of 5.132 volts. Assuming a scaling factor of ten, the comparator input voltage is .5132 volts. Also assume a reference voltage of one volt. After the conversion cycle is complete, the D/A switches are set:

```
MSB                    LSB
 1 0 0 0 0 0 1 1 0 1 1 0
```

With this resolution of twelve bits, the control logic adds the partial V_{ref} values for the switches that remain closed to approximate the voltage input. The MSB has a value of 0.500. Respectively, the remaining "set" bits have values of 0.0078, 0.0039, 0.001, and 0.0005. These add up to 0.5132. Control logic shifts the decimal point and displays a measurement of 5.132 volts.

For specific information on the operation for the High-Speed Voltmeter, refer to the HP 3852A Service Manual.

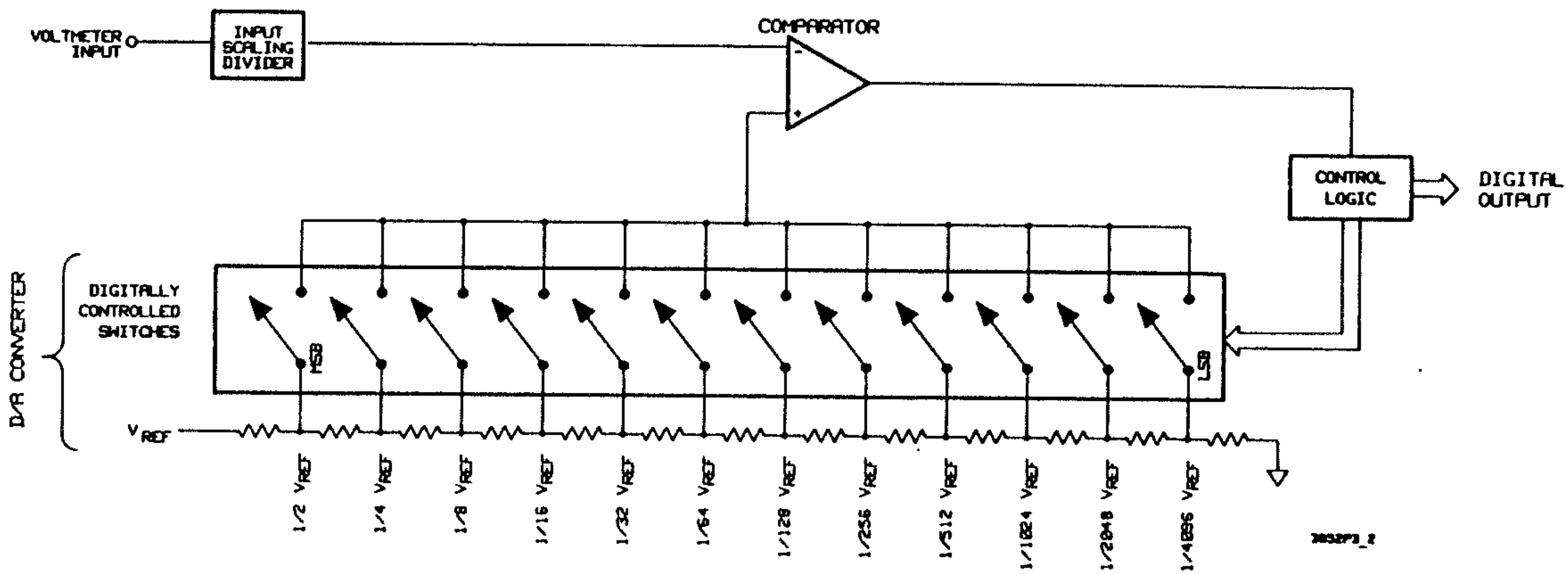


Figure 3-2. Simplified Successive Approximation Converter

Specifications

Table 3-1 lists the specifications for the HP 44702 High-Speed Voltmeter. The specifications are the performance standards or limits against which the voltmeter is tested. Included in the table are supplemental characteristics of the voltmeter and should be considered as additional and general information. Because of the many operational capabilities of the voltmeter, exercise care when performance testing the voltmeter's specifications.

Any changes in the specifications due to manufacturing changes, design, or traceability to the National Bureau of Standards will be covered in a manual change supplement.

Table 3-1. HP 44702 Specifications

To meet specifications over the entire operating temperature range, allow 1 hour for warm-up.

Voltage Measurements:

Voltmeter Ranges/Resolution

Range	Maximum Display	Resolution/ Sensitivity	Max. Input Voltage[1]
40.0 mV	±40.00	9.77 µV	
0.32 V	±320.0	78.1 µV	
2.56 V	±2.560	625.0 µV	±10.4 V peak
10.24 V	±10.24	2.5 mV	

(1) Protected to ±12 V peak. With relay to backplane open, protected to ±42 V peak.

Voltmeter Accuracy
± (%of reading + number of counts)
18-28 °C, R.H. <85%, Auto Zero on

90 Days

Range	% of Readings	Number of counts (volts)
40 mV	0.05	4 (39 µV)
0.32 V	0.05	2 (156 µV)
2.56 V	0.05	2 (1.25 mV)
10.24 V	0.05	2 (5.00 mV)

1 Year

Add 0.05% of reading to 90 day accuracies

Temperature Coefficients (0-55 °C)

Add as an additional error if outside of 18-28 °C:
± (% of reading + number of counts)/°C

Range	% of Reading	Number of counts (volts)
40 mV	0.004	0.05 (0.488 µV)
0.32 V	0.002	0.05 (3.91 µV)
2.56 V	0.002	0.05 (31.3 µV)
10.24 V	0.002	0.05 (125 µV)

Autoranging

The High Speed voltmeter can autorange at full speed of 100,000 readings per second for scanned static signals. Proper autoranging is not guaranteed if the signal changes at >6 volts/sec.

Bandwidth

R_{source} = 50 ohms

	Range	
	40 mV	0.32, 2.56, 10.24 Volt
0.1% Flatness	10 kHz	15 kHz
1.0% Flatness	45 kHz	55 kHz
-3dB Bandwidth	250 kHz	400 khz

Settling Time (using HP 44702A and 24 Channel FET multiplexer with ribbon cable scan)
R_{source} = 50 ohms

		To 0.1% of full scale of destination range[2]			
		Range			
Step Size	To 0.1% of step[1] all ranges	10.24	2.56	320mV	40mV
±10.24 V	<10µS	<10µS	<30µS	<100µS	<1mS
± 2.56 V	<10µS	<10µS	<10µS	<20µS	<120mS
±320 mV	<10µS	<10µS	<10µS	<10µS	<20µS
± 40 mV	<10µS	<10µS	<10µS	<10µS	<10µS

(1) To within 0.1% of step size for all ranges (fixed or autorange).
(2) To within 0.1% of full scale of destination range (4 counts).
Destination range may be determined by the scan list or by the result of an auto range.

Pacer

Range: 10µS to 17 minutes
Accuracy: ±(0.01% of setting +0.25 µS)
Resolution: 0.25 µS

Input/Isolation Resistance

High to Low, Low to Guard, Guard to chassis (25°C at 85% RH or 40°C at 60% RH) >10^{8} Ω

Input Capacitance

At 1 MHz, all inputs (backplane, ribbon cable or banana jacks)

Hi to Low: < 100pf
Hi to Low to chassis: < 200pf

Bias Currents

Currents sourced by high or low, through the voltmeter to chassis . These currents may affect accuracy for source impedances >1kΩ. A current bias path (<100kΩ) to chassis must be provided to insure proper operation.

VM inputs at 0 volts with respect to chassis

Voltmeter Inputs (backplane, ribbon cable, or rear panel)	RH <85% @ 28°C or <60% @ 40°C 0-28°C	0-55°C
Input Closed	± 1.4 nA	± 18 nA
Input Open	± 1.2 nA	± 13 nA

Effective Common Mode Rejection

ECMR = effective common mode rejection
(To voltmeter rear panel, 1000 Ω unbalance in low lead, DC to 60 Hz)
RH < 85% @ 28°C or <60% @ 40°C

DC to 60Hz Range	ECMR (dB)	Max CMR Volts
40 mV	90	
320 mV	80	±10.24
2.56 V	70	
10.24 V	70	

Resistance Measurements

Resistance Accuracy
90 days, 23°C ± 5°C, RH <85%
± % of reading + counts

Resistance Function (current source)[1]	% of Reading	Range	Number of Counts (ohms)
10 kΩ (1 mA)	0.07	40 Ω	4 (39.1mΩ)
		320 Ω	2 (156 mΩ)
		2.56 kΩ	2 (1.25 mΩ)
		10.24 kΩ	2 (5.0 mΩ)
100 kΩ (100 μA)	0.07	400 Ω	4 (391mΩ)
		3.2 kΩ	2 (1.56 Ω)
		25.6 kΩ	2 (12.5 Ω)
		102.4 kΩ	2 (50.0 Ω)
1 MΩ (10 μA)	0.07	4 kΩ	4 (3.91 Ω)
		32 kΩ	2 (15.6 Ω)
		256 kΩ	2 (125 Ω)
		1.024 MΩ	2 (500 Ω)

(1) Compliance: ± 10.24 V
Output Resistance: $>10^8$
Current Source Accuracy: 2% of full range

Temperature coefficient[1]
(All three resistance functions)
±(% of reading + number of counts)/°C

Range	
1 (low)	0.005 + 0.05
2	0.003 + 0.05
3	0.003 + 0.05
4 (high)	0.002 + 0.05

(1) Add this error for temperatures outside of 18 - 28°C.

1 Year Accuracy:

add 0.03% to all ranges

Installation and Checkout

This section discusses installation and initial testing of the HP 44702 High-Speed Voltmeter. Actual installation procedures for the voltmeter may be found in Chapter 3 of the HP 3852A DA/C Mainframe Configuration and Programming Manual.

Reading Storage Memory

The HP 44702A voltmeter comes with a standard 8k (actually 8,192) reading storage memory. The HP 44702B comes with an additional 56k reading storage memory, for a total of 64k (actually 65,536), installed and tested at the factory. If you purchased the HP 44702A with its 8k memory and would like to upgrade it to 64k memory, contact your local HP sales office and purchase the HP 44703C High-Speed Voltmeter Extended Memory Card. An Installation Note accompanies the kit to show qualified, service-trained technicians how to install it.

Installing the Dedicated Interface Cable

Instructions for installing the dedicated high speed interface cable between the HP 44702 voltmeter and either the HP 44711A, 44712A, or 44713A High-Speed FET Multiplexers are found in Chapter 3 of the HP 3852A DA/C Mainframe Configuration and Programming Manual. This cable is necessary only if you intend to do high speed scanning with the FET multiplexer accessories. For general backplane scanning, other than high speed, with the FET multiplexer accessories, the dedicated interface cable must be disconnected from the High-Speed Voltmeter and connected to the cable connector on the FET accessories.

Warnings and Cautions

Two Warnings and two Cautions appear on the High-Speed Voltmeter's case. These are indicated by the symbol ⚠ followed by a numeric subscript. In the order of the numeric subscript, these warnings are described below. For more complete information refer to the HP 3852A Mainframe Configuration and Programming Manual.

⚠1 This Warning reminds you that even when the High-Speed Voltmeter is removed from the mainframe or extender frame, hazardous voltages may still be present on the external wiring to the voltmeter backpanel.

⚠2 This Warning is found on the metal cover of the voltmeter. It warns you that hazardous voltages may can still be present on the voltmeter terminals if instrument power and external field wiring are not removed.

⚠3 This Caution refers to the fact that when a specific number of voltmeter or other accessories are installed in the same frame (mainframe or extender), they place an excessive drain on the frame's power supply. Refer to Chapter 3 in the HP 3852A Mainframe Configuration and Programming Manual for information on how many voltmeters and other accessories may be installed in a frame.

⚠4 This Caution is found on the rear panel of the High-Speed Voltmeter and on the high speed FET multiplexer accessories. It reminds you that before removing either accessory, ensure that the dedicated interface cable is disconnected.

The GPIO Interface

Figure 3-3 shows the GPIO interface pinout used by the HP 44702 voltmeter. The GPIO Interface is a flexible parallel interface that sends or receives 16 bits of data per transfer.

Figure 3-3. GPIO Connector

GPIO Connector

The GPIO connector on the back of the voltmeter is a standard 50 pin female connector. Attach the male end of the cable from your system controller's interface. Make sure it is firmly seated before tightening the screws.

Controller Interface

Your system controller's GPIO interface must be configured with a Full-Mode Handshake and positive true Logic Sense. Figure 3-4 is a timing diagram showing the Full-Mode Handshake required by the HP 44702 High-Speed Voltmeter. Notice that the voltmeter's data transfer out requires the BSY clock source. Table 3-2 shows the logic sense of the GPIO peripheral control lines.

Table 3-2. Peripheral Control Lines

Dout	Din	Handshake	PSTS	PFLG	PCTL
High=1 Low =0	High=1 Low =0	Full	Low =OK High=OK-	Low =BSY High=RDY	Low =SET High=CLR

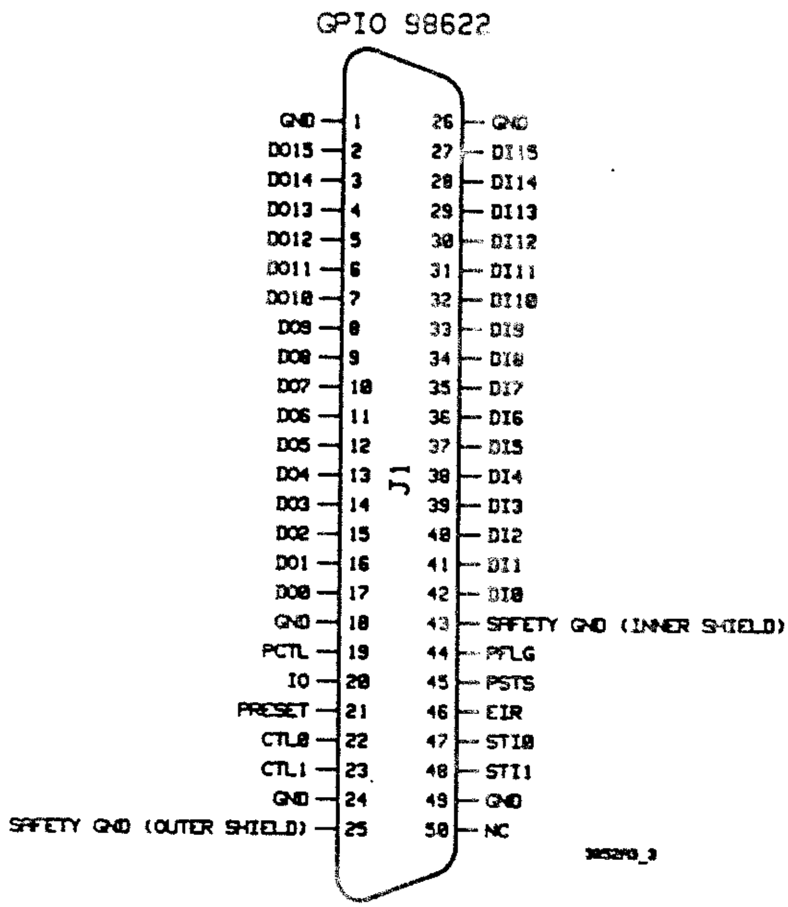


Figure 3-3. GPIO Connector

Figure 3-4. Full-Mode Handshake Timing Diagrams

HP Series 200 GPIO Controller

Figure 3-5 shows how to set the Data-In Clock Source and Option Select switches on the HP 98622A GPIO Interface for an HP Series 200 controller.

Figure 3-5. Switch Settings for HP98622A GPIO Interface

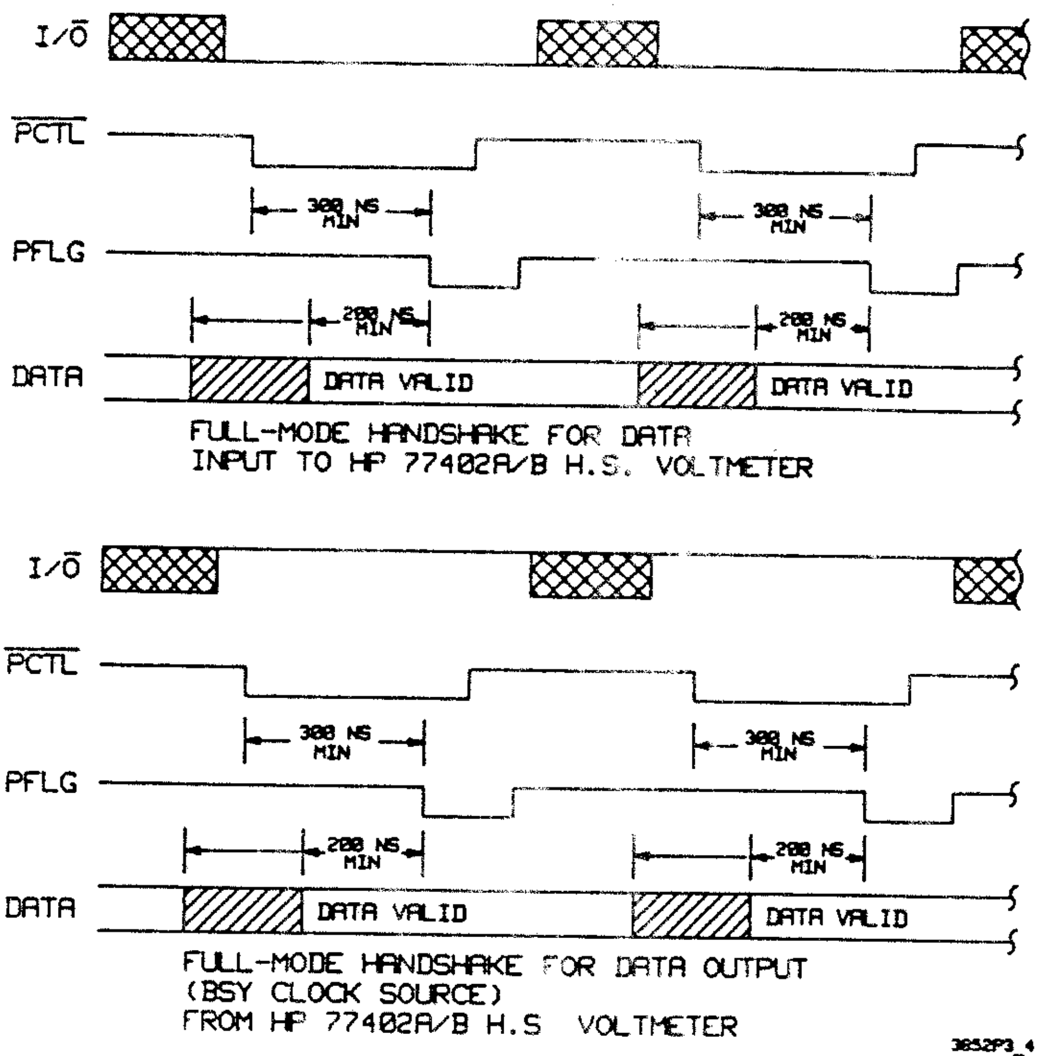


Figure 3-4. Full-Mode Handshake Timing

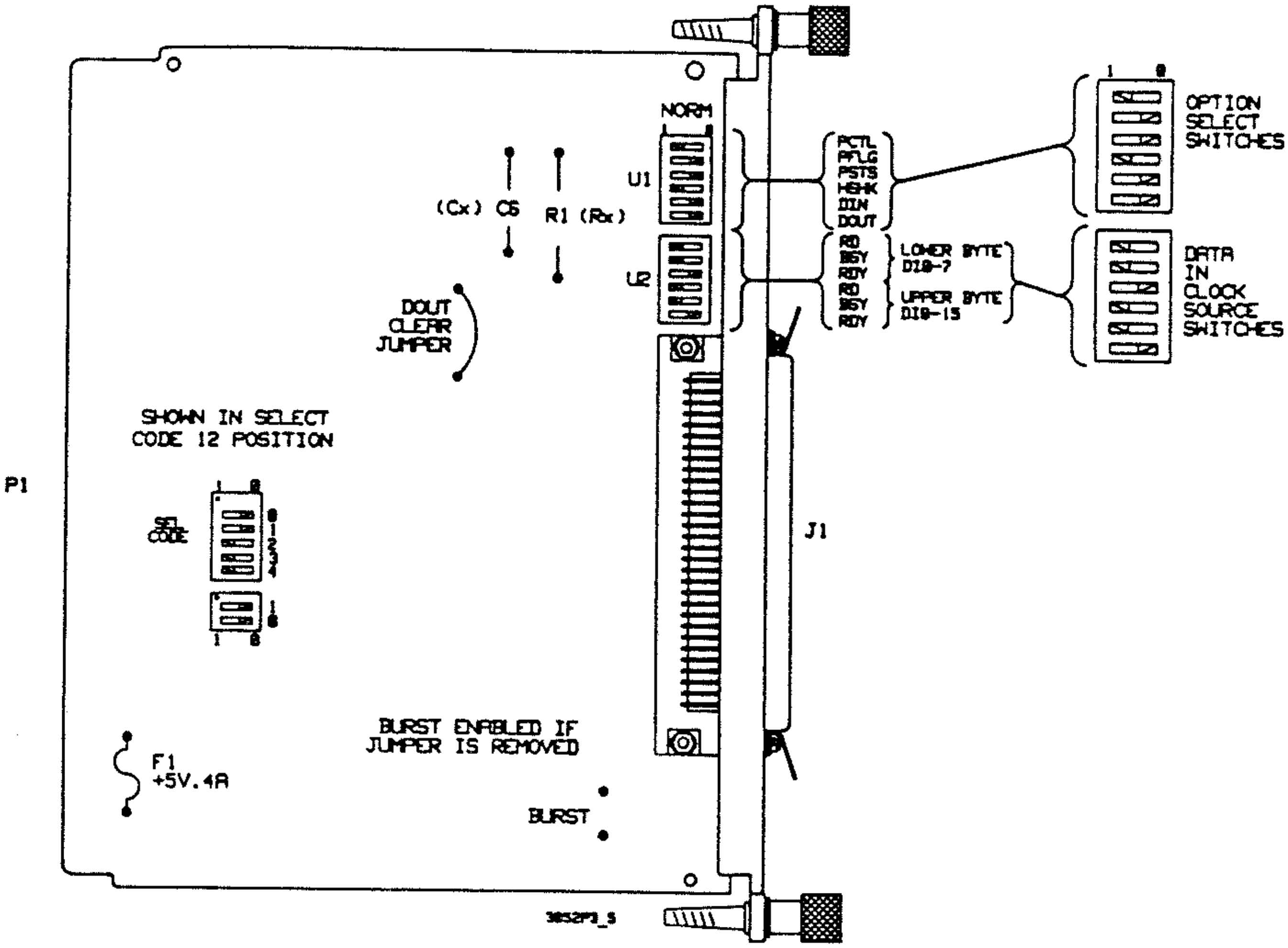


Figure 3-5. Switch Settings for HP 98622A GPIO Interface

External Trigger

Two External Trigger BNC connectors on the voltmeter backpanel provide a method of synchronizing the voltmeter to external activities or devices. Both inputs are TTL compatible and may be actuated by a simple switch closure (internal pull-up resistors are provided). The "0" (left hand) BNC connector can output a trigger pulse for simultaneous operation of up to five other High Speed Voltmeters. Refer to the programming section under triggering for more information.

Initial Checkout

Once the voltmeter accessory has been installed, check for proper installation by executing the ID? command. Remember that the High-Speed Voltmeter takes up two slots in the mainframe or extender. *Always address the voltmeter by the lowest slot.* That is, if the voltmeter is installed in slots 6 and 7, use slot 6 as the voltmeter address.

ID?

The following four line program verifies whether the voltmeter is correctly installed in the mainframe. In this example, the voltmeter is installed in slots 6 and 7. If you have installed your voltmeter in different slots, lines 100 and 120 must be corrected appropriately.

```
100  OUTPUT 709; "ID? 0600" ! CHECKS ID IN MAINFRAME SLOT 600
110  ENTER 709; Ident$
120  PRINT "ACCESSORY IN SLOT 6 =";Ident$ ! PRINT ACCESSORY ID
130  END
```

The command "ID? 0600" can also be entered from the mainframe front panel.

If the voltmeter has been correctly installed in slots 6 and 7 of the mainframe, the message "ACCESSORY IN SLOT 6 = 44702A" will be displayed on the system controller. If the HP44702B voltmeter (64k memory) is installed, the message would read "ACCESSORY IN SLOT 6 = 44702B".

Addressing an empty accessory will return a value of "000000" to the controller.

Resetting the HP 44702

Many times during operation, you may wish to return to the power-on state. The reason may be an error in entering commands, you want to return the voltmeter to its default values before proceeding to the next program segment, or you simply don't know what state the voltmeter is in and you want to reset it to a known state. The reset function returns the High-Speed Voltmeter to its power-on state without cycling power. Any readings in the internal reading storage memory will be lost after a reset.

To reset the voltmeter, send:

```
OUTPUT 709; "RESET 0600"
```

or

```
OUTPUT 709; "RST 0600"
```

The High-Speed Voltmeter performs a thorough self-test when reset. The results of this test are saved and returned as part of the confirmation test. Therefore, if you want to have a complete and up-to-date test, and if you don't mind loosing the state of the voltmeter, reset the voltmeter before performing the confirmation test.

Voltmeter Test

The Voltmeter Test ensures that the High-Speed Voltmeter is operating properly but resets the voltmeter to its power-on state. The checksum on the non-volatile memory is also tested to ensure that calibration constants are valid.

NOTE

Passing the voltmeter Test does not guarantee that the voltmeter is properly calibrated. It means only that the calibration constants are within an acceptable range. It is possible to calibrate the voltmeter to an inaccurate standard.

Execute the following line for the test. When the voltmeter passes its self test and if no other errors are recorded in the error register, the message "SELF TEST OK" is displayed on the mainframe front panel. If the test fails, the message "SELF TEST FAILED" results.

```
OUTPUT 709;"TEST 0600"
```

Results of the test are stored in the error register. When the test passes, a "0" is stored in the error register. The following four line program executes the confirmation test from the system controller.

```
100 OUTPUT 709; "TEST 0600; ERR?"
110 ENTER 709; Testr
120 PRINT "VOLTMETER TEST RESULTS: ";Testr
130 END
```

Programming the High-Speed Voltmeter

The remainder of this chapter contains step-by-step procedures that teach you how to operate and program your HP 44702 High Speed Voltmeter. It is divided into four major sections. The first section discusses general operation of the voltmeter. This includes the measurement functions of the voltmeter, ranging, trigger control, interrupts, and more. The second section discusses general purpose scanning in the System Mode of operation. High speed scanning with the voltmeter in the System Mode is covered in the third section. This third section includes scanning with the FET multiplexers. Finally, the fourth section discusses advanced programming and operation with the GPIO interface.

Power-on Conditions

Table 3-3 shows the power-on voltmeter conditions.

Table 3-3. Power-on Conditions

Voltmeter Function	Ranging	Signal Source	Buffer Type	Reading Destination	Trigger Source	Mode
DC Voltage	Autorange	Backpanel Terminals	FIFO	Mainframe	Hold/Int	System

Each of these power-on conditions will be discussed in this section of the chapter. The Command Reference Manual shows the power-on condition for each voltmeter function and the default parameters selected when programming the voltmeter.

To assure that the voltmeter specifications over its entire operating range, allow a minimum of 1 hour for warm-up.

General Voltmeter Operation

When the frame (either mainframe or extender) is turned-on, and power applied to the High-Speed Voltmeter, the voltmeter wakes up in its Systems Mode. In this mode, the High-Speed Voltmeter can be used for general voltage and resistance measurements and backplane scanning. For more detailed information, refer to the Command Reference Manual.

This section gives programming and operation basics. All of the examples in this chapter are given in an enhanced BASIC programming language such as the HP Series 200 or Series 80 use.

At least six tasks must be performed in making a measurement. In sequential order they are:

- Select the voltmeter.
- Select the voltmeter mode.
- Select the measurement source.

- Select the measurement function and range.
- Select the type of triggering and trigger the voltmeter.
- Read the measurement.

Each of these tasks will be discussed in detail giving an example of each one. These will be followed by several complete measurement examples. For most of these tasks, you can use the default or power-on conditions. For others you must specify the action.

In addition to these seven main tasks, you also have other settings that you can select from. For example, you can select the reading destination, interrupts, and select the data format.

Selecting the Voltmeter

Since multiple voltmeters may reside in the mainframe and/or extenders, you must specify which voltmeter you are sending commands to. The USE command specifies the particular voltmeter that is being programmed and has the format:

```
USE slot
```

Specify the slot number where the voltmeter resides. The slot number is a four digit number in the form ES00, where E is the extender number (0 for the mainframe) and S is the slot number.

At power-on, the HP 3852A mainframe searches for the lowest numbered slot that contains a voltmeter, counter, or digital input accessory. Commands for these accessories require a USE *slot* destination. The mainframe saves that slot number for use with any command that requires direction to a particular slot. This USE *slot* number remains active until it is updated by the USE *slot* command or the mainframe is reset.

The USE command may be sent as a stand-alone command or specified as a parameter with most other commands. USE sent as a parameter of another command is valid only for that command.

For example, to send the USE command separately, send:

```
OUTPUT 709; "USE 0600" ! VOLTMETER IN SLOTS 6,7 OF MAINFRAME
```

To send USE as a parameter of the FUNC command:

```
OUTPUT 709; "FUNC DCV, AUTO, USE 0600"
```

All examples in this chapter assume the HP 44702 High-Speed Voltmeter is installed in slots 6 and 7 of the mainframe. Therefore, the voltmeter will always be addressed in slot 6.

Selecting the Voltmeter Mode

Your HP 44702 High-Speed Voltmeter has two modes of operation. In the first mode, called the System Mode, the HP 3852A mainframe controls all multiplexer accessories and the High-Speed Voltmeter acts very similar to the HP 44701A Integrating Voltmeter. The System Mode is the power-on mode for the High-Speed Voltmeter. *All the examples in this chapter, prior to the section on High-Speed Scanning, must have the voltmeter in System Mode.*

The second mode, called the Scanner Mode, allows the High-Speed Voltmeter to act independently of the HP 3852A mainframe. In this mode, the voltmeter can directly control up to 8 high speed FET multiplexer accessories through a dedicated interface cable. This mode will be discussed in the high speed scanning section of this chapter.

The SCANMODE command sets the voltmeter mode. Sending SCANMODE ON sets the voltmeter to the Scanner Mode. Send SCANMODE OFF to set the voltmeter to the System Mode. Send the following command to ensure the voltmeter is in the System Mode for the examples in this chapter.

```
OUTPUT 709; "SCANMODE OFF"
```

NOTE

Changing the SCANMODE setting completely resets the voltmeter. All voltmeter configuration should be done after setting the SCANMODE.

Selecting the Measurement Source

The HP 44702 voltmeter can make measurements from four different sources. The four sources are: the voltmeter's backpanel terminals (EXT), a multiplexer accessory connected to the mainframe's internal backplane analog bus (INT), the dedicated high speed interface cable connected to the FET multiplexer accessories (RIBBON), and an internal zero volt input (OFF). The RIBBON destination is valid in the Scanner Mode only. Refer to the TERM command in the Command Reference manual.

To specify the voltmeter's backpanel terminals as the measurement terminals, send:

```
OUTPUT 709; "TERM EXT, USE 0600"
```

To make measurements from a multiplexer asccessory via the frame's backplane, set the TERM to INT. Uzse the CLOSE command to close the multiplexer accessory's channel.

```
OUTPUT 709; "TERM INT, USE 0600"
```

Measurement Functions

Your High-Speed Voltmeter has four measurement functions that can be programmed from the mainframe or from the system controller. These four functions are DC volts, four-wire resistance to 10k ohms, four-wire resistance to 100k ohms, and four-wire resistance to 1M ohms. Use the voltmeter FUNC command to program the measurement function. For example, to program the voltmeter to measure DC voltages, send:

```
OUTPUT 709; "FUNC DCV"
```

or

```
OUTPUT 709; "FUNC DCV, USE 0600" ! VOLTMETER IN MAINFRAME SLOT 6
```

For more information on the FUNC command, refer to the Command Reference Manual.

DC Voltages

Your High-Speed Voltmeter can measure DC voltages in four ranges: 40mV (sensitivity 9.77µV), 320 mV (sensitivity 78.1µV), 2.56 Volts (sensitivity 625µV), and 10.24 volts (sensitivity 2.5 mV). Both positive and negative voltages may be measured.

You can add a parameter to the measurement function command (FUNC) and specify the maximum voltage to be measured. The voltmeter will automatically select the appropriate range for the measurements. Specifying AUTO will allow the voltmeter to autorange for each measurement without a reduction in measurement speed. See the section on ranging the voltmeter.

For example:

```
OUTPUT 709; "FUNC DCV, 1.5, USE 0600"
```

specifies the DC voltage function, a maximum voltage to be measured of 1.5 volts (selects the 2.56 volt range) and the voltmeter in slot 6.

CAUTION

The voltmeter input is protected to 12 volts peak. Do not, under any circumstances, apply more than 12 volts DC peak to the voltmeter. Damage to the voltmeter may occur.

NOTE

After using a voltmeter to make measurements through a multiplexer accessory, the voltmeters's input terminals remain connected to the backplane analog bus. When another voltmeter is used to make measurements in the same mainframe or extender, the input terminals of both voltmeters are connected in parallel which lowers the effective input impedance of each. To prevent this, disconnect the unused voltmeter's input terminals from the backplane by selecting its rear terminals (TERM EXT command) or by resetting the voltmeter.

Figure 3-6 illustrates the connections to the rear panel terminals for DC voltage measurements.

Figure 3-6. DC Voltage Connections

DC Current

An appropriate shunt resistor, located external to the voltmeter, allows the voltmeter to measure DC current. The shunt may be mounted on one of the relay multiplexer accessories. The voltage drop across the resistor is measured and divided by the value of the resistor. This yields the value of the current through the resistor.

Resistance Measurements

The voltmeter has three 4-wire resistance measurement functions. These resistance functions allow you to measure resistance in three broad ranges. OHMF10K measures resistances up to 10 kohms with a source current of 1 mA. The OHMF100K function measures resistances up to 100 kohms with a source current of 100 µA. Finally, the OHMF1M function measures resistances up to 1 Mohm with a source current of 10 µA. The relay and FET multiplexer accessories automatically switch the High-Speed Voltmeter's internal current source from the mainframe or extender's backplane to the resistance measured.

CAUTION

After performing resistance measurement backplane scanning operations, the voltmeter's current source remains connected to the backplane current bus. If another voltmeter is used to make backplane resistance measurements, the current sources will be connected in parallel yielding erroneous measurements. After using the High-Speed voltmeter for backplane resistance measurements, either set the voltmeter's TERM to external, set the voltmeter's function to DCV or reset the voltmeter.

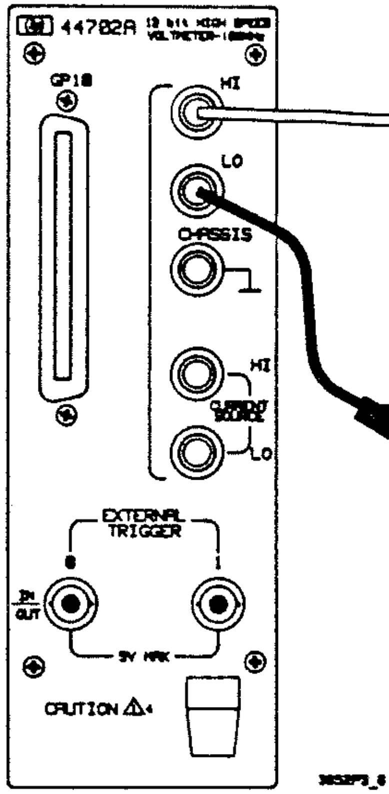


Figure 3-6. DC Voltage Connections

NOTE

For 4-Wire resistance measurements, each multiplexer accessory channel specified in a channel list identifies an independent 4-Wire ohms measurement. The channel number specified must indicate the voltage "sense" input channel on Bank A. The respective current "source" channel on Bank B will close automatically for each multiplexer accessory. For more information, refer to the individual multiplexer accessory manuals.

For example, to set the voltmeter to the OHMF100k function, send:

```
OUTPUT 709; "FUNC OHMF100K, USE 0600"
```

Within each measurement function you may specify one of four measurement ranges (see the FUNC and RANGE commands) by specifying the maximum resistance to be measured within that function. You may also specify AUTO for autoranging within the function. For example:

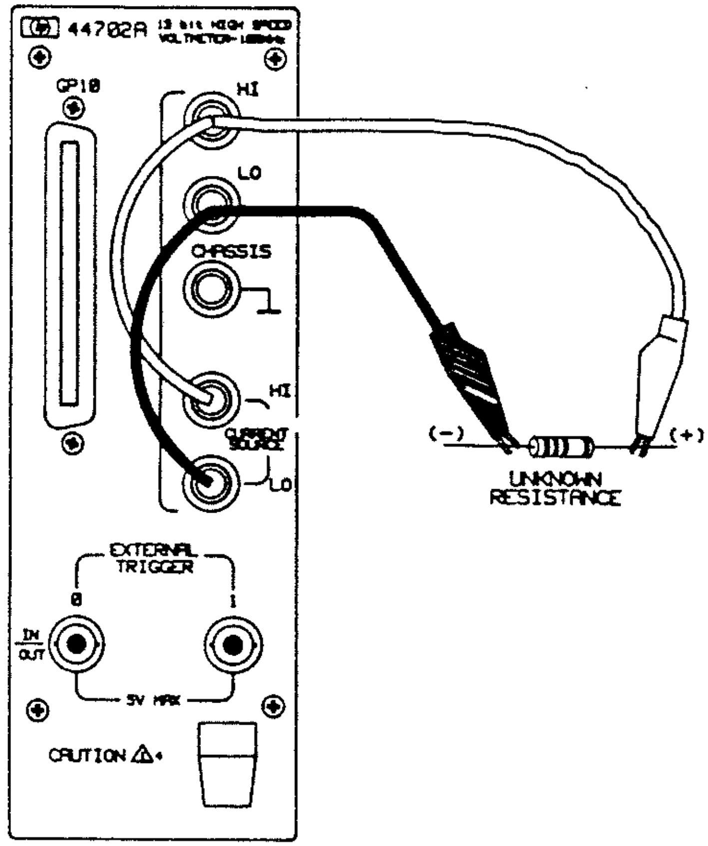
```
OUTPUT 709; "FUNC OHMF100K, 5E3" ! SELECTS 25.6 KΩ RANGE
```

or

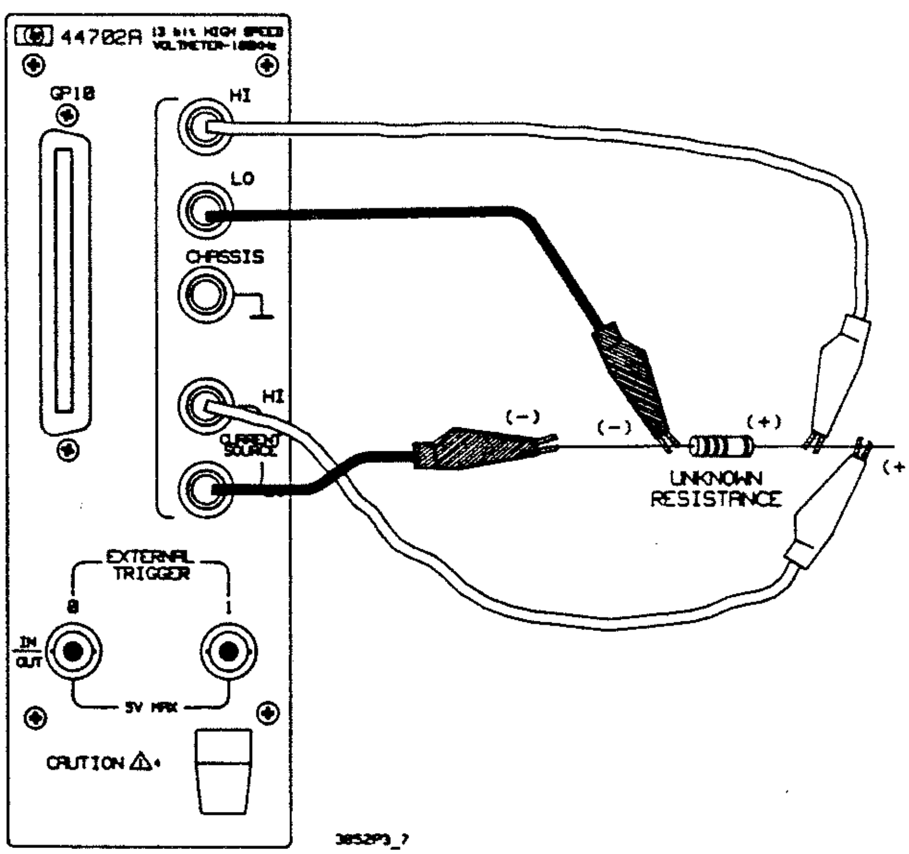
```
OUTPUT 709; "FUNC OHMF100K, AUTO" ! SELECTS AUTORANGING
```

Figure 3-7 illustrates the rear panel terminal connections for making 2- and 4-wire resistance measurements.

Figure 3-7. Resistance Measurement Connections



2-WIRE
RESISTANCE
MEASUREMENTS



4-WIRE
RESISTANCE
MEASUREMENTS

Figure 3-7. Resistance Measurement Connections

NOTE

The "on" resistance of the FET switches is 2.6kΩ to 3.6kΩ per FET switch. This resistance must be accounted for when using the FET multiplexer accessories for resistance measurements. The 2-wire ohms measurements do not remove the "on" resistance of the FET switches. The 4-wire ohms measurements do remove the "on" resistance of the FET switches.

Ranging the Voltmeter

You can specify the measurement range of the voltmeter either as a parameter of the FUNC command or separately with the RANGE command. You specify the range as the input signal's maximum expected amplitude (or the maximum resistance for ohms measurements). The HP 44702 voltmeter then chooses the correct range for the measurement. for example, if you are measuring DC voltages with a maximum input of 5.5 volts, send either:

```
OUTPUT 709; "FUNC DCV, 5.5"
```

or

```
OUTPUT 709; "RANGE 5.5"
```

Overload Indication. Input voltages in excess of the measurement range gives a value of 1E+38. This will result with common mode voltages in excess of 10.5V from chassis.

You may also specify AUTO as the range parameter and the voltmeter will autorange all measurements with no measurement speed penalty. In the autorange mode, the voltmeter selects the most sensitive range where the input (either voltage or resistance) is less than 90% of the full scale.

With high speed scanning (Scanner Mode), autorange has a small amount of settling time delay when switching from a high range to a lower range. Therefore, all large value voltages should be connected in sequence and all lower voltages should be connected in sequence. You may want to include a "dummy" channel between the higher voltages and the lower voltages to give the adequate time for the voltmeter to settle on the lower range.

If the voltmeter is in Scanner Mode and the terminals selected are RIBBON (for high speed scanning with the FET multiplexers), and if autorange is enabled, then the ARMODE command lets you select when the autoranging will occur. If you select AFTER (power-on condition), then autoranging takes place after the measurement trigger is received. Although this mode does not inject any delay or jitter, if a significant amount of time passes between measurements, the autorange may be premature. AFTER is used when the signal measured are static (thermocouple voltages, resistances, etc.). ARMODE may be used in either voltmeter mode, but it is most useful in the Scanner Mode.

If you select BEFORE, then autoranging is done as soon as the channel is advanced and prior to the measurement trigger. Note that this injects a 9.75 µS measurement delay with 87nS jitter. BEFORE should only be used when digitizing dynamic signals (AC voltages, etc.).

For example, to set ARMODE to AFTER, send,

```
OUTPUT 709; "ARMODE AFTER, USE 0600"
```

Zeroing the Voltmeter Input

The AZERO ONCE command insures that any offset errors internal to the voltmeter are nulled from subsequent readings. The voltmeter zero's only when you instruct it to. Therefore, for highest accuracy especially on lower ranges, you should execute AZERO ONCE just prior to each group of measurements. This is done by sending:

```
OUTPUT 709; "AZERO ONCE, USE 0600"
```

Triggering the Voltmeter

Triggering is the function that carefully controls the timing of measurement samples. The High-Speed Voltmeter derives its triggering capabilities from its eight trigger sources and three trigger functions. The three trigger functions are called Measure, Scan, and Stop.

Before discussing these three functions let's first look at a typical triggering scheme. Figure 3-8 illustrates the timing relationships with the three trigger functions. Notice that the Scan Trigger initiates the triggering sequence. Each individual measurement is initiated by a Measurement Trigger. The Stop Trigger disables the next scan trigger and halts the voltmeter operation as soon as the current scan is complete. A scan may be only one measurement, several measurements on one input or channel, or a group of measurements made on different multiplexer channels.

Figure 3-8. Trigger Control

In this diagram, *ts* denotes the "Scan Pacer" period – that is, the time interval between Scan Triggers. The Scan Delay, *td*, is the programmable time delay from the Scan Trigger to the first measurement in each scan. The time period between Measurement Triggers, called the Measure Pacer period, is denoted by *tm*.

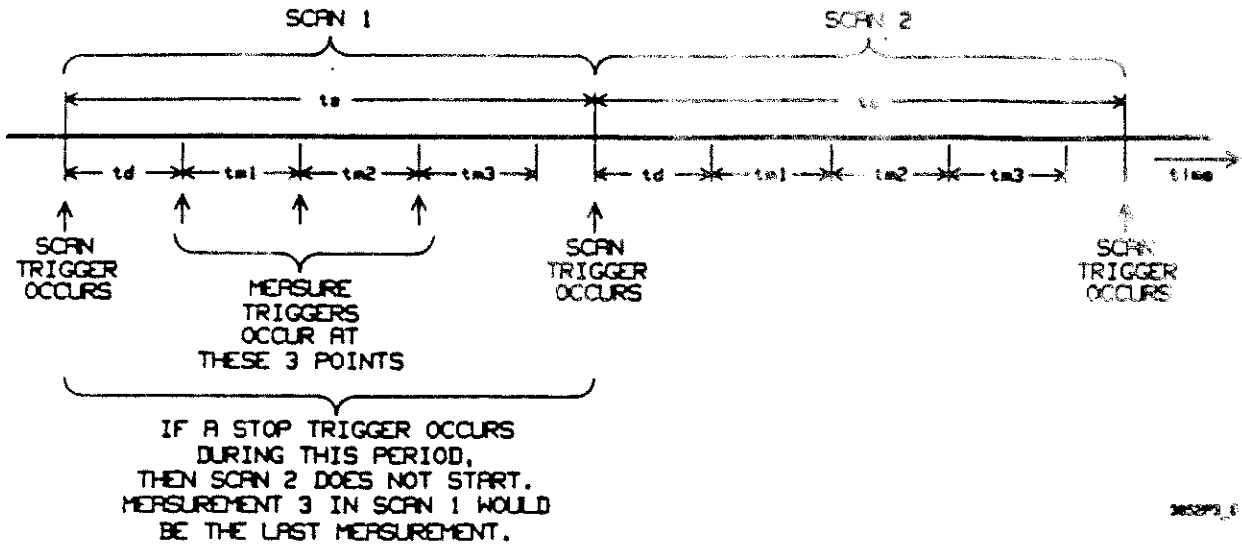


Figure 3-8. Trigger Control

Scan and Measure Triggering

The Scan Trigger enables the High-Speed Voltmeter for a single pass through the specified measurements. Remember, the specified measurements may be one measurement from a specified source, several measurements from one source, or several measurements from several sources. The successive recurrence of the Scan Trigger determines the rate at which scans are initiated. No measurement is directly related to the occurrence of the Scan Trigger. Instead, the Scan Trigger only enables the Measure Trigger to initiate measurements and cause passage through the specified Scan List.

The successive recurrence of the Measure Trigger determines the rate at which the measurements are made. After the scan is complete, the Measurement Trigger is disabled until a new Scan Trigger is received.

NOTE

In the voltmeter System Mode, you have control over the Scan trigger only. The Measure and Stop triggers are controlled by the mainframe.

A Scan or Measurement Trigger that recurs before its function is complete is ignored. It is up to you to decide whether missed triggers are significant to your application.

Stop Trigger

The Stop trigger function disables the Scan Trigger. The measurement operation will subsequently terminate at the end of the current scan. No more Scan Triggers, and hence no more Measurement Triggers, will be accepted. After the Stop trigger occurs, the mainframe or GPIO controller may be flagged (see Interrupts later in this section). This allows measurements to continue until terminated by an external event.

Associated with the Stop Trigger is the ability to specify how many scans must be completed before the Stop Trigger is accepted and the ability to specify how many scans will be completed after the Stop Trigger is accepted. These will be discussed later under Scanning.

Trigger Sources

The High-Speed Voltmeter has eight trigger sources. Some of these trigger sources have a user-definable slope (positive or negative). Trigger sources with fixed slopes are automatically generated internally when the source is selected. Table 3-4 lists the Trigger Sources for the three Trigger Functions and indicates the whether or not the slopes are user defined. For additional information, refer to the TRIG command in the Command Reference Manual.

Table 3-4. Trigger Sources

Trigger Source	Trigger Slope*	Trigger Functions: Stop Trigger	Scan Trigger	Meas Trigger
EXT0	U	Backpanel 0	Backpanel 0	Backpanel 0
EXT1	U	Backpanel 1	Backpanel 1	Backpanel 1
SYS	F	Backplane Trig	Backplane Trig	Backplane Trig
SCAN	F	Closing	Closing	Closing
GPIO	U	GPIO Trigger	GPIO Trigger	GPIO Trigger
MEAS	U	Threshold	Threshold	Off
SGL/HOLD	F	Soft Halt	Soft Scan**	Soft Meas
INT	F	Scan End**	Scan Pacer	Meas Pacer**

* U means user definable slope, F means fixed slope.

** Default sources for the specified trigger function.

EXT0 and EXT1 use the BNC connectors on the High-Speed voltmeter's backpanel. They refer to BNC 0 and BNC 1 respectively. These trigger inputs are TTL compatible and may be actuated with a switch closure to ground. BNC 0 can also output a trigger pulse. See the TRIGOUT command for more information.

SYS trigger refers to a system trigger such as the HP-IB Group Execute Trigger command. Refer to the mainframe TRG command for more information. Backplane Trigger simply implies that the triggering information is controlled by the mainframe.

The SCAN trigger source is a signal on the mainframe's (or extender's) backplane that indicates when a relay or FET channel has closed. Hence the function is named CLOSING. This is the normal trigger source when the mainframe is controlling scanning operations. The voltmeter may be in either System or Scanner mode.

The GPIO controller can also trigger the voltmeter as one of the control signals. It can also be generated externally. This will be discussed in more detail later in this chapter.

The THRESHOLD trigger function, for the MEAS trigger source, is generated by the analog portion of the voltmeter when the signal input crosses a predetermined value (see the PERC command) in a predetermined direction (see the SLOPE command). Note that this is truly edge triggering and not simply level triggering. This is valid in either System or Scanner mode.

The SGL/HOLD trigger source takes the number of reading specified by NRDGS. The Trigger impulse may come from either the HP-IB controller or the HP 3852A mainframe front panel.

INT trigger is effectively an automatic SGL trigger. When one measurement has been made, the voltmeter will sit idle until the measurement is read. The voltmeter will then trigger again and wait until the measurement is read.

Soft Halt, Soft Scan, Soft Meas, Scan End, Scan Pacer, and Meas Pacer are internal functions and will be discussed later in this chapter under Advanced Programming.

Let's look at a few triggering examples before proceeding. In the Systems Mode, to set the voltmeter to external trigger from the BNC 0 connector, send:

```
OUTPUT 709; "TRIG EXT0, USE 0600"
```

If you want the voltmeter to trigger as soon as a channel is closed, send:

```
OUTPUT 709; "TRIG SCAN, USE 0600"
OUTPUT 709; "CLOSE 0215" ! CLOSE CHANNEL 15 IN SLOT 2, & TRIG VM.
```

Other Triggering Commands

Several other triggering commands are available to enhance your control of the voltmeter. The following discussions give general information about using the commands. For more detailed information about each command, refer to the Command Reference Manual.

Trigger Output

The TRIGOUT command sets the external "0" BNC connector to either output trigger pulses or receive trigger pulses. Sending OFF as the TRIGOUT parameter cause the BNC to receive TTL level trigger pulses. In which case the slope is determined by the SLOPE command. TRIGOUT OFF is the power-on setting.

Sending ON as the TRIGOUT parameter causes the BNC connector to output measurement trigger pulses. This TTL output pulse is an 9.9µS negative going pulse. It marks exactly when samples of the input signal are taken. It can also synchronize several other HP 44702 High-Speed Voltmeters. In this case, one voltmeter acts as the master, generating the trigger pulse while all other High-Speed Voltmeters unconditionally trigger upon receipt of the trigger pulse. TRIGOUT OFF is the power-on setting, TRIGOUT ON is the default parameter. Note that when TRIGOUT ON is set, no trigger source can be set to EXT0.

For example, to set TRIGOUT ON, send either:

```
OUTPUT 709; "TRIGOUT ON, USE 0600"
```

or

```
OUTPUT 709; "TRIGOUT, USE 0600" ! USE DEFAULT VALUE
```

Number of Readings per Trigger

In the Systems Mode, the NRDGS command specifies the number of readings (measurements) per trigger. Thus, when the voltmeter receives the trigger signal, it will take the specified number of measurements.

In the Scanner Mode, NRDGS specifies the number of readings per channel. Multiple channels may be specified in a scan list and each channel will be measured the specified number of times before closing the next channel.

The maximum number that may be specified with the NRDGS command is 65535. For example, to set the number of readings to 50 send:

```
OUTPUT 709; "NRDGS 50, USE 0600"
```

Trigger Delay

The DELAY command has two parameters: trigger delay and sample period. The trigger delay simply delays the effect of the Scan Trigger and thus the scan itself. Typically, you would use the trigger delay in situations where the input sources need time to settle before the measurements are made. The trigger delay has a programmable range of 0 to 16.38 mS (16.38E-3).

The sample period is the delay time between readings. It has a programmable range of 0 to 1073.74 seconds.

NOTE

When a random scan trigger source is used with an internally generated Measure Trigger, there is an additional -250 nS to 0 nS uncertainty. When the Scan Trigger is generated internally the uncertainty is eliminated since all triggering is synchronized to the same clock. When the trigger delay is set to zero the uncertainty is also eliminated since the scan delay generator is is removed from the system timing.

For example, to set the trigger delay to 10 mS and the sample period to 5 mS, send:

```
OUTPUT 709; "DELAY 0.01,0.005, USE 0600"
```

Trigger Threshold

The PERC command sets the trigger threshold level for the high speed voltmeter. You specify the threshold as a percentage (± 127%) of the full scale value of the measurement range. For example, to set the threshold to ≈4 volts DC with the voltmeter on the 10.24 volt range, send:

```
OUTPUT 709; "PERC 40, USE 0600" ! SET PERC TO 40% = 4 VOLTS
```

The threshold trigger source is generated by the analog portion of the voltmeter when the input signal crosses a predetermined value (set by the PERC command) in a predetermined direction (set by the SLOPE command). When using the Threshold Trigger Source to trigger a scan, the trigger occurs when the first channel in the scan list crosses the preset threshold. This is because the first channel in the scan list is closed while waiting for the Scan Trigger.

Trigger Slope

SLOPE sets the trigger slope for the voltmeter. It is used only with the EXT0, EXT1, MEAS, and GPIO modes for the TRIG command. All other modes use an internally generated slope. You have a choice of two parameters with the SLOPE command; LH for a low-to-high (positive) transition, or HL for a high-to-low (negative) transition.

For example, to set the slope for the GPIO trigger to low-to-high (positive) transition, send:

```
OUTPUT 709; "USE 600; TRIG GPIO; SLOPE LH" ! LO-TO-HI TRANSITION
```

Reading the Measurement Data

Three commands are available to assist you in getting measurement data from the voltmeter to your system computer. Two of these commands (CHREAD and XRDGS) actually transfer the measurement data, and the third (RDGS) sets the reading destination. Again, for more information, refer to the Command Reference Manual.

Reading Storage Memory

All measurements made by the High-Speed Voltmeter are stored in the internal reading storage memory. They will remain in this buffer until called for by the CHREAD or the XRDGS command. The reading storage memory is a circular buffer and old readings may be over-written by new readings. The RDGSMODE command determines when interrupts will occur for readings left in the reading storage memory and whether or not new readings will overwite old readings. Data is always read in a First-In-First-Out mode.

Up to 8192 readings may be stored in the standard memory. Up to 65536 readings may be stored with the Extended Memory module in the HP44702B voltmeter.

Reading Destination

The RDGS command sets the destination for the measurement data. If the destination is set to the SYStem (HP 3852A mainframe), then measurement data is sent to the mainframe and can be sent the system controller via the HP-IB interface. Voltmeter interrupts are sent to the mainframe also. SYS is the power-on and default value.

You may also specify GPIO as the reading destination. This disables the voltmeter interrupts and sends measurement data directly to the voltmeter GPIO interface. Readings sent to the GPIO interface are sent in 16-bit binary format. Refer to the GPIO section later in this chapter for more information.

To set the reading destination to the mainframe, send:

```
OUTPUT 709; "RDGS SYS, USE 0600"
```

Reading the Data

The two commands for reading the measurement data from the voltmeter are CHREAD and XRDGS. When you execute CHREAD, the mainframe will wait until the measurement result is available. No other commands may be executed during this time. You have a choice of either storing the measurement result in an array (you must specify the array name) or numeric variable, or sending the result to the HP-IB buffer and front panel display (if MON is enabled or the programming command came from the front panel) in a specified format.

To store the measurement result in an array or numeric variable, send:

```
OUTPUT 709; "DIM [array name]" OUTPUT 709; "CHREAD 0600, INTO [array
name]"
```

All variables, whether array or numeric, need to be defined in a DIM, REAL, INTEGER, or PACKED statement. If a numeric variable is specified, the measurement will be stored in the variable and may be recalled later for data manipulation. If you specify an array, the measurement may be indexed into a specific element of the array. Measurements stored in an array or variable may be read with the VREAD command.

Variable and array names may be up to eight characters long. The first character must be a letter (A-Z) but the remaining seven may be numbers (0-9). Variable and array names must not be the same as HP 3852A keywords (i.e CLOSE, CHREAD, RDGS, etc.). For more information on using arrays and variables refer to Chapter 6 of the HP 3852A Mainframe Configuration and Programming MAnual.

The measurement will be sent to the HP-IB interface buffer and front panel display if MON is enabled and the command came from the HP-IB interface or to the front panel display only if the command came from the front panel.

Readings Format

Allowable formats are: RASC for real numbers, DASC for double precision real numbers, IASC for short integers, LASC for long integers, PACK for 16-bit binary format (see later in this chapter for more information), IN16 for 16-bit integer, and RL64 for 64-bit real numbers. Default for the HP-IB interface and front panel display is RASC; the GPIO interface allows only the 16-bit binary. For more information, refer to Chapter 6 in the HP 3852 Mainframe Programming and Configuration Manual.

Using Arrays

The XRDGS command acts similar to the CHREAD command but allows you to transfer more than one reading. Like the CHREAD command, the mainframe will wait for the measurement data to become available if they are not all immediately available. If you do not specify how many readings to transfer, the readings will be transferred after the current scan and send all available readings.

For example, to transfer 50 readings into an array RGS1, send:

```
OUTPUT 709; "REAL Rgs1 (49); XRDGS 0600,50, INTO RGS1"
```

Once the measurement results are stored in a mainframe array use the VREAD command to read the measurements to the system computer:

```
10 OUTPUT 709; "INBUF ON"
20 OUTPUT 709; "VREAD Rgs1"
30 FOR I=1 TO 50
40 ENTER 709; A
50 DISP A
60 NEXT I
70 END
```

or

```
10 DIM A(49)
20 OUTPUT 709; "INBUF ON; VREAD Rgs1
30 ENTER 709; A(*)
40 PRINT A(*)
50 END
```

Configuring the Voltmeter

Let's look at one more command before some actual program examples. The CONF command lets you specify a measurement function and initializes the High-Speed Voltmeter for the correct measurement. Fourteen measurement functions are available with the CONF command. They are: DCV, OHM, OHM10K, OHM100K, OHM1M, OHMF, OHMF10K, OHMF100K, OHMF1M, TEMPtype, REFT, THMtype, THMFtype, and RTDtype. These are explained in Table 3-5.

Table 3-5. CONF Measurement Functions

Measurement Function	Description
DCV	Measure DC voltage
OHM	Measure 2-wire ohms* (same as OHM100K)
OHM10K	Measure 2-wire ohms up to 10K ohms*
OHM100K	Measure 2-wire ohms up to 100K ohms*
OHM1M	Measure 2-wire ohms up to 1M ohms*
OHMF	Measure 4-wire ohms** (same as OHMF100K)
OHMF10K	Measure 4-wire ohms up to 10K ohms**
OHMF100K	Measure 4-wire ohms up to 100K ohms**
OHMF1M	Measure 4-wire ohms up to 1M ohms**
TEMPtype	Measure the reference temperature then measure the thermocouple voltage. Convert measured voltage (compensated by the ref. temp.) to degrees C. Thermocouple types: J, K, T, S, R, B, E, N14, and N28.
REFT	Measure the reference temperature of thermistor on isothermal block.
THMtype	Configure for a 2-wire ohms measurement on a thermistor.* Convert the resistance to degrees C. Thermistor types: 2252 (for 2252 ohm thermistor) 5K (for 5k ohm thermistor) 10K (for 10k ohm thermistor)
THMFtype	Configure for 4-wire ohms measurement on a thermistor.** Convert the resistance to degrees C. Thermistor types: same as THMtype above.
RTDtype	Configure for 2-wire ohms measurement on an RTD.* The mainframe converts the resistance to a temperature in degrees C. RTD types: 85 (for RTDs with alpha = 0.00385 ohms/ohm/degree C) 92 (for RTDs with alpha = 0.003916 ohms/ohm/degree C)
RTDFtype	Configure for a 4-wire ohms measurement on an RTD.** The mainframe converts the resistance to a temperature in degrees C. RTD types: same as RTDtype above.

* For 2-Wire resistance measurements, the current source connects to the voltmeter sense inside the multiplexer accessory. All accessory channels are available for measurements.

** For 4-Wire resistance measurements, the current source connects to Bank B of the multiplexer accessory The voltmeter sense connects to Bank A of the accessory. You are responsible for connecting the current source to the resistance to be measured. Specify only the voltmeter sense channel on Bank A for measurement; the respective channel on Bank B will close automatically.

CONF can then be used with the multiplexer OPEN and CLOSE commands to take measurements. To set the High-Speed voltmeter to the DC volts function and all other default conditions, send:

```
OUTPUT 709; "CONF DCV ;USE 0600"
```

Program Examples

Although the following program examples are simple, they show the fundamentals of programming the High-Speed Voltmeter. In the next section of this manual we will look at scanning through a series of multiplexer channels.

Example 1. Reading from the Backpanel Terminals

In this example we will use the High-Speed Voltmeter to take a simple DC voltage measurement from its backpanel terminals. The system controller will display the voltage reading. Connect the voltage to be measured to the backpanel terminals and execute the following program.

```
10 OUTPUT 709; "USE 0600" ! VOLTMETER IN MAINFRAME SLOT 600
20 OUTPUT 709; "CONF DCV; TERM EXT; TRIG SGL"
25 !           DC VOLTAGE, EXTERNAL TERMINALS, SINGLE TRIGGER
30 OUTPUT 709; "CHREAD 0600,RASC" !READ MEASUREMENT, REAL NUMBER FMT
40 ENTER 709, A ! ENTER MEASUREMENT
50 DISP A ! DISPLAY MEASUREMENT
60 END
```

In this program we specified the voltmeter with the USE command in line 10. Line 20 then configures the voltmeter, and triggers the voltmeter for the measurement. The measurement will appear on the system controller display.

Example 2. Multiple Readings

The following program takes 50 readings from the backpanel terminals, stores them in an array called RGS1, and then transfers the readings to the controller where they are displayed.

```
10 OUTPUT 709; "REAL RGS1 (49)" ! DIMENSION ARRAY
20 OUTPUT 709; "USE 0600; CONF DCV; TERM EXT; NRDGS 50; TRIG SGL"
25 !  DC VOLTAGE, EXTERNAL TERM'S, 50 READINGS/TRIG, SINGLE TRIGGER
30 OUTPUT 709; "XRDGS 0600,50,INTO RGS1" !TRANSFER READINGS TO RGS1
40 OUTPUT 709; "VREAD RGS1" ! GET MEASUREMENTS
50 FOR I=1 TO 50
60 ENTER 709; A ! ENTER MEASUREMENT
70 PRINT A ! PRINT THE MEASUREMENTS
80 NEXT I
```

```
90 END
```

If you system computer has advance array handling capabilities, modifying the following lines will transfer the readings faster:

```
5 DIM A(49)

50 ENTER 709; A(*)
60 PRINT A(*) ! OR PRINT USING "(K),/";A(*)
70 END
```

Example 3. Measurements from a Multiplexer Accessory

This example is similar to the first except the source of the measurement will be from a multiplexer accessory installed in slot 4 of the mainframe. The program takes a voltage reading from channel 5 of the accessory.

```
10 OUTPUT 709;"USE 0600" ! VOLTMETER IN MAINFRAME SLOT 600
20 OUTPUT 709;"CONF DCV; TERM INT"
25 ! DC VOLTAGE, INTERNAL BACKPLANE
30 OUTPUT 709; "CLOSE 405,491"  ! CLOSE MULTIPLEXER CHANNEL 405 & TR
40 OUTPUT 709; "TRIG SGL"   ! SINGLE TRIGGER
50 OUTPUT 709;"CHREAD 0600,RASC" ! READ MEASUREMENT, REAL NUMBER FMT
60 ENTER 709, A ! ENTER MEASUREMENT
70 DISP A ! DISPLAY MEASUREMENT
80 END
```

Interrupts

With a reading rate of 100,000 readings per second it would take only a short time to fill the internal reading storage memory. Consequently, the High-Speed voltmeter must interrupt mainframe or the GPIO controller (the destination is determined by the RDGS command) when data becomes available. You also need to determine whether new readings will over-write old readings in the reading storage memory. The RDGSMODE command gives you this capability.

With the RDGSMODE command you have four alternatives:

- **DAV** causes the voltmeter to interrupt as soon as any measurement data is available, The data will not over-write the old data in the reading storage memory.
- **BURST** causes the interrupt to occur only when the reading storage memory has room for 4096 more readings. New readings will not over-write old readings in the memory. This mode is primarily used when high speed scanning with the FET multiplexer accessories.
- **COMPLETE** causes the voltmeter to interrupt only when the scan sequence is complete. New readings will over-write old readings in the reading storage memory. Only the readings specified by PRESCAN and POSTSCAN will be available.
- **END** causes the interrupt to occur when the scan sequence is complete or the reading storage memory is full, whichever occurs first. An abortive situation occurs if the number of readings specified is greater than the buffer size. New

readings will not over-write in the reading memory.

For example, to set the interrupt mode to END, send:

```
OUTPUT 709; "RDGSMODE END, USE 0600"
```

Enabling Interrupts

Once you have decided what will cause the reading storage interrupt you must enable the voltmeter to actually interrupt the controller. The ENABLE INTR command allows the voltmeter to interrupt the GPIO controller or the HP 3852A mainframe.

NOTE

The RDGSMODE must be set prior to enabling the interrupt.

If your destination (see RDGS) is the HP 3852A mainframe, you must have the RQS mask set to acknowledge the Slot Interrupt bit. A service request can then be sent through the HP-IB interface to the system controller. This can be done by sending:

```
10 OUTPUT 709; "RQS 512; RQS ON" ! SET RQS MASK FOR DATA READY
20 OUTPUT 709; "RDGS SYS; RDGSMODE END"
30 OUTPUT 709; "ENABLE INTR; ENABLE INTR SYS"
```

Your system controller must, whether it is an HP-IB controller or a GPIO controller, be programmed to adequately respond to the interrupt. We will give GPIO interrupt examples later in this chapter. For more information regarding the HP-IB interrupts, refer to the HP 3852A DA/C Installation and Programming Manual. The voltmeter will clear the interrupt when either the mainframe or system controller (HP-IB or GPIO) reads the data from the reading storage memory.

Interrupt Query

The interrupt query command (INTR?) returns the lowest slot generating a system interrupt. If no slot is generating an interrupt, the number -1 is returned. The following program demonstrates its use:

```
10 OUTPUT 709; "INTR?"
20 ENTER 709; A
30 PRINT "Slot number ";A;" is interrupting."
40 END
```

Disabling Interrupts

To disable the voltmeter interrupts send the DISABLE INTR command. Interrupts are also disabled by changing the RDGS or RDGSMODE setting. For example, to disable interrupts, send:

```
OUTPUT 709; "DISABLE INTR, USE 0600"
```

Calibration

To maintain the highest accuracy, your HP 44702 voltmeter should be calibrated periodically. For complete calibration information refer to the service manual.

NOTE

Attempting to calibrate the voltmeter without adequate voltage and resistance standards will result in a loss of accuracy. Do not attempt to calibrate the voltmeter or read the calibration constants without following the specific directions in the service manual.

General Backplane Scanning

Scanning is the process of sequencing through a list of multiplexer relays or FET switches making one or more measurements on each channel. Connections between the multiplexer accessories and the voltmeter are made on the mainframe or extender's analog backplane. Hence the name Backplane Scanning. In the Systems Mode of the HP 44702 High Speed Voltmeter, scanning can be done through the mainframe or extender backplane using any of the available HP 3852AA multiplexer accessories. High speed scanning using only the FET multiplexer accessories will be discussed in a later section of this chapter.

Configuration Phase

Two phases, the configuration phase and the measurement phase, compose each scanning/measurement sequence. You configure the High-Speed Voltmeter by executing the CONF command (discussed earlier) with the appropriate function parameter or by executing individual configuration commands such as FUNC, RANGE, NRDGS, etc. Of course you can execute the CONF command followed by some of the individual commands (such as RANGE or NRDGS) to change the default parameters of CONF.

Measurement Phase

The measurement phase performs the actual scanning and measuring associated with the specified configuration and channel list. The channel list is the list of multiplexer channels the voltmeter is to measure. There are two general methods of accomplishing the measurement phase. The first approach is to execute individual commands such as OPEN, CLOSE, TRIG SGL, CHREAD, etc. The second approach use more sophisticated commands such as MEAS, CONFMEAS, and MONMEAS.

Example 4. Individual Commands

Let's look at a simple example demonstrating the individual command approach. In this example, the voltmeter will make 10 readings on each multiplexer channel before proceeding to the next channel. The voltmeter is installed in slots 6 and 7 of the mainframe and the HP 44705A 20 channel Relay Multiplexer is installed in slot 5 of the mainframe.

```
10 OUTPUT 709; "REAL RGS1 (199)" ! DIMENSION ARRAY
20 OUTPUT 709; "USE 0600; AZERO ONCE; CONF DCV; TRIG HOLD; NRDGS 10"
25             ! DC VOLTAGE, 10 READINGS/TRIGGER, AND HOLD TRIGGER
30 OUTPUT 709; "CLOSE 591"          ! CLOSE TREE SWITCH
40 OUTPUT 709; "TRIG SCAN"
50 FOR I= 0 TO 19 STEP 1
60    OUTPUT 709; "CLOSE";500+I
70    OUTPUT 709; "TRIG SGL" ! TRIGGER THE VOLTMETER FOR 10 READINGS
80    OUTPUT 709; "XRDGS 0600, 10, INTO RGS1"
85                ! TRANSFER READINGS TO RGS1
90    OUTPUT 709; "OPEN";500+I
100 NEXT I
110 OUTPUT 709 "VREAD RGS1" ! READ ARRAY VALUES
120 FOR I = 0 TO 200
130 ENTER 709; A
140 DISP A
150 NEXT I
160 END
```

This individual command approach is slow and awkward. The MEAS command allows you to do the same task much easier. The MEAS command causes the voltmeter to scan and measure the specified multiplexer channels.

Simple Scanning

MEAS reconfigures the voltmeter as needed for the scanning process. Trigger, for example, is changed from HOLD/SGL to SCAN. You must configure the voltmeter for the appropriate measurement function before executing the MEAS command. MEAS also disables any interrupts that were previously enabled for the voltmeter. MEAS has the same measurement functions as CONF, these are explained in Table 3-6.

Table 3-6. MEAS, CONFMEAS, AND MONMEAS Measurement Functions

Measurement Function	Description
DCV	Measure DC voltage
OHM	Measure 2-wire ohms* (same as OHM100K)
OHM10K	Measure 2-wire ohms up to 10K ohms*
OHM100K	Measure 2-wire ohms up to 100K ohms*
OHM1M	Measure 2-wire ohms up to 1M ohms*
OHMF	Measure 4-wire ohms** (same as OHMF100K)
OHMF10K	Measure 4-wire ohms up to 10K ohms**
OHMF100K	Measure 4-wire ohms up to 100K ohms**
OHMF1M	Measure 4-wire ohms up to 1M ohms**
TEMPtype	Measure the reference temperature then measure the thermocouple voltage. Convert measured voltage (compensated by the ref. temp.) to degrees C. Thermocouple types: J, K, T, S, R, B, E, N14, and N28.
REFT	Measure the reference temperature of thermistor on isothermal block.
THMtype	Configure for a 2-wire ohms measurement on a thermistor.* Convert the resistance to degrees C. Thermistor types: 2252 (for 2252 ohm thermistor) 5K (for 5k ohm thermistor) 10K (for 10k ohm thermistor)
THMFtype	Configure for 4-wire ohms measurement on a thermistor.** Convert the resistance to degrees C. Thermistor types: same as THMtype above.
RTDtype	Configure for 2-wire ohms measurement on an RTD.* The mainframe converts the resistance to a temperature in degrees C. RTD types: 85 (for RTDs with alpha = 0.00385 ohms/ohm/degree C) 92 (for RTDs with alpha = 0.003916 ohms/ohm/degree C)
RTDFtype	Configure for a 4-wire ohms measurement on an RTD.** The mainframe converts the resistance to a temperature in degrees C. RTD types: same as RTDtype above.

* For 2-Wire resistance measurements, the current source connects to the voltmeter sense inside the multiplexer accessory. All accessory channels are available for measurements.

** For 4-Wire resistance measurements, the current source connects to Bank B of the multiplexer accessory. The voltmeter sense connects to Bank A of the accessory. You are responsible for connecting the current source to the resistance to be measured. Specify only the voltmeter sense channel on Bank A for measurement; the respective channel on Bank B will close automatically.

Example 5. MEAS and CONFMEAS Commands

Let's look at the same example we had earlier but using the MEAS command. The voltmeter will measure each channel on the multiplexer accessory 10 times before progressing to the next channel. The readings will be stored in the array RGS1.

```
10 OUTPUT 709; "REAL RGS1 (199)" ! DIMENSION ARRAY
20 OUTPUT 709; "USE 0600; CONF DCV; NRDGS 10"
25             ! DC VOLTAGE, 10 READINGS/TRIGGER, TRIGGER HOLD
30 OUTPUT 709; "MEAS DCV, 0500-0519, INTO RGS1"
35             ! DC VOLTAGE, CHANNELS 0500 TO 0519, STORE INTO RGS1
40 OUTPUT 709; "VREAD RGS1"
50 FOR I=0 TO 200
60 ENTER 709; A
70 DISP A
80 NEXT I
90 END
```

In line 20, the CONF command sets all the defaults, such as autorange, for the voltmeter. The DCV parameter for the MEAS command (line 30) sets only the measurement function. All other functions, such as ranging or number-of-readings-per-trigger, must be established before executing MEAS.

Using the separate CONF and MEAS commands allows other events or programming steps to intervene between the two commands. For example, we could specify manual ranging on the voltmeter and zero the input. It is also possible for interrupts, alarm conditions or limit tests to occur between the CONF and MEAS command which could reconfigure the voltmeter (if so programmed).

If you do not need to change any of the voltmeter defaults (such as NRDGS, ranging, delays, etc.) and you want nothing to intervene between the two steps, both commands can be executed simultaneously with the CONFMEAS command. CONFMEAS has the same measurement functions as CONF and MEAS. Refer to Table 3-6 for the CONFMEAS measurement functions.

The following line can replace lines 20 and 30 of the provious program exampole. CONFMEAS does not allow for multiple readings per channel (NRDGS) though, so only a total of 20 readings will be taken.

```
20 OUTPUT 709; "USE 0600; TRIG HOLD; CONFMEAS DCV, 0500-0519, INTO
RGS1"
```

Scanner Control

Two commands allow you to control the timing of the Scan Trigger and scanner advance. These commands are not valid if the TERM command is set to RIBBON.

The first of these commands, STRIG, specifies the source of the trigger signal that initiates the scanning. The power-on/default parameter, SCAN, causes the scanning to begin as soon as a scanning command (either MEAS or CONFMEAS) is executed. This power-on/default condition was used in the earlier MEAS example and will be assumed in all scanning examples in this chapter. Other STRIG parameter choices are: CHADV which uses the external Channel Advance BNC connector, KEY which initiates scanning when the HP 3852A front panel SADV key is pressed, and PACER where the mainframe pacer is used to initiate scanning.

If you set SCANMODE ON (Scanner Mode), then you must also meet SCTRIG and TRIG requirements. You need to meet only TRIG requirements if SCANMODE is OFF (System Mode)

The second scanner control command is SADV. This command specifies the source of the channel advance signal which indicates when to open the current multiplexer channel, close the next channel in the scan list, and trigger the voltmeter. This command is especially helpful if you need multiple readings on a channel per trigger. The power-on/default parameter for SADV is SCAN. SCAN advances to the next channel only when the specified number-of-readings-per-trigger (NRDGS command) have been made. Other SADV parameter choices are: CHADV which uses the external Channel Advance BNC connector, KEY which advances scanning when the HP 3852A front panel Scan Advance key is pressed, and PACER where the mainframe pacer is used to advance scanning.

Monitoring the Scan

The MONMEAS command can help you check your field wiring. It functions similar to the CONFMEAS command in that you define a measurement function. MONMEAS repeatedly samples a channel in the scan list and the results are displayed on the mainframe front panel. The scanner will advance to the next channel in the scan list only when you press the front panel SADV key.

Consider the following example. As before, the voltmeter is installed in slots 6 and 7 of the mainframe, an HP 44705A Relay Multiplexer accessory is installed in slot 5. Execute the command:

```
OUTPUT 709; "MONMEAS DCV, 0500-0519, USE 0600"
```

The HP 3852A displays the measurement function and channel number in the left-hand display and the voltage measurement in the right-hand display. Now press the SADV key on the front panel. The scanner will advance to the next channel. Continue pressing the SADV key as the scanner increments through the scan list.

High Speed Scanning

This section of the chapter discusses scanning with the high speed FET multiplexers using the dedicated interface cable. We will look at more of the advanced features of the HP 44702 High Speed Voltmeter and how you can use them to solve your scanning needs.

For information on installing the dedicated interface cable between the high speed FET multiplexer assemblies and the High Speed Voltmeter, refer to the HP 3852A Installation and Programming Manual. Only the HP 44711A 24 channel, 44712A 48 channel, and the 44713A Thermocouple Compensated 24 channel High Speed FET multiplexer accessories may be used with the dedicated interface cable. For information on installing, configuring and using the high speed FET multiplexer accessories, refer to the respective chapter in this manual.

Up to 6 of these high speed FET multiplexers may be connected with the dedicated interface to one High-Speed Voltmeter in the mainframe. Eight multiplexers may be connected to a voltmeter in an extender frame.

NOTE

Error 128, `NO VALID CHANNEL IN LIST` occurs when you attempt to execute a scanning sequence but the dedicated interface cable is not connected.

The High-Speed Voltmeter commands discussed in this section are valid only with the voltmeter in the Scanner Mode. To set the voltmeter in this mode, execute:

```
OUTPUT 709; "SCANMODE ON, USE 0600"
```

NOTE

Anytime you change the setting of SCANMODE, the voltmeter completely resets. All of your voltmeter configuration should be done after setting the SCANMODE. With SCANMODE ON, the SCTRIG must be set to HOLD when any other configuration command is issued.

Set the Function

As before, you must set the measurement function and ranging prior to starting the scan. Use either the individual commands such as FUNC and RANGE or the CONF default command. Any of the four measurement functions are valid in high speed scanning with the FET multiplexers.

Triggering

In the earlier programming section of this chapter we learned about the three trigger functions and the eight trigger sources. As a brief review, consider Figure 3-9. This figure illustrates the timing relationships with the three trigger functions. Notice that the Scan Trigger initiates the triggering sequence. The Measurement Trigger initiates each individual measurement. The Stop trigger disables the Scan Trigger and halts the voltmeter operation as soon as the current pass is complete.

Figure 3-9. Trigger Control

In this diagram, *ts* denotes the "Scan Pacer" period -- that is, the time interval between Scan Triggers. the Scan Delay, *td*, is the programmable time delay from the Scan Trigger to the first measurement in each scan. The time period between Measurement Triggers, called the Measurement Pacer period, is denoted by *tm*. For more information on triggering the voltmeter, refer back to the Triggering the Voltmeter section of this chapter.

Scan Trigger

The Scan Trigger enables the High-Speed voltmeter for a single pass through the specified scan list. The successive recurrence of the Scan Trigger determines the rate at which scans are initiated. No measurement is directly related to the occurrence of the Scan Trigger. Instead, the Scan Trigger only enables the Measurement Trigger to initiate measurements and cause passage through the specified scan list. In the Scanner Mode you have full control over the Scan Trigger with three commands: SCTRIG, SCSLOPE and SCDELAY.

SCTRIG sets the source of the Scan Trigger. SCTRIG must be set to HOLD when issuing other setup commands. Table 3-7 lists the possible Scan Trigger source parameters and their meanings.

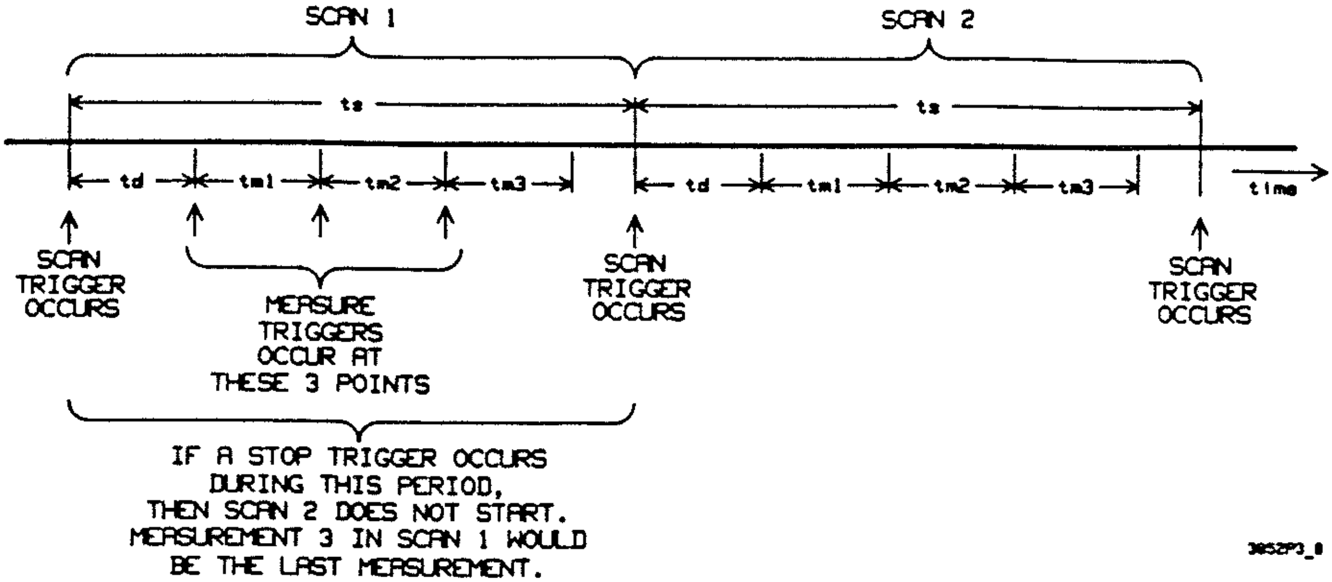


Figure 3-9. Trigger Control

Table 3-7. Scan Trigger Sources

Source Parameter	Description
SCAN	Trigger when a multiplexer channel (backplane) closes
SGL	Single trigger (default)
HOLD	Trigger off (power-on condition)
EXT0	External BNC connector 0 (see also TRIGOUT)
EXT1	External BNC connector 1
SYS	System trigger pulse*
INT	Voltmeter Internal Trigger
MEAS	Trigger on measurement level (see PERC command)
GPIO	GPIO Trigger

* Refer to the mainframe TRG command for more information.

For example, to set the Scan Trigger off, send:

```
OUTPUT 709; "SCTRIG HOLD"
```

For more information on these trigger sources, refer back to the section on Trigger Sources.

Scan Trigger Slope

If you have selected either MEAS, EXT0, EXT1, or GPIO as the source for SCTRIG, you can also set the Scan Trigger slope. SCSLOPE sets the slope to either a high-to-low (HL) transition or a low-to-high (LH) transition. To set the slope for a low-to-high transition, send:

```
OUTPUT 709; "SCSLOPE LH, USE 0600"
```

This trigger slope is stored and used whenever any one of the above trigger modes are set.

Scan Trigger Delay

With the SCDELAY command you can specify two things. First, the scan trigger delay parameter sets the minimum amount of time between the Scan Trigger and the enabling of the Measurement Trigger. You specify this delay within the range of 0 to 16.38 mS (16.38E-3 seconds).

Second, if you have specified INT as the SCTRIG source, you can specify the minimum time allowed between successive Scan Triggers. This is called the Pace Delay. You specify this parameter in seconds with a range of 0 to 1073.74 seconds.

For example, to set a 10mS delay before the first Measurement Trigger and a one minute delay between Scan Triggers, send:

```
OUTPUT 709; "USE 600; SCTRIG INT; SCDELAY 10E-3, 60"
```

Automatic Repeat Scanning

If you need to make multiple passes through your scanlist, you can select whether each pass will require a separate Scan Trigger or whether only the first pass will require a Scan Trigger with all subsequent passes starting automatically. The ASCAN command sets this automatic scanning feature either on or off.

To turn the automatic scanning feature on, send:

```
OUTPUT 709; "ASCAN ON"
```

Measure Trigger

The Measure Trigger source is set by the TRIG command discussed earlier. It initiates the individual measurements. Table 3-8 lists the possible parameters. Note, in the Scanner Mode TRIG sets the Scan Trigger, in System Mode TRIG sets the Measure Trigger.

Table 3-8. Measure Trigger Sources

Source Parameter	Description
SCAN	Trigger when a multiplexer channel closes
SGL	Single trigger (default)
HOLD	Trigger off (power-on condition)
EXT0	External BNC connector 0 (see also TRIGOUT)
EXT1	External BNC connector 1
SYS	System trigger pulse*
INT	Voltmeter Internal Trigger
MEAS	Trigger on measurement level (see PERC command) (valid only in System Mode)
GPIO	GPIO Trigger

* Refer to the mainframe TRG command for more information.

For example, to set the Measurement Trigger to the external BNC 0 connector, send:

```
OUTPUT 709; "TRIG EXT0"
```

For more information on these trigger sources, refer back to the section on Trigger Sources.

Measure Trigger Slope

The slope of the Measure Trigger can be set with the SLOPE command. This command is valid only in the EXT0, EXT1, MEAS, and GPIO settings of TRIG. SLOPE sets the slope to either a high-to-low transition (HL) or a low-to-high (LH) transition. To set the slope for a high-to-low transition, send:

```
OUTPUT 709; "SLOPE HL"
```

Sample Period

If you have set the Measurement Trigger to INT (TRIG INT) then you can also specify the sample period (SPER command). The sample period is the time between successive Measurement Triggers. Its function is similar to the DELAY command in the voltmeter System Mode. You specify SPER in seconds with a range of 0 to 1073.74.

For example, to set SPER to 30 seconds, send:

```
OUTPUT 709; "TRIG INT; SPER 30"
```

Stop Trigger

The Stop Trigger function (STTRIG) disables the Scan Trigger. The measurement operation will will subsequently terminate at the end of the current pass. No further Scan Triggers and hence no further Measure Triggers will be accepted. When a Stop Trigger occurs, SCTRIG is set to HOLD.

Eight sources are available for the Stop Trigger. These are explained in Table 3-9.

Table 3-9. Stop Trigger Sources

Source Parameter	Description
SCAN	Trigger when a multiplexer channel closes
SGL	Single trigger (default)
HOLD	Trigger off (power-on condition)
EXT0	External BNC connector 0 (see also TRIGOUT)
EXT1	External BNC connector 1
SYS	System trigger pulse*
INT	Stop when Prescan and Postscan are satisfied**
MEAS	Trigger on measurement level (see PERC command)
GPIO	GPIO Trigger

* Refer to the mainframe TRG command for more information. ** One scan default

For example, to set the Stop Trigger to internal (INT), send:

```
OUTPUT 709; "STTRIG INT"
```

For more information on these trigger sources, refer back to the section on Trigger Sources.

Stop Trigger Slope

If you have selected either EXT0, EXT1, MEAS, or GPIO as the source for STTRIG, you can also set the Stop Trigger slope. STSLOPE sets the slope for a high-to-low (HL) transition or a low-to-high (LH) transition. To set the slope for a high-to-low transition, send:

```
OUTPUT 709; "STSLOPE HL"
```

Pre- and Post-Scanning

If you have a need to center your data measurements around some particular event, you can use the POSTSCAN and PRESCAN commands. The event should coincide with the Stop Trigger.

PRESCAN specifies the number of passes through the scan list before the Stop trigger will be accepted. The default is one (Prescan) pass through the scan list before the Stop Trigger is recognized.

For example, if you need at least five passes through your scan list before you stop triggering, send:

```
OUTPUT 709; "PRESCAN 5"
```

Similarly, if you need a specific number of passes through the scan list after the Stop Trigger occurs, use the POSTSCAN command. The power-on value for this command is zero.

To specify three passes through the scan list after the Stop Trigger is accepted, send:

```
OUTPUT 709; "POSTSCAN 3"
```

If RDGSMODE were set to COMPLETE, these last two examples would yield a total of eight scans; five before the Stoop Trigger is received and three after the Stop Trigger is received.

Allotting Memory

When you begin taking multiple readings with the High-Speed Voltmeter and storing them in internal arrays, you need to allot adequate memory space if RDGSMODE is set to complete. The equation for determining memory space is very simple. Add the number of Postscans to the number of Prescans. Multiply this number by the number of channels in the scan list. Finally, multiply this number by the number of readings per channel (NRDGS command):

```
((PRESCANS + POSTSCANS) * NO. OF CHANNELS IN LIST) * NRDGS VALUE
```

For example, if you specify 10 prescans, 10 postscans, twenty channels in the scan list, and 10 readings per channel; you would need to allot space for 4000 readings:

```
((10 + 10) * 20) * 10 = 4000
```

Scan List Setup

When you are ready to start scanning you will need to define a list of channels to scan through. This is called the scan list. The scan list may consist of one channel that you want to measure a number of times or it may consist of any group of channels. You may want to measure each channel a number of times before moving on to the next channel. The CLWRITE command allows you to specify the channel list, the type of ranging, and configure the dedicated interface cable for the type of measurement you want to make.

CLWRITE is valid only in the Scanner Mode and TERM must be set to RIBBON and has three parameters: Interface Bus, Channel List, and Range List.

Interface Bus Parameter

The Interface Bus parameter configures the dedicated interface bus for the type of measurements you want to make. You have three choices: SENSE, COM and SEP.

SENSE turns on only the voltmeter sense bus. The current source bus is off. This is used for DC voltage measurements only.

COM turns on the current source bus but connects it to the voltmeter sense bus at the multiplexer assembly. This is useful for 2-wire resistance measurements and retains full channel usage on the FET multiplexer assembly.

SEP turns on the current source bus but connects it to the second decade in the FET multiplexer accessory. This is useful for making 4-wire resistance measurements. The number of usable channels in the multiplexer accessory is reduced by half because the current source connects to the bank B on the accessory. In the channel list, specify only channels in Bank A; the respective channel in Bank B will close automatically.

Channel List Parameter

The channel list is the list of channels that are scanned through when the proper triggers are received. All channels in this list must be connected to the High-Speed Voltmeter through the dedicated interface cable.

Range and Range List Parameter

You may specify the measurement range for each channel or channel list in the scan list or you can specify one range for the entire channel list. You may also specify auto ranging. Each range is the maximum value expected for the corresponding channel in the channel list. This parameter is optional. If it is not specified, then autoranging is assumed.

For example, to set the scan list for DC voltage measurements, on channels 500 through 523, send:

```
OUTPUT 709; "USE 600; SCANMODE ON; TERM RIBBON" OUTPUT 709; "CLWRITE
SENSE, 500-523"
```

or

```
OUTPUT 709; "CLWRITE SENSE, 500-523, RANGE AUTO"
```

If you want to make ten measurements with channels 0 through 4 and 6 through 8 on the 2.56 range and channels 5 and 9 on the 10.24 range, send:

```
OUTPUT 709; CLWRITE SENSE, 500-504,505,506-508,509 RANGE 2,10,2,10"
```

High Speed Scanning Examples

The following examples show the fundamentals of high speed scanning with the HP 44702 voltmeter and the high speed FET multiplexers. In all of these examples, the measurements are stored in the voltmeter's internal reading storage memory and later transferred to the system controller via the HP-IB interface. In the next section of this chapter we will demonstrate how to use the GPIO interface for high speed transfer of measurement data.

Example 6. Simplified High Speed Scanning

In this first high speed scanning example, we will make one pass through a small scan list and use all the default triggers. The voltmeter will scan FET channels 500-519. The FET multiplexer accessory must connect to the voltmeter through the dedicated interface cable. Install the FET multiplexer accessory in slot five of the mainframe.

```
 5 DIM Rdg (20)
10 OUTPUT 709; "USE 600"
15        ! VOLTMETER IN MAINFRAME SLOT 6
20 OUTPUT 709; "SCANMODE ON; SCTRIG HOLD; FUNC DCV; TERM RIBBON"
25        ! HIGH SPEED SCAN, TRIGGER HOLD, DC VOLTS, RIBBON TERMINAL
30 OUTPUT 709; "CLWRITE SENSE 500-519; AZERO ONCE; SCTRIG SGL"
35        ! INT. BUS FOR DCV, CHANS, 500-519, AUTO ZERO, TRIGGER ONC
40 OUTPUT 709; "XRDGS 0600"
45        ! TRANSFER READINGS TO CONTROLLER
50 FOR I = 1 TO 20
60 ENTER 709; Rdg(I)
70 PRINT "READING #";I;" = ";Rdg(I)
80 NEXT I
90 END
```

Example 7. High Speed Scanning with Scan Trigger

This example is similar to the last one except that we have added a Scan Trigger source and a 10 mS Scan Trigger delay. The voltmeter will scan through the scan list (channels 500-519) one time. The Scan Trigger source is the BNC connector 0. The Measure Trigger source remains internal. After the twenty measurements are made, they are sent to the system controller.

```
 5 DIM Rdg (20)
10 OUTPUT 709; "USE 600" ! VM IN MAINFRAME SLOT 6
15        ! VOLTMETER IN MAINFRAME SLOT 6
20 OUTPUT 709; "SCANMODE ON; SCTRIG HOLD; FUNC DCV"
30 OUTPUT 709; "ASCAN OFF; TERM RIBBON"
35        ! H-S SCAN,TRIG OFF, DC VOLTS, DEDICATED INTERFACE
40 OUTPUT 709; "CLWRITE SENSE 500-519; AZERO ONCE; SCTRIG EXTO"
45        ! INT. BUS FOR DCV, CHANS 500-519, AUTO ZERO, TRIG EXT.
50 OUTPUT 709; "XRDGS 600"
55        ! TRANSFER READINGS TO CONTROLLER
60 FOR I = 1 TO 20
70 ENTER 709; Rdg(I)
80 PRINT "READING #";I;" = "; Rdg(I)
90 NEXT I
100 END
```

Example 8. Scanning with Interrupts

This third high speed scanning example interrupts the controller when the voltmeter finishes its scan. The Voltmeter will take 10 readings on each of 20 channels for a total of 200 readings. The Scan Trigger source is the BNC connector 0. The Measure Trigger is internal. The Readings Mode (RDGSMODE) is set to COMPLETE although END could also be used.

```
10 OPTION BASE 1
```

```
20 DIM Readings (200)
30 OUTPUT 709; "RQS 512; RQS ON"
35       ! INTERRUPT CONTROLLER ON SLOT INTERRUPT
40 ON INTR 7 GOSUB 1000
50 ENABLE INTR 7;2
55       ! SET-UP CONTROLLER INTERRUPT HANDLING
60 OUTPUT 709; "USE 600" ! VM IN MAINFRAME SLOT 6
70 OUTPUT 709; "SCANMODE ON; SCTRIG HOLD; FUNC DCV"
80 OUTPUT 709; "TERM RIBBON; NRDGS 10"
85       ! H-S SCAN, TRIG HOLD, DC VOLTS, RIBBON, 10 READS/TRIG
90 OUTPUT 709; "RDGSMODE COMPLETE" ! INTERRUPT WHEN COMPLETE
100 OUTPUT 709; "ENABLE INTR SYS; ENABLE INTR, USE 600"
105      ! ENABLE THE VOLTMETER TO INTERRUPT MAINFRAME
110 OUTPUT 709; "STTRIG EXT1; TRIG INT" ! SET TRIGGERS
120 OUTPUT 709; "CLWRITE SENSE 500-519; AZERO ONCE" ! SET SCANLIST
130 OUTPUT 709; "SCTRIG EXT0" ! SCAN TRIGGER SET-UP
140 GOTO 140 ! WAIT FOR INTERRUPT
1000 P=SPOLL(709)
1010 OUTPUT 709; "XRDGS 600"
1020 FOR I=1 TO 200 ! GET ALL READINGS FROM READING MEMORY
1030 ENTER 709; Readings(I)
1040 PRINT "READING #";I;" = "; Readings(I)
1050 NEXT I
1060 END
```

Example 9. Pre- and Post-Scanning

This last example of high speed scanning is similar to Example 8 but adds Pre- and Post- Scanning. At least five complete scans wills be taken before the Stop Trigger is accepted. Three complete scans will be made after the Stop Trigger is accepted. By setting the Pre- and Post- Scan counters, the voltmeter retains only the specified number of measurements in its reading storage memory. There are twenty readings per scan (channels 500-519) and a minimum of eight scans. This means that the voltmeter will retain only the last 160 readings in its reading storage memory.

```
5 OPTION BASE 1
10 DIM Readings(160)
20 OUTPUT 709;"RQS 512; RQS ON"
25       ! INTERRUPT MAINFRAME ON SLOT INTERRUPT
30 ON INTR 7 GOSUB 1000
40 ENABLE INTR 7;2
45       ! SET-UP CONTROLLER INTERRUPT HANDLING
50 OUTPUT 709; "USE 600"! VM IN MAINFRAME SLOT 6
60 OUTPUT 709; "SCANMODE ON; SCTRIG HOLD; FUNC DCV"
70 OUTPUT 709; "ASCAN ON; TERM RIBBON"
80 OUTPUT 709; "STTRIG EXT1; TRIG INT" ! SET TRIGGERS
80 OUTPUT 709; "RDGSMODE COMPLETE" !  INTERRUPT WHEN COMPLETE
90 OUTPUT 709; "PRESCAN 5; POSTSCAN 3" ! SET PRE- AND POST- SCAN
100 OUTPUT 709; "CLWRITE SENSE 500-519; AZERO ONCE" ! SET SCANLIST
110 OUTPUT 709; "ENABLE INTR, USE 600; ENABLE INTR SYS"
115      ! SET-UP VOLTMETER INTERRUPT
120 OUTPUT 709; "SCTRIG EXT0" ! SCAN TRIGGER SETUP
130 GOTO 130 ! WAIT FOR INTERRUPT
1000 OUTPUT 709;"XRDGS 600"
```

```
1010 ENTER 709; Readings(*)
1020 PRINT Readings(*)
1030 END
```

Synchronizing Multiple Voltmeters

Up to 6 High-Speed Voltmeters may be synchronized for simultaneous operation. One of the voltmeters is designated as the master, the remaining five are slaves. Each voltmeter must connect to its own FET multiplexer accessories through the dedicated interface and should have identical length channel lists.

The TRIGOUT ON command sets the BNC 0 connector on the master voltmeter to output each measurement trigger. This trigger is cascaded to the other voltmeters which must be programmed to accept the measurement pulse from one of the external BNC connectors; either TRIG EXT0 or TRIG EXT1. Thus, each voltmeter will increment the scan list and take a measurement synchronized to the master voltmeter.

The preferred method is to set up all the voltmeters and single trigger (Scan) the slaves. The Measure Triggers will be held off by the master. Then trigger the master to initiate measurements. This guarantees that no race condition will develop causing any of the slaves to miss a Measure Trigger.

Figure 3-10 shows how to connect the BNC connectors together.

Figure 3-10. Synchronizing Multiple Voltmeters

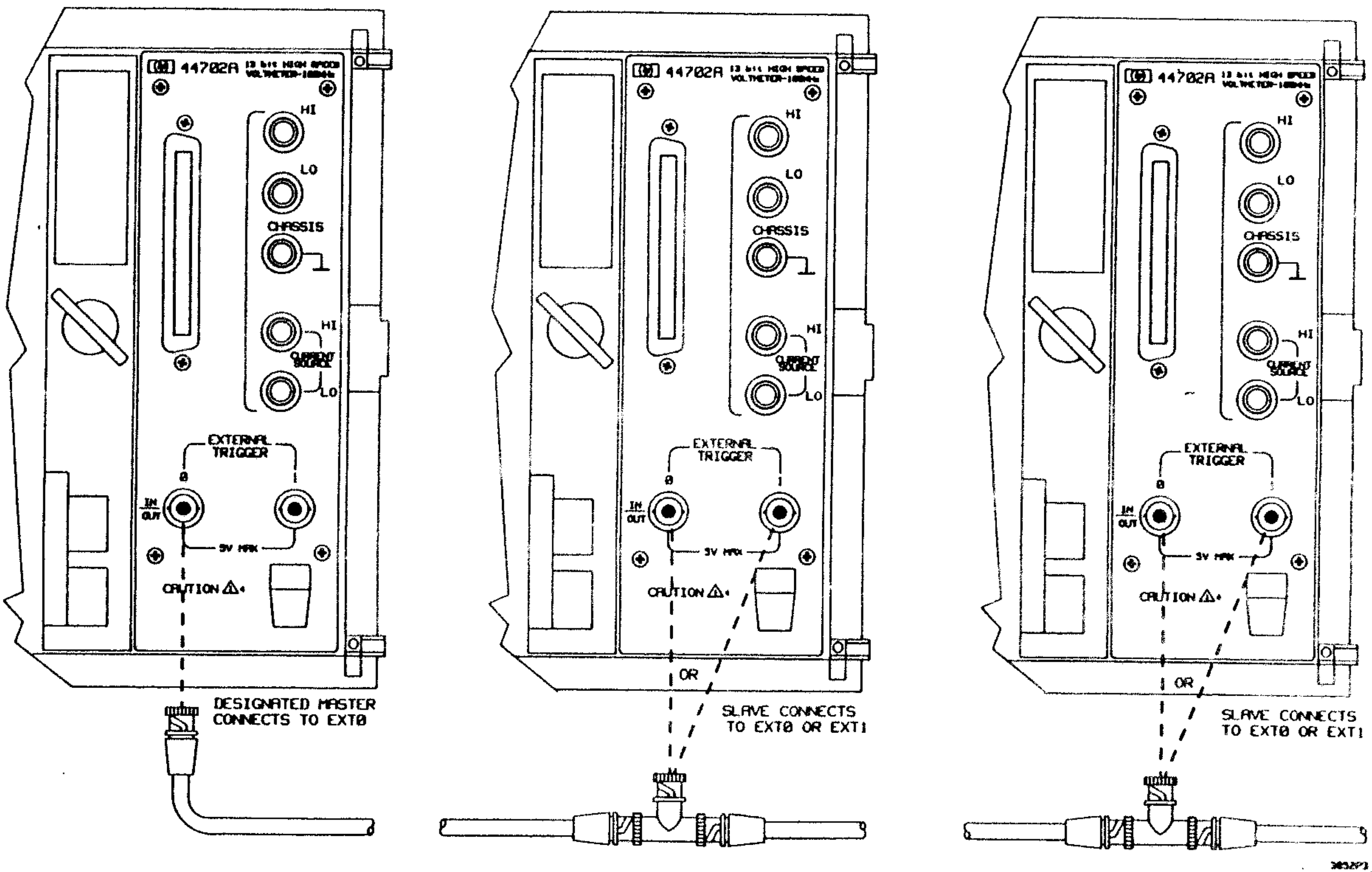


Figure 3-10. Synchronizing Multiple VM's

Example 10. Synchronizing Three Voltmeters

The following program shows how to program three voltmeters for synchronous operation. The voltmeter is mainframe slot 6 is designated the master voltmeter. The other two, one in extender 1 slot 6 and the other in extender 2 slot 6, are slaves. Two 24 channel FET multiplexer accessories connect to each High-Speed Voltmeter through their dedicated interface cables. The Scan Trigger is a system Group Execute Trigger and the Measure Trigger is input through the external BNC0 connector on both slaves. This program makes one pass through the scan list and stops. Of course, the digital interface must also connect the mainframe to the extenders.

```
10 OPTION BASE 1
20 DIM Readings1(48), Readings2(48), Readings3(48)
30        ! SET UP THE MASTER VOLTMETER, NEXT 4 LINES
40 OUTPUT 709; "USE 600; SCANMODE ON; SCTRIG HOLD; FUNC DCV"
50 OUTPUT 709; "TERM RIBBON; ASCAN ON; AZERO ONCE; TRIGOUT ON"
60 OUTPUT 709; "CLWRITE SENSE 400-523; RDGSMODE COMPLETE"
70 OUTPUT 709; "SCTRIG SYS"
80        ! SET UP SLAVE NUMBER 1, NEXT 3 LINES
90 OUTPUT 709; "USE 1600; SCANMODE ON; SCTRIG HOLD; FUNC DCV"
100 OUTPUT 709; "TERM RIBBON; ASCAN ON; AZERO ONCE; TRIG EXT0"
110 OUTPUT 709; "CLWRITE SENSE 1400-1523; RDGSMODE COMPLETE"
120 OUTPUT 709; "SCTRIG SGL"
130        ! SET UP SLAVE NUMBER 2, NEXT 3 LINES
140 OUTPUT 709; "USE 2600; SCANMODE ON; SCTRIG HOLD; FUNC DCV"
150 OUTPUT 709; "TERM RIBBON; ASCAN ON; AZERO ONCE; TRIG EXT0"
160 OUTPUT 709; "CLWRITE SENSE 2400-2523; RDGSMODE COMPLETE"
170 OUTPUT 709; "SCTRIG SGL"
175        ! VOLTMETERS ARE SET-UP, PREPARE TRIGGER
180 OUTPUT 709; "TRIG SGL,USE 600"! SET SCAN TRIGGER FOR THE MASTER
190 TRIGGER 709 ! TRIGGER THE VOLTMETERS
195        ! TRANSFER READINGS
200 OUTPUT 709; "XRDGS 600, 48"
210 ENTER 709; Readings1(*)
220 OUTPUT 709; "XRDGS 1600, 48"
230 ENTER 709; Readings2(*)
240 OUTPUT 709; "XRDGS 2600, 48"
250 ENTER 709; Readings3(*)
260 PRINT Readings1(*); Readings2(*); Readings3(*)
270 END
```

Advanced Programming and the GPIO Interface

This section of the chapter shows you how to get more measurement and control capabilities from your High-Speed Voltmeter. Specifically, we will show you how to directly control triggering and interrupts, how to read the complete status of the voltmeter, and how to do high speed data transfers from the voltmeter's reading storage memory.

This section of the chapter is intended for those individuals who thoroughly understand the operation of the High-Speed Voltmeter. Make sure you read through the entire Advanced Programming section and follow each example carefully otherwise data loss may occur or you may set the voltmeter to an unknown state.

Accessing the Registers

The High-Speed Voltmeter has its own micro-processor which allows it to run independently of the HP 3852A mainframe. This processor allows access to the internal registers which actually control the voltmeter and monitor its status. Two registers provide status information: the Status Register and the Identity Register. Two other registers provide voltmeter control: the Control Register and the Trigger Register. A fifth register provides access to the voltmeter's reading storage memory and is called the Data Buffer Register.

Status Register

The Status Register is a read-only register which means that you can read the contents of the register but you cannot write data to the register. It provides information on the High-Speed Voltmeter's status in a manner that does not interrupt the voltmeter's microprocessor. This includes information on the availability of data, the readiness for data or commands, the completion of requested tasks, and the occurrence of errors.

Identity Register

This register is also a read-only register and identifies the High-Speed Voltmeter and also indicates whether or not the 56k memory expansion is installed or not (HP 44702A or 44702B).

Control Register

The Control Register is a write-only register which means that you are allowed to write data to it but not read data from it. It controls interrupts and resets the voltmeter. This means that interrupts can be selectively enabled or disabled.

Trigger Register

The Trigger Register is also a write-only register. It is used only for generating software triggers (either Scan, Measure, or Stop triggers). All other trigger controls are generated by the voltmeter's own microprocessor as directed by the HP 3852A mainframe or the GPIO system controller.

Data Buffer Register

The Data Buffer Register supplies the HP 3852A mainframe or the GPIO controller with measurement data from the voltmeter's reading storage memory. It is not really a register but provides access to the reading storage memory where measurements are stored.

Other Registers

Other registers exist in the High-Speed Voltmeter but they do not provide useful information or control functions for the user. For example, commands are sent to the voltmeter's microprocessor through the Command Register. It is the receipt of a command that initiates actions by the microprocessor and gives meaning to subsequent data transfers.

Another register is the Data Register. This register is used for all data transfers (except measurement data) between the voltmeter's microprocessor and either the HP 3852A mainframe or the GPIO controller.

These two registers are mentioned in the following discussion even though you do not have access to either the Data or Command registers.

NOTE

Although other registers do exist in the High-Speed Voltmeter, do not attempt to read from or write to any registers other than the Status, Control, Identity, Trigger and Data Buffer Registers. Attempting to read from or write to any other registers may cause the voltmeter to go to an unknown state, invalidate all measurements, or "lock-up".

Using the Registers

Data transfers within the digital section of the High-Speed Voltmeter share a common bus. This means that any request for data transfers must wait until a time slot is found when the internal bus is not busy. When measurements are being taken and sent to the GPIO controller at the maximum A/D conversion rate, the bus is approximately 40% utilized. Excessive access to any of the registers by either the HP 3852A mainframe or the GPIO controller, such as repeatedly checking status, can dominate the bus, causing the Data Buffer to overflow.

Let's look at each register in more detail and see how to use the five registers. There are two methods of reading from or writing to the registers. One method uses the HP-IB interface with the HP 3852A mainframe. The second method directly accesses the registers through the GPIO interface. Both methods require a Register Address. The Register Addresses for the five registers are shown in Table 3-10.

Table 3-10. Register Addresses

Register	Register Type*	Register Address
Identity	R	0
Status	R	1
Data Buffer	R	4
Control	W	0
Trigger	W	1

* R means read-only register, W means write-only register

Reading the Registers

We mentioned before that two methods exist for reading the contents of the registers. The first method reads the register contents through the HP 3852A mainframe over the HP-IB interface. The command for doing this is SREAD. It has the form:

SREAD ***slot, register address [,storage or fmt]***

The *slot* parameter specifies the HP 3852A mainframe or extender slot where the High-Speed Voltmeter is installed. The *Register Address* is defined in Table 3-10. *Storage or Fmt* allows you to specify the destination or format of the returned register value.

The following example shows how to read a value from a register:

```
OUTPUT 709; "SREAD 600,Reg_address"
ENTER 709; A
```

The second method of reading the contents of registers is over the GPIO interface. This involves a four-step process. First, set the GPIO interface Control line to low. This tells the voltmeter that the next piece of data is a Register Address. Then we send the Register Address. Next set the GPIO interface Control line high again for data. Finally, we enter the register value. The following example demonstrates these four steps:

```
10 CONTROL 12,2;5                         ! SET CONTROL LINE LOW
20 OUTPUT 12 USING "#,W"; Reg_address     ! OUTPUT REGISTER ADDRESS
30 CONTROL 12,2;4                         ! SET CONTROL LINE HIGH
40 ENTER 12 USING "#,W"; Reg_value        ! ENTER REGISTER VALUE
50 END
```

In this example, 12 is the system controller's GPIO interface select code.

Reading the Data Buffer

The reading storage memory retains the measurement data as a 16-bit integer word. One bit indicates whether the reading is valid or not. Two bits indicate the measurement range. The remaining thirteen bits form a sign/magnitude number. Figure 3-11 illustrates the measurement data format.

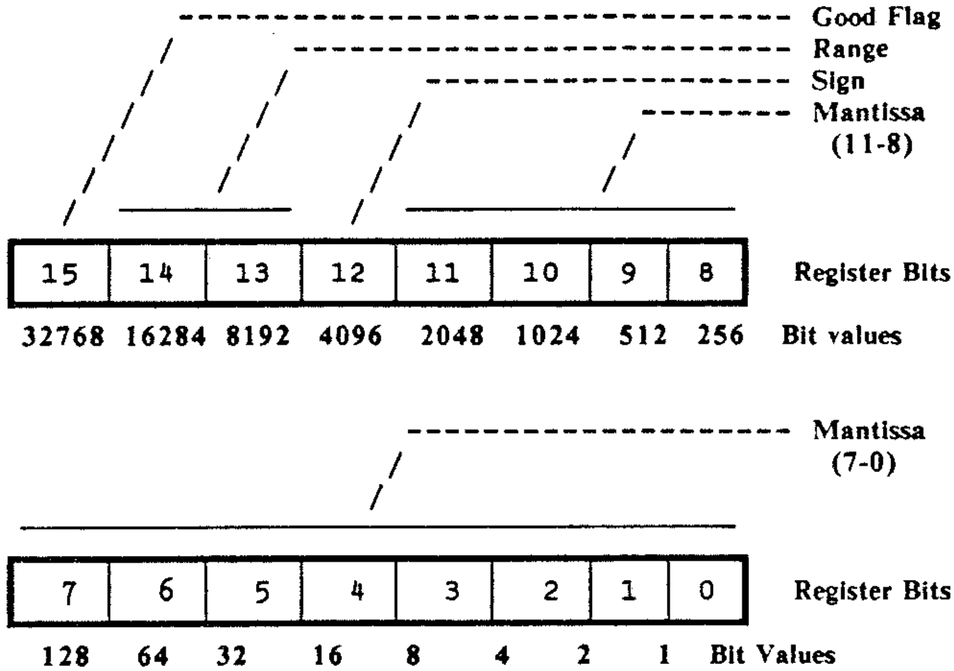


Figure 3-11. Measurement Data Format

The most significant bit (bit 15) indicates whether the reading is valid or not. A high (logic 1) bit indicates a good or valid reading. If the bit is returned low (logic 0), then the measurement is invalid. The most likely cause for invalid measurements is saturated input amplifiers caused by a common mode voltage greater than 10.5 volts or too large of a voltage applied to the voltmeter input for the given range.

Bits 14 and 13 indicate the voltmeter's measurement range. These two bits can be decoded as shown in Table 3-11.

Table 3-11. Measurement Range Bits

Bit 14	Bit 13	Range
0	0	+/- 40 mV
0	1	+/- 320 mV
1	0	+/- 2.56 V
1	1	+/- 10.24 V

Bit 12 of the measurement data word indicates the sign of the measurement. A low (logic 0) indicates a positive voltage. A high (logic 1) indicates a negative voltage.

The mantissa, the lower 12 bits of the word, represent the absolute value or magnitude of the measurement. This value is skewed by a factor of 4095. To obtain the actual measurement value, do a Binary AND operation with the returned measurement data and 4095.

Example 11 demonstrates how to read a measurement value over the GPIO interface and decode it for the actual reading.

Example 11. Decoding Measurement Data

This program, written exclusively for the HP series 200 desktop computers with BASIC 3.0, shows how to decode one word of measurement data. Of course, the program must be run for each measurement made by the High-Speed Voltmeter. The voltmeter is configured over the HP-IB interface , through the HP 3852A mainframe as usual. The measurement data is returned to the system controller over the GPIO interface (interface select code 12).

```
10 OUTPUT 709; "USE 600; CONF DCV; TERM EXT" ! CONFIGURE FOR DC VOLT
20 OUTPUT 709; "RDGS GPIO; AZERO ONCE; TRIG SGL"   ! READING DEST. I
30 CONTROL 12,2;5
40 OUTPUT 12 USING "#,W";4
50 CONTROL 12,2;4
60 ENTER 12 USING "#,W"; Reading
70 Good_flag = BIT (Reading,15)
80 Sign = BIT (Reading,12)
90 Range = BINAND (Reading,24576) DIV 8192
100 Value = BINAND (Reading, 4095)
110 IF Good_flag THEN Volts =Value/102400.0
120 IF Sign THEN Volts = -Volts
130 SELECT Range
140 CASE 0
150   Volts = Volts
160 CASE 1
170   Volts = 8 * Volts
180 CASE 2
190   Volts = 64 * Volts
200 CASE 3
210   Volts = 256 * Volts
220 END SELECT
230 PRINT
240 PRINT Volts
250 END
```

If you want to look at the binary representation of the measurement data, add the following lines.

```
63 FOR I = 15 TO 0 STEP -1
64 PRINT BIT (Reading,I);
65 NEXT I
```

Reading the Identity Register

The HP 3852A mainframe determines the identity of the accessory in each mainframe or extender slot. The Identity Register on the High-Speed Voltmeter provides this information to the mainframe controller. The High-Speed Voltmeter has been assigned an identity code of 08 (Hex). The presence of the High-Speed Voltmeter Extended Memory Card (provides a total of 64k reading storage memory) is indicated in the Card Option bit (bit 0). This register may be accessed at any time; however, the GPIO handshake may be delayed up to 750µS immediately after reset.

Figure 3-12 shows the bit format of the Identity Register.

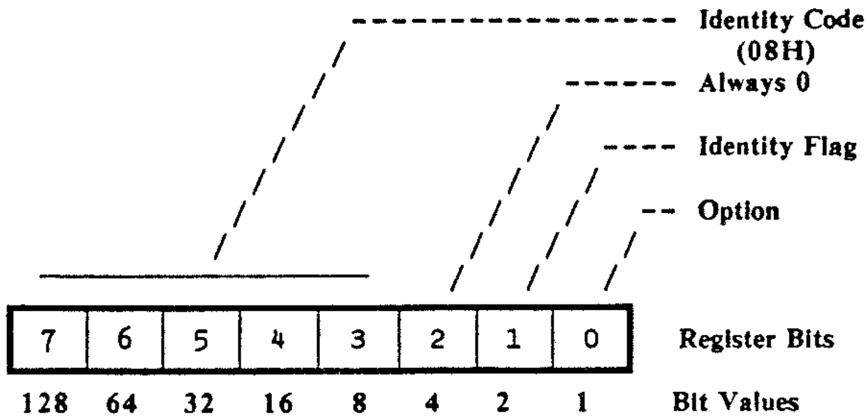


Figure 3-12. Identity Register

The Identity Flag (bit 1) is set with the Control Register as you desire. It has no effect or meaning other than what you ascribe to it.

The Option Bit (Bit 0) is encoded as shown in Table 3-12.

Table 3-12. Option Bit Encoding

Option Bit	Meaning
0	8K Reading Storage Memory
1	64K Reading Storage Memory

The following programs show how to read this register.

```
10 OUTPUT 709; "SREAD 600,0"
20 ENTER 709; A
30 PRINT A
40 END
```

or:

```
10 CONTROL 12,2;5
20 OUTPUT 12 USING "#,W";0
30 CONTROL 12,2;4
40 ENTER 12 USING "#,W";A
```

```
50 PRINT A
60 END
```

Reading the Status Register

The Status Register provides the HP 3852A mainframe or the GPIO controller information on what the High-Speed Voltmeter is doing and what it has done. This register may be accessed at any time; however, the handshake may be delayed for up to 750 µS immediately after reset.

Figure 3-13 shows the bit format of the Status Register.

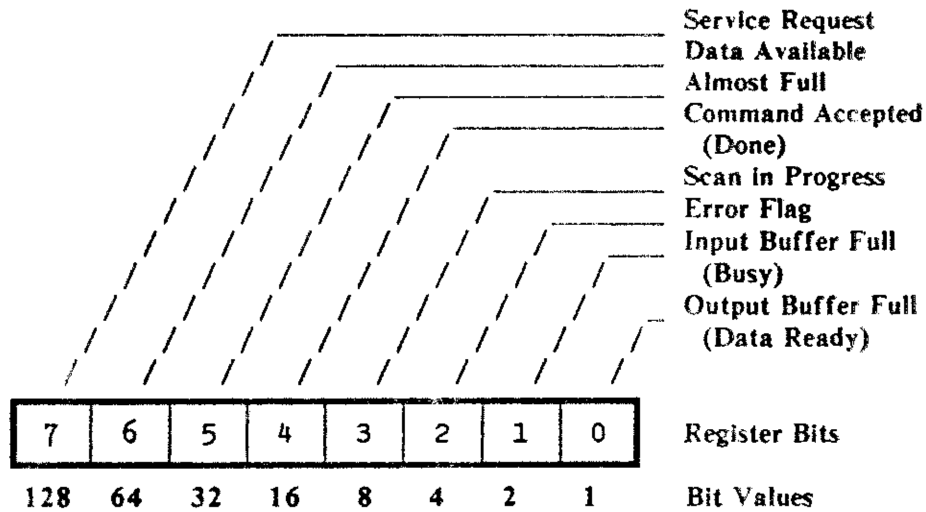


Figure 3-13. Status Register

Bit 0 The Output Buffer Full Flag (Bit 0) indicates that the voltmeter's microprocessor has acquired the requested data and placed it into the Data Buffer Register. Therefore, it is ready to be acquired by neither the GPIO controller or the HP 3852A mainframe. Once the data has been read, the bit is cleared. Data may be read from the Data Buffer Register at any time except the first 750 µS after reset, regardless of the state of Bit 0 in the Status Register. However, attempting to read data from the Data Buffer Register when this flag is not set may result in data to be read more than once, skipped data, or erroneous data to be received.

Bit 1 Similarly, the Input Buffer Full Flag (Bit 1) indicates that the High-Speed Voltmeter is not prepared to receive data. Any attempt to send data to the High-Speed Voltmeter while the voltmeter is busy (Bit 1 is high, logic 1) may cause lost data, multiple reads or erroneous data.

Bit 2 The Error Flag (Bit 2) indicates that an error has been detected since the reception of the last command. The Error Flag is cleared by sending a new command.

Bit 3 The Scan-in-Progress Flag indicates that the High-Speed Voltmeter is still taking measurements according to previous instructions. Any command received during this time that reconfigures the High Speed Voltmeter in such a way that might affect the ongoing scan will be rejected. Requests for certain data and status information will also be rejected while the scan is in progress.

Bit 4 The Command Accepted Flag (Bit 4) indicates that the voltmeter's microprocessor has received and checked a command and any associated parameters. It has also performed as much of the requested task as possible upon receipt of the command and parameters. This means that commands that expect data to be returned will see the Command Accepted Flag go true (logic High, 1) after the first datum to be returned is placed in the Data Register. Other commands will be completely finished when the Command Accepted Flag goes true.

When the Command Accepted Flag does become true, the Error Flag is valid, having been set according to the partial check done so far. If an error has not been detected, the microprocessor is ready to carry out the command, which may include returned data. The Command Accepted Flag returns to a false state when the microprocessor notices a new command in the Command Register. This occurs before the Command Register is read by the microprocessor and therefore the Input Buffer Full flag returns to false.

Bit 5 When the voltmeter is set to the Burst Mode (see the RDGSMODE command), the occurrence of the Data Available Flag and/or its associated interrupt normally indicates that the reading storage memory is almost full. The Almost Full Flag is set when the reading storage memory contains room for only 4096 (or less) more readings.

Bit 6 The Data Available Flag (Bit 6) indicates that measurement data is available in reading storage memory.

Bit 7 The Service Request (Bit 7) indicates interrupt status and can also be used to indicate available data. This feature is enabled by the control register. However, it can and should be used for other situations where service is needed.

Example 12. Reading the Status Register

The following program reads the High-Speed Voltmeter's Status Register and decodes the results. The GPIO interface select code is 12.

```
10 CONTROL 12,2;5
20 OUTPUT 12 USING "#,W";1
30 CONTROL 12,2;4
40 ENTER 12 USING "#,W";Status
50 PRINT "   STATUS REGISTER"
60 PRINT "--------------------"
70 PRINT "SERVICE REQUEST   =";BIT(Status,7)
80 PRINT "DATA AVAILABLE    =";BIT(Status,6)
90 PRINT "ALMOST FULL       =";BIT(Status,5)
100 PRINT "COMMAND ACCEPTED  =";BIT(Status,4)
110 PRINT "SCAN IN PROGRESS  =";BIT(Status,3)
```

```
120 PRINT "ERROR FLAG        =";BIT(Status,2)
130 PRINT "INPUT BUFFER FULL =";BIT(Status,1)
140 PRINT "OUTPUT BUFFER FULL=";BIT(Status,0)
150 END
```

Writing to the Registers

Just as there are two methods for reading from the internal registers, so there are two methods for writing data to certain registers. The first method writes data to the register through the HP 3852A mainframe over the HP-IB interface. The command for doing this is SWRITE. It has the form:

SWRITE ***slot, register address, register value***

Again, the *slot* parameter indicates the mainframe or extender slot where the High-Speed Voltmeter is installed. The *Register Address* is defined in Table 3-10. *Register value* is the numeric value that you are setting the register to.

The following example shows how to send data to a register.

```
OUTPUT 709; "SWRITE 600,Reg_address,Reg_value"
```

The second method of writing a value to a register is over the GPIO interface. Just as when reading from a register, writing to a register involves a four-step process. First, set the GPIO interface Control Line to low. This tells the voltmeter that the next piece of data is a Register Address. Next, send the register address. Third, set the GPIO interface Control Line high again for data. Finally, send the value for the register. The following example demonstrates these four steps:

```
10 CONTROL 12,2;5                      ! SET CONTROL LINE LOW
20 OUTPUT 12 USING ",W"; Reg_address   ! SEND REG ADDRESS
30 CONTROL 12,2;4                      ! SET CONTROL LINE HIGH
40 OUTPUT 12 USING "#,W"; Reg_value    ! SEND REGISTER VALUE
```

In this example, 12 is the system controller's GPIO interface select code.

Writing to the Control Register

The Control Register allows the HP 3852A mainframe or GPIO controller to override certain functions of the High-Speed Voltmeter. This register may be written to at any time but the handshake may be delayed for up to 750 µS after reset.

NOTE

Remember, these instructions are carried out immediately and unconditionally. They will disrupt anything the the High-Speed Voltmeter is doing.

Figure 3-14 shows the bit format of the Control Register.

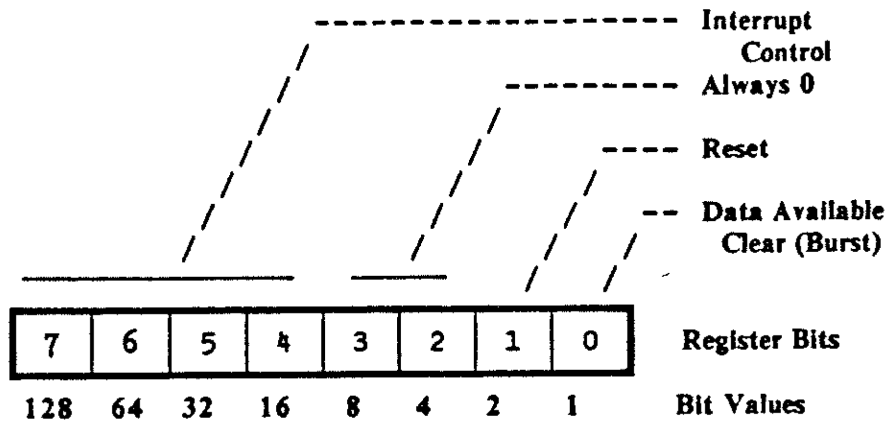


Figure 3-14. Control Register Format

Bit 0 In the Burst Mode, Data Available is indicated when the reading storage buffer almost becomes full (only 4096 readings left). Data Available normally remains true until the reading storage memory is totally emptied by reading the measurements out. However, the user may wish to read only a portion of the available data and then be notified when the reading storage memory again reaches the almost full mark. The most common example of this is where measurements are still being made and entering the reading storage memory while you are reading out earlier measurements. Thus it may require an unknown number of measurements to empty the reading storage memory.

Writing a "1" (logic high) to the Data Available Clear bit of the Control Register will clear Data Available unless the reading storage memory is already almost full. Of course, if the reading storage memory is already empty, Data Available will have been cleared. This bit has no effect if the voltmeter is not in the Burst Mode.

Bit 1 The Reset Bit (Bit 1) causes the High-Speed Voltmeter to unconditionally initialize itself to its power-on state. You cannot directly write to this bit. The GPIO controller should use its Peripheral Reset Line or the Reset command.

Bits 2 & 3 Bits 2 and 3 are always 0.

Bits 4-7 The Interrupt Control Field of the Control Register allows you to enable and disable portions of the interrupt system. This includes selectively enabling and disabling General Purpose (GP) and high speed scanning (HS) interrupts to the HP 3852A mainframe or GPIO controller. It also allows you to direct the DataAvailable indication and Service Request to the General Purpose Interrupt of the HP 3852A mainframe. Data Available is the only allowable cause of a high speed scanning (SCANMODE ON) interrupt.

The Interrupt Control Field consists of a four-bit code encoded as shown in

Table 3-13.

Table 3-13. Interrupt Control Field Encoding

Code (Bit 7-Bit 4)	Action
0000	No Action
0001	Reserved - DO NOT USE
0010	Clear Identity Flag (see Identity Register)
0011	Set Identity Flag (see Identity Register)
010X	Reserved - DO NOT USE
0110	Disable Data Available to GP of mainframe
0111	Enable Data Available to GP of mainframe
1000	Disable backplane GP interrupt
1001	Enable backplane GP interrupt
1010	Disable backplane HS interrupt
1011	Enable backplane HS interrupt
1100	Disable GPIO GP interrupt
1101	Enable GPIO GP interrupt
1110	Disable GPIO HS interrupt
1111	Enable GPIO HS interrupt

All of these features come up in the disabled state when the High Speed voltmeter powers-up or resets. The Identity Flag shows up in Bit 1 of the Identity Register. It has no other effect and can be used for any purpose you ascribe to it.

Setting and Reading the Identity Flag

The following example shows how to set the Identity Flag in the Identity Register and then read the Identity Register.

```
10 CONTROL 12,2;5
20 OUTPUT 12 USING "#,W";0
30 CONTROL 12,2;4
40 OUTPUT 12 USING "#,W";48
50 CONTROL 12,2;5
60 OUTPUT 12 USING "#,W";0
70 CONTROL 12,2;4
80 ENTER 12 USING "#,W";A
90 PRINT A
100 END
```

Writing to the Trigger Register

The Trigger Register allows the HP 3852A mainframe or GPIO controller to generate triggers. It may be written at any time except the first 750 µS immediately after reset. Refer to the section on triggers for more information.

The bit format for the Trigger Register is shown in Figure 3-15.

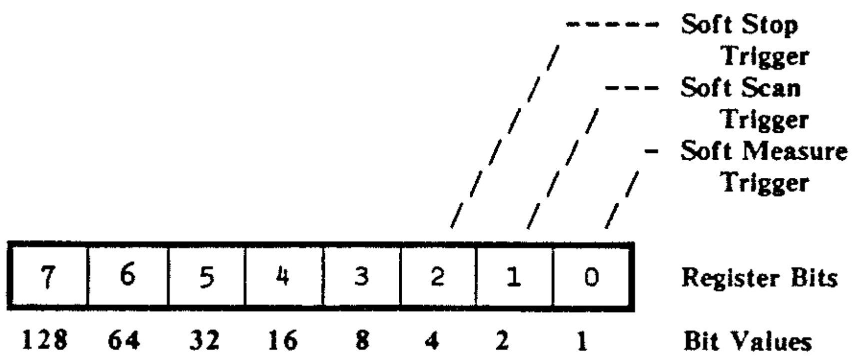


Figure 3-15. Trigger Register

Remember that this register generates the specified triggers.

To generate a Soft Scan Trigger, execute the following sequence:

```
10 CONTROL 12,2;5
20 OUTPUT 12 USING "#,W"
30 CONTROL 12,2;4
40 OUTPUT 12 USING "#,W"; 2
50 END
```

High-Speed Date Transfer

Many times it is just as important to transfer the readings to the system controller just as quickly as the measurements can be taken. The program examples in this final section demonstrate how to do just that. These four programs were written specifically for the HP 200 series desktop computers with HP 3.0 Basic. No attempt was made to optimize these programs for general purpose use. Instead, they were designed to demonstrate the fundamentals of high speed data transfer.

Example 14. General Purpose High-Speed Data Transfer

This program shows the general sequence of events required to transfer data from the High-Speed Voltmeter to the system controller over the GPIO interface. The program assumes that the voltmeter can store all the readings within its reading storage memory. That is, if the voltmeter has an 8K reading storage memory (HP 44702A), fewer than 8192 readings will be taken. If the voltmeter has a 64K reading storage memory, fewer than 64K readings will be taken.

All the readings will be transferred to the system controller and then stored on a mass storage disc. The readings will then be re-transferred back to the system controller and converted to normal reading format.

```
10 OPTION BASE 1
20 DIM A(8000)
30 MASS STORAGE IS ":CS80,700,0,0"
40 CREATE BDAT "Data_file",500
50 ASSIGN @Path_1 TO "Data_file"
60 OUTPUT 709; "USE 600; SCANMODE ON; SCTRIG HOLD"
70 OUTPUT 709; "FUNC DCV; ASCAN ON; TERM RIBBON"
80 OUTPUT 709; "RDGS GPIO; NRDGS 40; PRESCAN 5; POSTSCAN 5"
90 OUTPUT 709; "CLWRITE SENSE 500-519; AZERO ONCE; SCTRIG SGL"
100 CONTROL 12,2;5
110 OUTPUT 12 USING "#,W";4
120 CONTROL 12,2;4
130 ENTER 12 USING "#,W";A(*)
140 ASSIGN @Path_1 TO *
150 !
160 !
170 ASSIGN @Path_2 TO "Data_file:CS80,700,0,0"
180 ENTER @Path_2;A(*)
190 ASSIGN @Path_2 TO *
200 FOR J=1 TO 8000
210 Good_flag = BIT(A(J),15)
220 Sign = BIT(A(J),12)
230 Range = BINAND(A(J),24576) DIV 8192
240 Value = BINAND(A(J),4095)
250 IF Good_flag THEN Volts= Value/102400.0
260 IF Sign THEN Volts = -Volts
270 SELECT Range
280   CASE 0
290   Volts = Volts
300   CASE 1
310   Volts = 8*Volts
320   CASE 2
330   Volts = 64*Volts
340   CASE 3
350   Volts = 256*Volts
360 END SELECT
370 PRINT Volts
380 NEXT J
390 END
```

Example 15. Faster Data Transfer

This program illustrates a faster method of transferring data from the voltmeter to the system controller. Again, this program assumes that the voltmeter can store all the readings taken. The program stores the data on a mass storage disc and then transfers them back to the system controller for conversion. The data conversion routine is not repeated in this example; refer to Example 14, lines 200 through 380.

NOTE

The remaining programs in this chapter require an HP 98620B Two-channel DMA card to be installed in the system computer.

```
10 OPTION BASE 1
20 INTEGER A(8000) BUFFER
30 MASS STORAGE IS ":CS80,700,0,0"
40 CREATE BDAT "Data_file"
50 ASSIGN @Path_1 TO "Data_file", 500
60 ASSIGN @Buffer_1 TO 12;WORD
70 ASSIGN @Buffer_2 TO BUFFER A(*);WORD
80 OUTPUT 709; "USE 600; SCANMODE ON; SCTRIG HOLD"
90 OUTPUT 709;"FUNC DCV; ASCAN ON; TERM RIBBON"
100 OUTPUT 709;"RDGS GPIO; NRDGS 40; PRESCAN 5; POSTSCAN 5"
110 OUTPUT 709;"CLWRITE SENSE 500-519; AZERO ONCE; SCTRIG SGL"
120 CONTROL 12,2;5
130 OUTPUT 12 USING"#,W";4
140 CONTROL 12,2;4
150 TRANSFER @Buffer_1 to @Buffer_2
160 TRANSFER @Buffer_2 TO @Path_1
170 ASSIGN @Path_1 to *
180 !
190 !
200 ASSIGN @Path_2 to "Data_file:CS80,700,0,0"
210 TRANSFER @Path_2 to @Buffer_2
220 ASSIGN @Path_2 TO *
230 !
240 ! ADD READING CONVERSION FROM EXAMPLE 14, LINES 200-380
```

Example 16. Data Transfer on Interrupt

This third program shows how the voltmeter can interrupt the system controller when the reading storage memory is almost full. Once the interrupt occurs, the system controller transfers the readings from the voltmeter to the mass storage disc. The readings are re-transferred to the system controller for conversion. As with the previous two programs, this program assumes that the voltmeter can store all of the readings in its reading storage memory.

```
10 OPTION BASE 1
20 INTEGER A(8000) BUFFER
30 MASS STORAGE IS ":CS80,700,0,0"
40 CREATE BDAT "Data_file",500
50 ASSIGN @Path_1 to "Data_file"
60 ASSIGN Buffer_1 TO 12; WORD
70 ASSIGN @Buffer_2 TO BUFFER A(*); WORD
80 OUTPUT 709; "USE 600; SCANMODE ON; SCTRIG HOLD"
90 OUTPUT 709;"FUNC DCV; ASCAN ON; TERM RIBBON; RDGSMODE BURST"
100 OUTPUT 709;"RDGS GPIO; ENABLE INTR; NRDGS 40"
110 OUTPUT 709; "PRESCAN 5; POSTSCAN 5"
120 OUTPUT 709;"CLWRITE SENSE 500-519; AZERO ONCE"
130 CONTROL 12,2;5
140 OUTPUT 12 USING"#,W";4
```

```
150 CONTROL 12,2;4
160 ON INTR 12 GOTO Intr_trap
170 ENABLE INTR 12;1
180 OUTPUT 709; "SCTRIG SGL"
190 Loop:   STATUS 12,5;Gpio_state
200         IF BIT(Gpio_state,2)=1 THEN Intr_trap
210         GOTO Loop
220 Intr_trap:  OFF INTR 12
230 TRANSFER @Buffer-1 TO @Buffer_2
240 TRANSFER @Buffer_2 TO @Path_1
250 ASSIGN @Path_1 TO *
260 !
270 !
280 ASSIGN @Path_2 to "Data_file:CS80,700,0,0"
290 TRANSFER @Path_2 to @Buffer_2
300 ASSIGN @Path_2 TO *
310 !
320 ! ADD READING CONVERSION FROM EXAMPLE 14, LINES 200-380
```

Example 17. Multiple Data Transfers

The previous three examples assumed that the voltmeter could store all the readings in its reading storage memory. But what if you need to make more readings than the reading storage memory can hold. For example, what if your voltmeter has the 8K reading storage memory (HP 44702A) but you need to make 32,000 readings? This program example shows how the interrupt capability is used to transfer more readings than the reading storage memory can hold to the system controller.

```
10 OPTION BASE 1
20 INTEGER A(32000) BUFFER
30 MASS STORAGE IS ":CS80,700,0,0"
40 CREATE BDAT"Data_file",500
50 ASSIGN @Path_1 to "Data_file"
60 ASSIGN Buffer_1 TO 12; WORD
70 ASSIGN @Buffer_2 TO BUFFER A(*); WORD
80 OUTPUT 709;"USE 600; SCANMODE ON; SCTRIG HOLD"
90 OUTPUT 709;"FUNC DCV; ASCAN ON; TERM RIBBON; RDGSMODE BURST"
100 OUTPUT 709;"RDGS GPIO; ENABLE INTR; NRDGS 50"
110 OUTPUT 709; "PRESCAN 10; POSTSCAN 10"
120 OUTPUT 709;"CLWRITE SENSE 500-519; AZERO ONCE"
130 CONTROL 12,2;5
140 OUTPUT 12 USING"#,W";4
150 CONTROL 12,2;4
160 ON EOT @Path_1 GOTO 240
170 ON INTR 12 GOTO Intr_trap
180 ENABLE INTR 12;1
190 OUTPUT 709; "SCTRIG SGL"
200 Loop: STATUS 12,5;Gpio_state
210     IF BIT(Gpio_state,2)=1 THEN Intr_trap
220     GOTO Loop
230 Intr_trap: ! INTERRUPT VALID
240 TRANSFER @Buffer-1 TO @Buffer_2
250 TRANSFER @Buffer_2 TO @Path_1
260 ASSIGN @Path_1 TO *
```

```
270!
280!
290 ASSIGN @Path_2 to"Data_file:CS80,700,0,0"
300 TRANSFER @Path_2 to @Buffer_2
310 ASSIGN @Path_2 TO *
320!
330! ADD READING CONVERSION FROM EXAMPLE 14, LINES 200-380
```

Command Summary

This section summarizes all applicable commands for the HP 44702A/B. It is composed of two subsections: Low-Level Commands, and High Level Commands. For an in-depth discussion of each command and its parameters, refer to the Command Reference Manual.

Low-Level Commands

A low-level command performs only simple operations such as changing the range, enabling autozero, or transferring readings.

ARMODE Selects when autoranging will occur; either before or after the Measure Trigger is received. (System or Scanner Mode)

ASCAN Selects the Autoscan function. ASCAN OFF requires a separate Scant Trigger for each pass through the scan list. ASCAN ON requires only a initial Scan Trigger for the first pass through the scan list, subsequent passes start automatically. (Scanner Mode only)

AZERO Controls the autozero function. (System or Scanner Mode)

CHREAD Transfers one reading from the specified voltmeter channel to the HP-IB output buffer/display, or to reading memory. (System or Scanner Mode)

CLWRITE Stores the channel and range lists to be scanned when the proper triggers are received. (Scanner Mode only and TERM RIBBON)

DELAY Sets the Trigger delay and Sample Period (time between triggers) for the voltmeter. (System Mode only)

DISABLE INTR Prevents the voltmeter from generating an interrupt when a reading becomes available. (Scanner or System Mode)

ENABLE INTR Enables the voltmeter to generate an interrupt when a reading becomes available.(System or Scanner Mode)

FUNC Selects the voltmeter's measurement function(DCV, OHMF etc.) and the measurement range. (System or Scanner Mode)

ID? Queries the specified slot for the accessory number installed in that slot. The High-Speed Voltmeter should return either "44702A" or "44702B". (System or Scanner Mode)

INTR? Returns the last channel number to cause an interrupt. If no channel has caused an interrupt, -1 (minus 1) is returned.

NRDGS Sets the number of readings made per trigger in the System Mode. Sets the number of readings per channel in the Scanner Mode. (Scanner or System Mode)

PERC Sets the trigger threshold to the specified percentage of the voltmeter range when used in a threshold trigger mode. (Scanner or System Mode)

POSTSCAN Selects the number of complete scans the voltmeter will make after the Stop Trigger is received. (Scanner Mode only)

PRESCAN Selects the number of complete scans through the scan list before the Stop Trigger is acknowledged. (Scanner Mode only)

RANGE Allows you to select the voltmeter's measurement range or the autorange mode. (System or Scanner Mode)

RDGS Determines whether measurement data and interrupts will be sent to the HP 3852 mainframe or the GPIO interface. (Scanner or System Mode)

RDGSMODE Determines when an interrupt will be generated for readings left in the voltmeter's reading storage memory and whether or not new readings will overwrite old readings when stored. (Scanner or System Mode)

RESET Resets the voltmeter to its power-on state. (System or Scanner Mode)

SCANMODE Selects the voltmeter mode; either Scanner Mode or System Mode. In the System Mode, the voltmeter may be used for single measurements or backplane scanning with the high level commands. In the Scanner Mode, the voltmeter has extra capabilities such a independent high speed scanning with the FET multiplexer accessories using the dedicated interface cable. (Scanner or System Mode)

SCDELAY Sets the Scan Trigger Delay and the time between successive Scan Triggers. (Scanner Mode only)

SCSLOPE Selects which edge (rising or falling) of the Scan Trigger input signal will trigger the voltmeter. (Scanner Mode only)

SCTRIG Selects the Scan Trigger source for the voltmeter. The Scan Trigger enables the Measure Trigger for all measurements in the scan list. (Scanner Mode only)

SLOPE Selects which edge (rising or falling) of the voltmeter trigger (System Mode) or Measure Trigger (Scanner Mode) will trigger the voltmeter. (Scanner or System Mode)

SPER Sets the Sample Period (time between start of successive scans) when TRIG INT is selected for the Scan Trigger. (Scanner Mode only)

SREAD Permits reading the status of an internal voltmeter register. (System or Scanner Mode)

STSLOPE Selects which edge (rising or falling) of the Stop Trigger input signal will trigger the voltmeter when using a threshold triggering mode. (Scanner Mode only)

STTRIG Selects the Stop trigger Source for the voltmeter. (Scanner Mode only)

SWRITE Permits writing to certain internal voltmeter registers. (Scanner or System Mode)

TERM Selects the voltmeter input terminals for making measurements. (Scanner or System Mode)

TEST Performs a nondestructive confirmation test of the voltmeter. A more in-depth test is performed when the voltmeter ie reset. (Scanner or System Mode)

TRIG Selects the voltmeter's trigger mode (System Mode) or the Measure Trigger source (Scanner Mode). (Scanner or System Mode)\MY="no";ME set TRIGOUT

TRIGOUT Determines if the voltmeter's rear panel BNC 0 connector will receive or output the Measure Trigger pulse. (System or Scanner Mode)

TRG Selects the trigger source when using the system trigger (TRIG SYS).

USE Since more than one voltmeter can be installed in the mainframe or an extender, the USE command designates which voltmeter will receive the subsequent command(s).

USE? Returns the present USE channel address.

XRDGS Transfers one or more readings from a voltmeter channel. (System or Scanner Mode)

High-Level Commands

The high-level commands perform a series of operations and, when scanning, provide additional measurement functions. These additional measurement functions are 2-wire ohms, 4-wire ohms with automatic Source channel designation, and automatic temperature measurements from RTDs, thermistors, and thermocouples.

CONF Configures the voltmeter to the specified measurement function (DCV, OHMF, etc.) and selects the default values for the other functions (autozero, range, etc.). (System or Scanner Mode)

CONFMEAS Configures the voltmeter to the specified measurement function (OHMF, DCV, etc.)and selects the default values for the other functions (autozero, range, etc.). This command also causes the specified multiplexer channel(s) to be scanned, measured, and the associated data conversions (ohms, temperature) to be performed on the results. The CONFMEAS command also scans and measures unspecified reference channels when making thermocouple temperature measurements. The CONFMEAS command is equivalent to the CONF command immediately followed by the MEAS command. (System or Scanner Mode)

MEAS Causes the specified multiplexer channels to be scanned and measured; and, if applicable, the associated data conversions (ohms, temperature) to be performed on the results. The MEAS command also scans and measures unspecified reference channels when making thermocouple temperature measurements.

If the function of the measurement device *is* compatible with the function specified in the MEAS command, the present state of the other functions (autozero, range etc.) are not changed. (To set these other functions to their default states, execute the CONF command prior to the MEAS command or use the CONFMEAS command.)

If the function of the measurement device *is* not compatible with the function specified in the MEAS command, the function is changed and autorange is selected.

If the trigger mode of the measurement device is previously set to HOLD or INT, executing the MEAS command changes the trigger mode to SCAN. If the trigger mode is previously set to SYS, it is not changed by the MEAS command. (System or Scanner Mode)

MONMEAS Selects the voltmeter measurement function (OHMF, DCV, etc.) and selects the default values for the other functions (autozero, range etc.). The MONMEAS command also steps to the first multiplexer channel in the list, repeatedly makes measurements, and sends the results to the display only (in RASC format). Pressing the SADV KEY advances to the next channel in the list. (System or Scanner Mode)

Chapter 4
HP 44705A
20-Channel Relay Mux

Contents

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HP 44705A 20-Channel Relay MUX

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HP 44705A

Introduction

This chapter shows how to configure and program the HP 44705A 20-Channel Relay Multiplexer (MUX) Accessory. The chapter has four sections: Introduction, Specifications, Configuring the 20-Channel Relay MUX, and Programming the 20-Channel Relay MUX.

- **Introduction** contains a chapter overview, a description of the relay MUX, a description of its functions, and shows suggested steps to get started.
- **Specifications** lists the specifications for the accessory.
- **Configuring the 20-Channel Relay MUX** contains a block diagram description of the accessory, shows how to hardware configure the terminal module, and shows how to connect field wiring to the terminal module.
- **Programming the 20-Channel Relay MUX** shows how to program the accessory for voltage, current, resistance, and temperature measurements.

Description

The relay MUX accessory is an analog signal multiplexer which is used to switch (multiplex) signals from up to 20 channels for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory provides switching capability for the 20 channels at scanning speeds up to 450 channels per second using an HP 3852A voltmeter accessory. This accessory can switch signals up to 170 VDC or 120 VAC rms (170V peak).

The relay MUX accessory consists of a 20-channel terminal module and a relay MUX component module. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Functions

The relay MUX accessory is used to switch signals for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory can be used to switch signals for four primary functions:

- Voltage Measurements.
- Current Measurements.
- Resistance Measurements.
- Temperature Measurements.

NOTE

Each channel on the relay MUX can be independently configured to allow multiple functions to be measured using the same accessory.

Voltage Measurements

The relay MUX can be used to switch signals for guarded (3-wire) DC voltage and AC voltage measurements. In the guarded voltage measurement function, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection. Use this function to make up to 20 voltage measurements per relay MUX accessory.

Current Measurements

The relay MUX can be used to switch signals for DC and AC current measurements using current sensing. Current sensing is a method of determining current using a shunt resistor that you install on the terminal module. Use this function to make up to 20 current measurements per relay MUX accessory.

Resistance Measurements

The relay MUX can be used to switch signals for 2-wire and 4-wire resistance (or ohms) measurements. The primary difference between the two types of resistance measurements is the accuracy. In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per relay MUX accessory.

The use of the 4-wire ohms measurement virtually eliminates the error caused by the test lead resistances. The current through the unknown resistance is the same regardless of the lead resistance but the voltmeter measures only the voltage across the resistance, not across the combined test lead and resistance. The 4-wire ohms function is essential when the highest accuracy is required. Since each 4-wire ohms measurement requires two channels, up to 10 resistance measurements can be made per relay MUX accessory.

Temperature Measurements

The relay MUX can be used to switch signals for temperature measurements using resistance temperature detectors (RTDs) and thermistors. RTDs are typically more stable and accurate than thermistors. Thermistors are more sensitive to temperature changes than RTDs. Because of the low resistance values of RTDs and thermistors, the most accurate method of measurement is the 4-wire ohms function. The 2-wire ohms function can be used in temperature applications where accuracy is not so important, such as when checking the integrity of your transducers.

Use the temperature measurement function to make up to twenty 2-wire measurements or ten 4-wire measurements (each 4-wire measurement requires two channels) per relay MUX accessory.

The HP 3852A resistance-to-temperature conversions support the following RTDs and thermistors:

RTDs supported:

$\alpha = 0.00385\ \Omega/\Omega°C$ (100Ω at 0°C)
$\alpha = 0.003916\ \Omega/\Omega°C$ (100Ω at 0°C)

Thermistors supported:

2252Ω at 25°C
5 kΩ at 25°C
10 kΩ at 25°C

NOTE

Other transducers can be measured using the relay MUX but only those listed above are supported by the HP 3852A conversions.

Getting Started

To use the relay MUX accessory for your application, you will need to follow three steps:

- Define your application.
- Configure the accessory for your application.
- Program the accessory for your application.

Define your Application

The first step is to define your application and determine if the accessory can meet the requirements of your application. The relay MUX can switch DC or AC inputs up to 170 VDC or 120 VAC rms (170V peak). Since each of the 20 channels can be independently configured, up to 20 different devices can be connected to the accessory. When selecting devices to be connected, refer to Table 4-1 "20-Channel Relay MUX Specifications" to ensure that the voltage and current requirements of your application are within the specifications for this accessory.

Configure the Accessory

The next step is to configure the accessory for your application. Refer to "Configuring the 20-Channel Relay MUX" for information on hardware configuration (setting jumpers and switches) and connecting field wiring to the terminal module for voltage, current, resistance, and temperature measurements.

Program the Accessory

The third step is to program the relay MUX for your application. Refer to "Programming the 20-Channel Relay MUX" to program the accessory for voltage, current, resistance and temperature measurements.

Specifications

Table 4-1 lists the specifications for the relay MUX. This table contains four categories: Input Characteristics, Operating Characteristics, RTD Characteristics, and Thermistor Characteristics.

WARNING

The HP 3852A and the HP 3853A internal analog buses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against possible personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the HP 3852A, HP 3853A, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum Allowable Peak Voltage
HP 3852A Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	350V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexer	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extenders, each instrument is considered as a separate circuit.

Table 4-1. 20-Channel Relay MUX Specifications

INPUT CHARACTERISTICS:

Maximum Input Voltage:
Between any two input terminals or to chassis:
170V peak, 170 VDC, 120 VAC rms

Maximum Current: 50 mA per channel non-inductive

Injected Current: ±1 nA DC
(Injected currents are sourced by the accessory into HIGH and LOW; RH < 85% @ 28°C or < 60% @ 40°C.)

Maximum Power: 1 VA per channel

DC Offset:
HIGH and LOW Relays: ±1 uV Per Relay
To backplane including tree switches: ±2 uV Differential
Guard Relays (Not low-thermal): ±100 uV

Closed Channel Resistance:
In Series: 100Ω ±10% in HIGH, LOW, and GUARD Lines
Contacts Only: 1Ω per contact

OPERATING CHARACTERISTICS:

Maximum Scan Rate (channels per second):
Using HP 3852A Voltmeter Accessories: 450
Using External Voltmeter: 500

Relay Characteristic Lifetime: [1]

Voltage [2]	Number of Cycles
10V	$> 10^8$
40V	1.5×10^7
100V	10^7

[1] Characteristic lifetime of a single relay on the HP 44705A in the mainframe with one HP 44701A Integrating Voltmeter.

[2] Total peak voltage between one scanned channel and the next or from a scanned channel to 0V (whichever is greater).

Synchronization: Break-Before-Make in scanning operation

Table 4-1. 20-Channel Relay MUX Specifications (cont'd)

RTD CHARACTERISTICS:

RTD Types Supported:

Type: Platinum, $\alpha = 0.00385\ \Omega/\Omega°C$
100Ω at $0°C$

Type: Platinum, $\alpha = 0.003916\ \Omega/\Omega°C$,
100Ω at $0°C$

THERMISTOR CHARACTERISTICS:

Thermistor Types Supported:

Type: 2252Ω at $25°C$

Type: $5\ k\Omega$ at $25°C$

Type: $10\ k\Omega$ at $25°C$

Configuring the 20-Channel Relay MUX

This section shows how to configure the relay MUX accessory. It contains a block diagram description of the accessory, information on hardware configuring the terminal module, and information on connecting field wiring to the terminal module.

Refer to "Programming the 20-Channel Relay MUX" to program the accessory for voltage, current, resistance, and temperature measurements.

WARNING

1 *SHOCK HAZARD. Only qualified, service-trained personnel who are aware of the hazards involved should install, remove, or configure any accessory. Before touching any installed accessory, turn off all power to the mainframe, extenders, and to all external devices connected to the mainframe, extenders, or accessories.*

WARNING

2 *POSSIBLE OPERATOR INJURY. Under most conditions of failure, the relays on the relay MUX will remain in whatever state your program has set them. However, for some equipment failures, the relays may not remain in their programmed state. If the relays settle in the closed state, the relay contacts may weld together and the highest voltage present on any one channel may be present on all channels. This condition may cause operator injury if the terminals are touched or equipment damage may result.*

For example, see Figure 4-1 which shows the block diagram for the relay MUX. If Channel 0 is at 100 volts and a failure occurs which causes the relay contacts to weld together, the 100 volts may be present on all 20 channels of the accessory.

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers attached.

Block Diagram Description

The relay MUX accessory consists of a 20-channel terminal module and relay MUX component module as shown in Figure 4-1. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Figure 4-1. 20-Channel Relay MUX Block Diagram

The component module is made up of 24 switches which are divided into two categories: bank switches and tree switches. Each of the 24 switches consists of three reed-actuated relays, one each for HIGH, LOW, and GUARD lines. There are a total of 20 bank switches which are divided into two groups of 10 channels each: BANK A and BANK B. The channels in BANK A are numbered 0 through 9 and the channels in BANK B are numbered 10 through 19.

NOTE

Only one channel per bank can be closed at a time. Closing a second channel in a bank will open any previously closed channel in that bank.

The component module contains four tree switches which are of two types: Source Bus tree switches and Sense Bus tree switches. Each of the two banks has one Source Bus tree switch and one Sense Bus tree switch. The tree switches control signal flow to and from the HP 3852A backplane and also isolate the bank switches from the backplane when they are not in use. The Sense Bus tree switches provide the connections to the backplane for making voltage measurements. The Source Bus tree switches provide the current source connections (+I and -I) to the backplane for resistance measurements.

An Isolation Jumper on the component module allows you to disconnect the tree switches from the HP 3852A backplane for special signal routing applications. For more information on the Isolation Jumper, refer to "Setting the Isolation Jumper".

Table 4-2 shows the channel definitions for the relay MUX accessory. Channels 0 through 19 control the bank switches and Channels 91 through 94 control the tree switches.

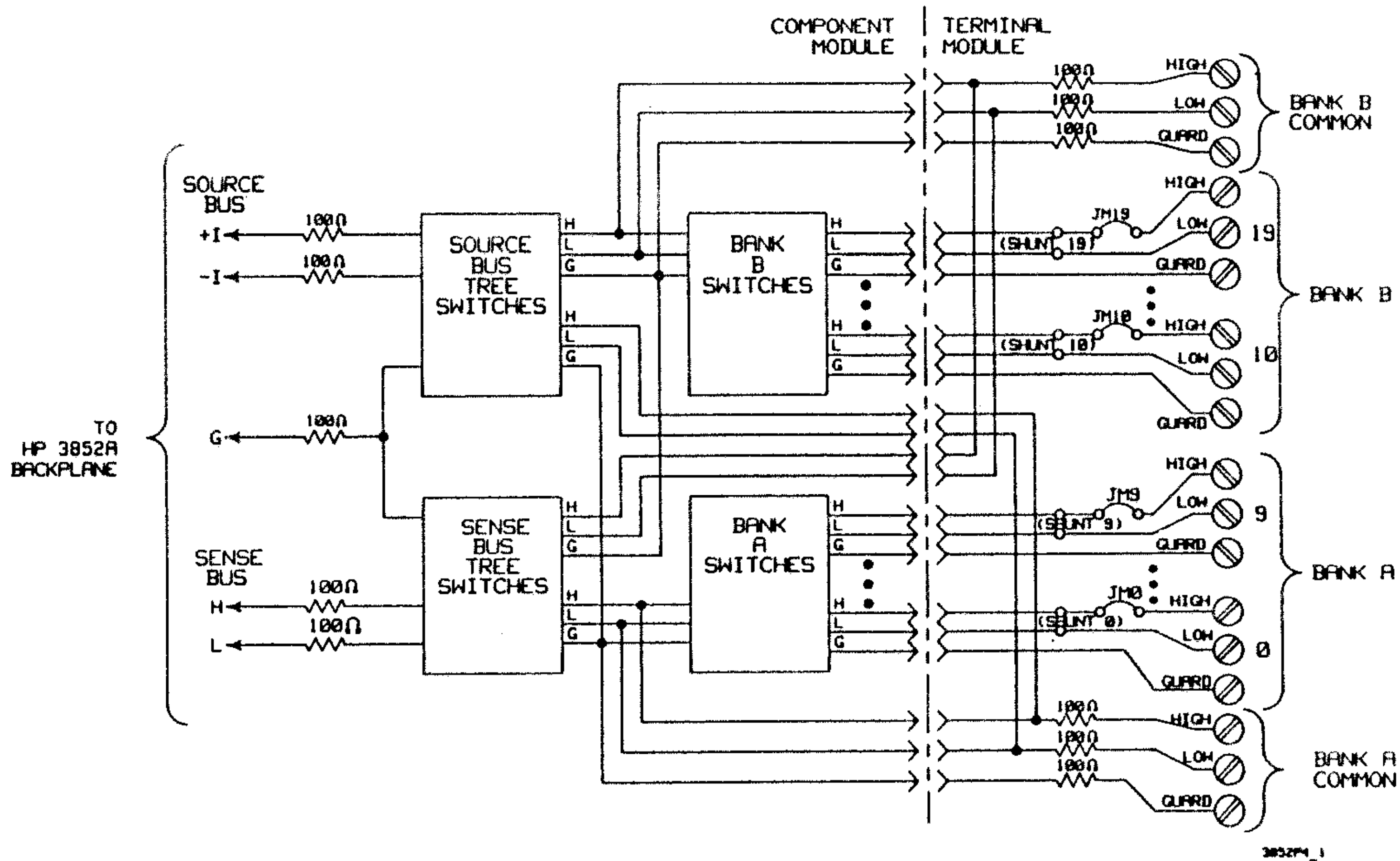


Figure 4-1. 20-Channel Relay MUX Block Diagram

Table 4-2. 20-Channel Relay MUX Channel Definitions

Channel	Definitions
0 - 9	BANK A switches
10 - 19	BANK B switches
91	Sense Bus Tree Switch (BANK A)
92	Sense Bus Tree Switch (BANK B)
93	Source Bus Tree Switch (BANK A)
94	Source Bus Tree Switch (BANK B)

NOTE

Two tree switches of the same type cannot be closed simultaneously (e.g., only one of the two Sense Bus tree switches can be closed at a time). Closing a second tree switch will open any previously closed tree switch of the same type.

The BANK A COMMON and BANK B COMMON terminals on the terminal module can be used to connect an external voltmeter or for diagnostic procedures. As factory configured, there are three 100Ω current limiting resistors in series with the BANK A COMMON terminal and three 100Ω current limiting resistors in series with the BANK B COMMON terminal.

Five 100Ω resistors on the component module connect the tree switches to the HP 3852A backplane. These resistors provide current limiting protection for the relays on the component module. The resistors do not affect resistance measurements (2-wire ohms error due to contact and trace resistance <2Ω). The resistors can be shorted out, but this will seriously shorten relay life if high voltages or currents are switched.

⚠ 1 Configuring the Terminal Module

This section explains how to hardware configure the terminal module. It shows how to set the Isolation Jumper and how to install low pass filters and attenuators on the terminal module for input signal conditioning.

Setting the Isolation Jumper

The tree switches on the relay MUX can be connected or disconnected from the HP 3852A backplane using the Isolation Jumper. Figure 4-2 shows the location of the Isolation Jumper (J1) on the component module. Note that the jumper has an EN (enable) position and a DIS (disable) position. For normal operation, the Isolation Jumper should be in the enable position to connect the tree switches to the HP 3852A backplane. For special applications that require tree switch isolation from the backplane, you can move the Isolation Jumper to the disable position.

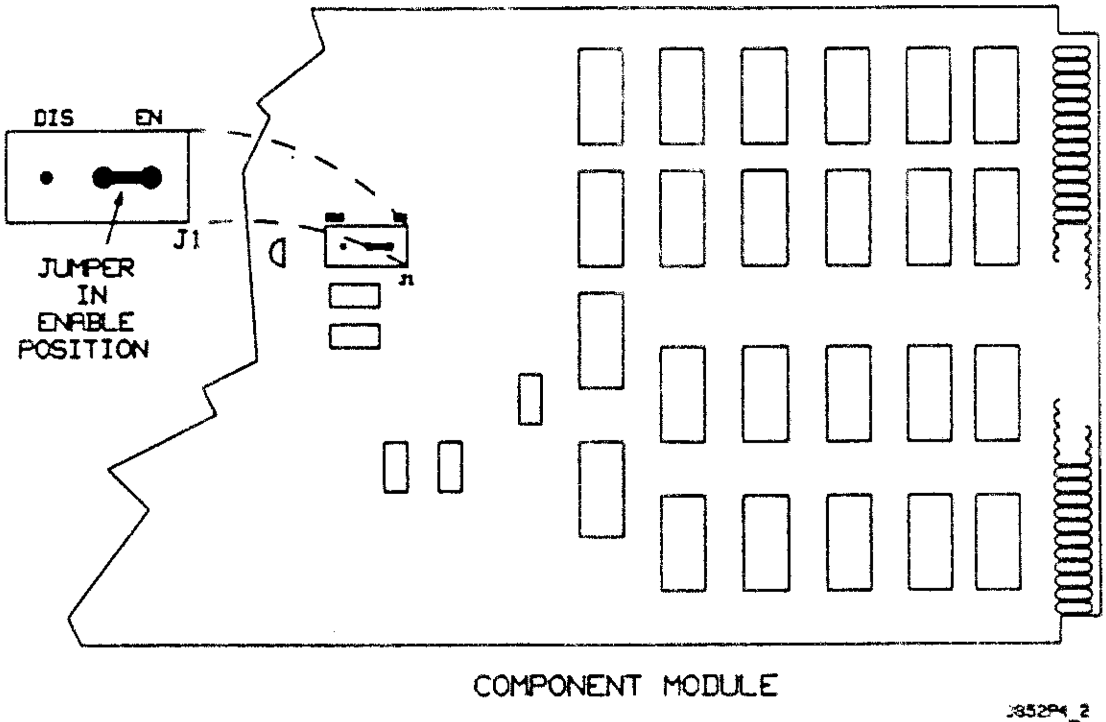


Figure 4-2. Setting the Isolation Jumper

NOTE

As factory configured, the Isolation Jumper is in the EN (enable) position.

Figure 4-2. Setting the Isolation Jumper

Installing Low Pass Filters

Space has been provided on the terminal module for you to install one-pole low pass filters for input signal conditioning on each channel. Figure 4-3 shows the normal channel configuration and the low pass filter channel configuration.

Figure 4-3. Low Pass Filter Channel Configuration

Figure 4-4 shows how to install a low pass filter on Channel 10 of the terminal module. To install the low pass filter, remove the jumper (SERIES JM 10) and install your resistor in its place. Install your capacitor in the SHUNT 10 position as shown. Precision components should be used to maintain accuracy.

Figure 4-4. Installing Low Pass Filters

Installing Attenuators

The space for low pass filters on the terminal module can also be used to install attenuators to reduce input signals to a usable level for the relay MUX. Figure 4-5 shows the normal channel configuration and how the channels are configured to attenuate input signals.

Figure 4-5. Attenuator Channel Configuration

Figure 4-6 shows how to install an attenuator on Channel 0 of the terminal module. To install the attenuator, remove the jumper (SERIES JM 0) and install resistor R1 in its place. Install resistor R2 in the SHUNT 0 position as shown. Precision components should be used to maintain accuracy.

Figure 4-6. Installing Attenuators

Connecting Field Wiring

The next step is to connect field wiring from your application to the appropriate terminals on the terminal module. The following section contains examples that show how to connect field wiring to the terminal module for voltage, current, resistance, and temperature measurements.

Figure 4-7 shows the terminal module with the cover removed. Each of the 20 channels has a HIGH, LOW, and GUARD terminal. Terminals 0 through 9 in BANK A are for Channels 0 through 9, respectively. Terminals 0 through 9 in BANK B are for Channels 10 through 19, respectively.

Figure 4-7. 20-Channel Relay MUX Terminal Module

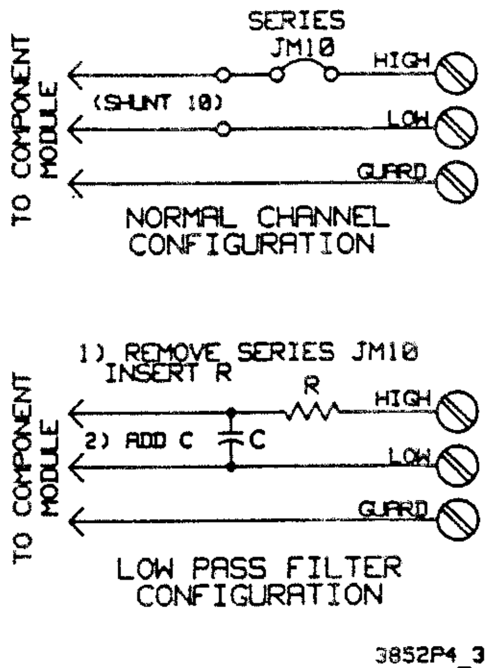


Figure 4-3. Low Pass Filter Channel Configuration

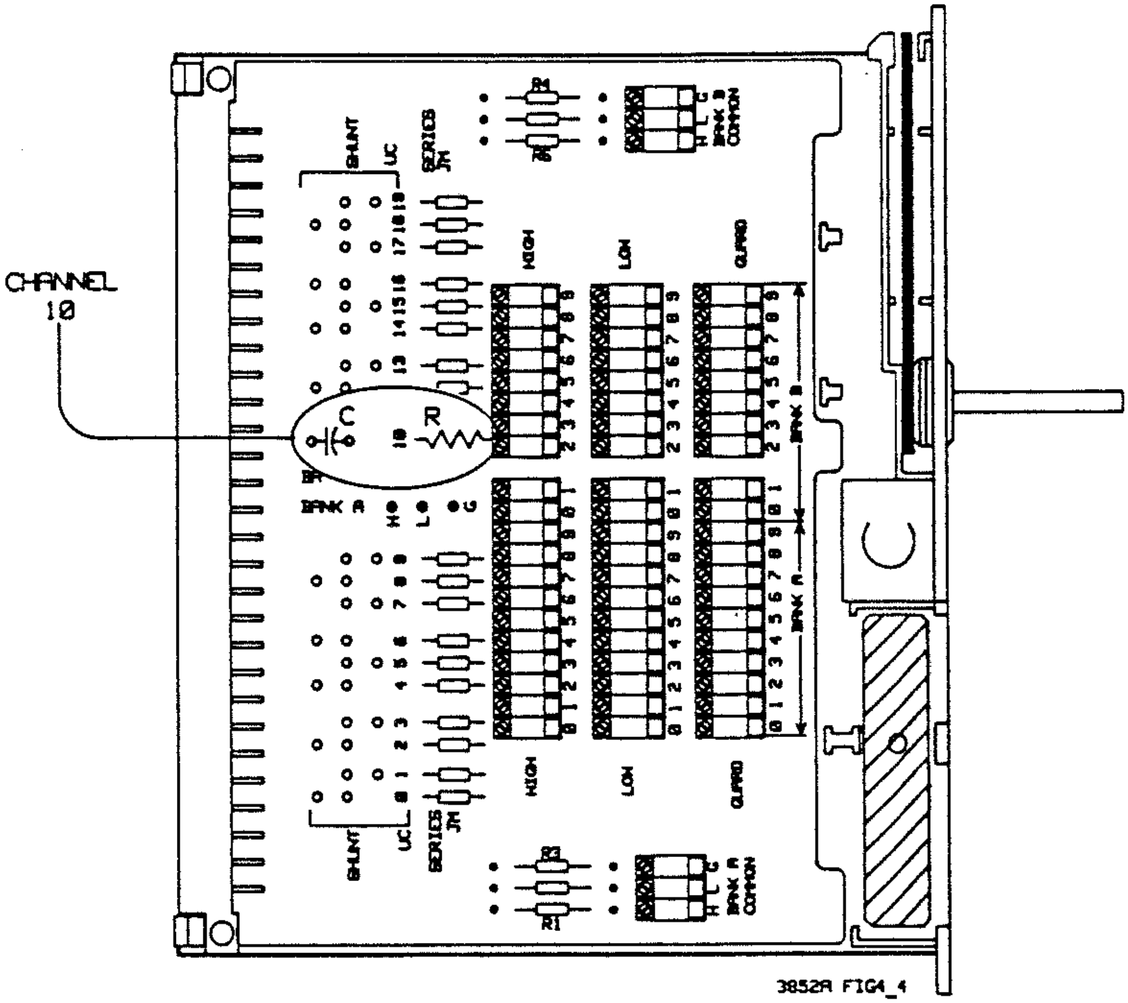


Figure 4-4. Installing Low Pass Filters

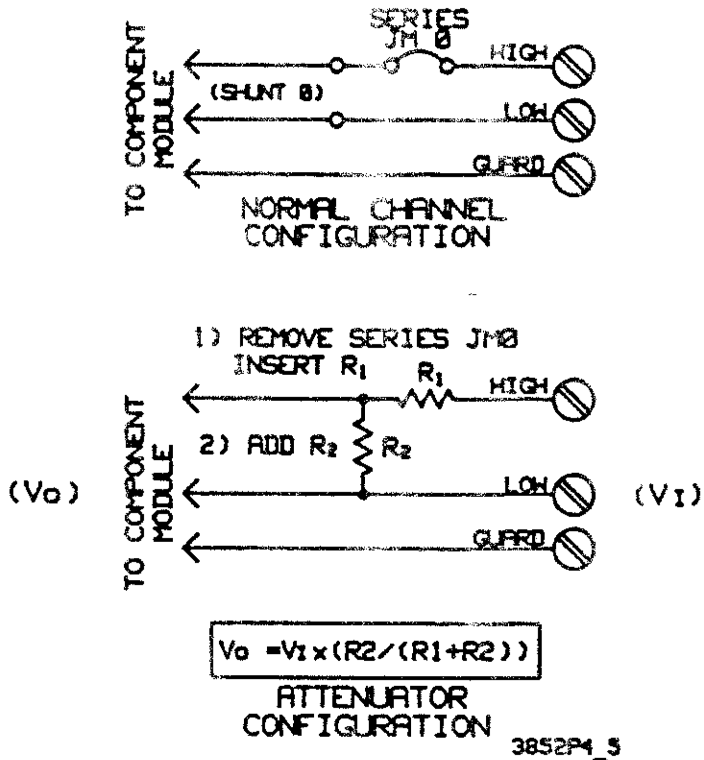


Figure 4-5. Attenuator Channel Configuration

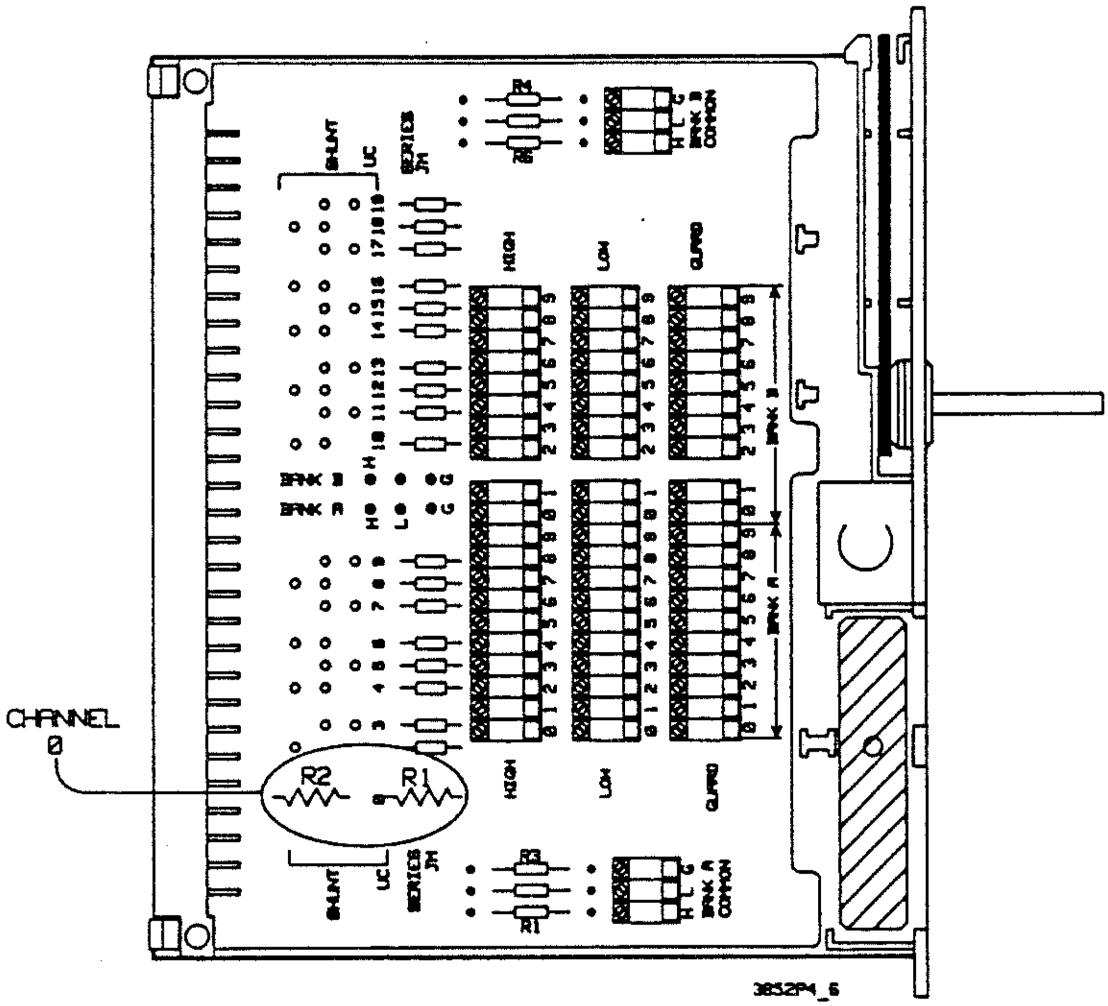


Figure 4-6. Installing Attenuators

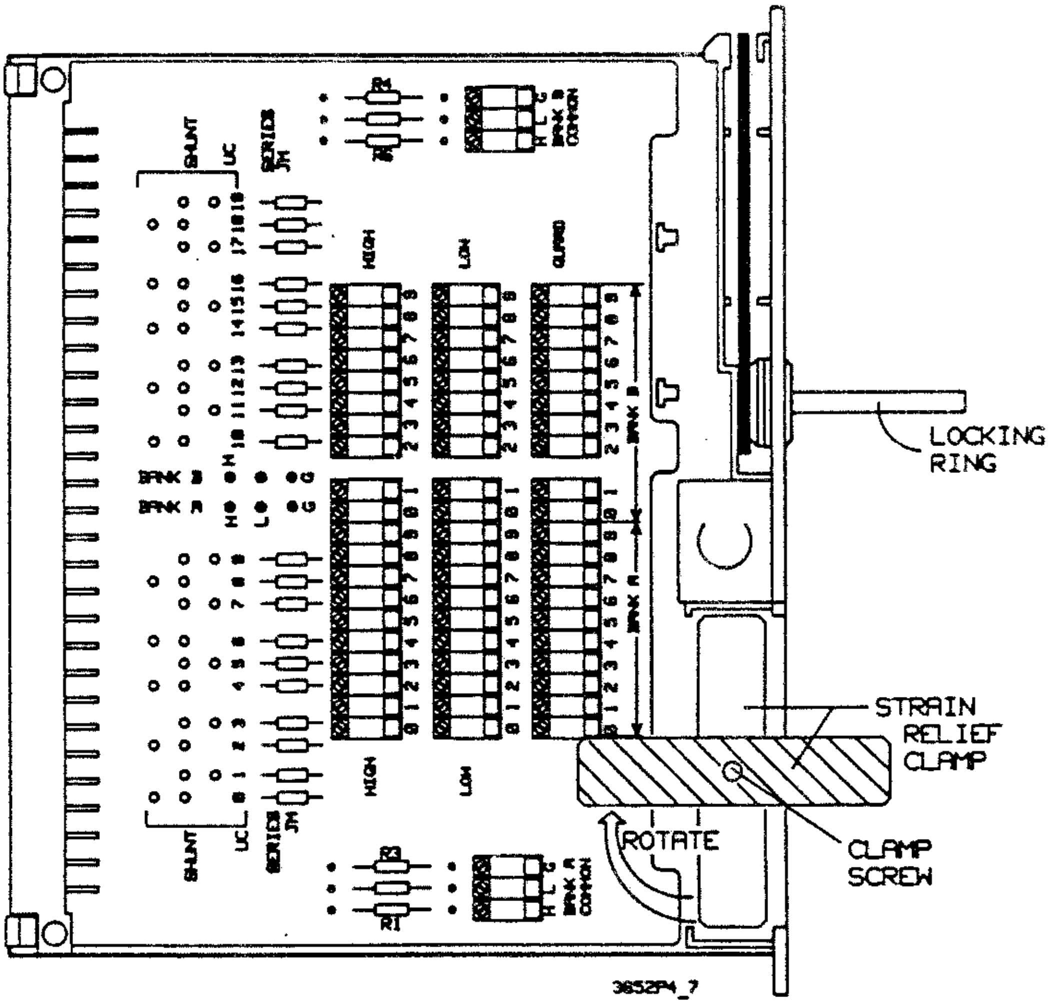


Figure 4-7. 20-Channel Relay MUX Terminal Module

When connecting field wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make it easier to route the wiring.

NOTE

When connecting components such as resistors, RTDs, or thermistors, the lead length may be too short to route through the strain relief clamp. In this case, the components will have to be stored inside the terminal module. When connecting these components, make sure that no leads are shorted together and bend the leads to allow the terminal module cover to be replaced.

Connections for Voltage Measurements

In the guarded (3-wire) voltage measurement function, the relay MUX accessory can switch signals for up to 20 DC or AC voltage measurements. When making guarded voltage measurements, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX is 170 VDC or 120 VAC rms (170V peak). Refer to Table 4-1 for the specifications.

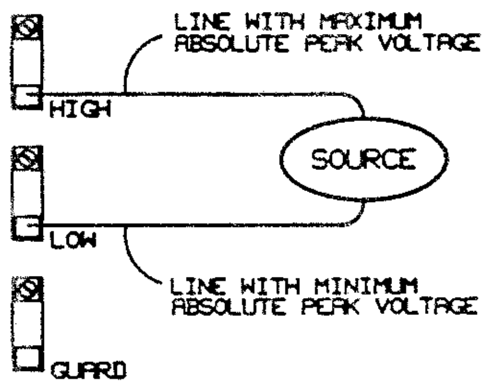
CAUTION

POSSIBLE EQUIPMENT DAMAGE. When making high-voltage measurements using the relay MUX, the HP 3852A analog backplane becomes charged to the voltage on the last channel connected to it. The next channel that you close may have to absorb all of the stored energy on the backplane.

If the backplane is not discharged after making a high-voltage measurement, the voltage present on the backplane must be added to the voltage being switched on the next channel to determine the total relay contact voltage. To maximize relay life and prevent damage to sensitive transducers by high backplane discharge voltages, see Figure 4-8.

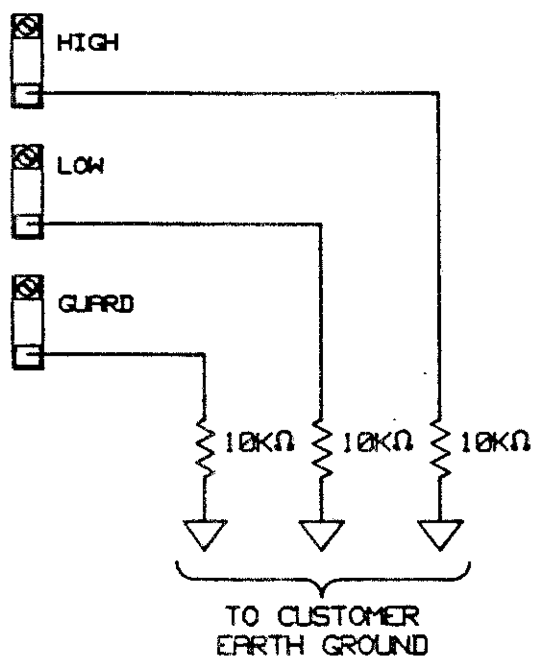
Figure 4-8. Discharging the HP 3852A Backplane

- When measuring high-voltages, connect the line which has the highest maximum absolute peak voltage of the source to the HIGH terminal on the terminal module. Connect the line which has the lowest absolute peak voltage of the source to the LOW terminal on the terminal module. Connect the guard line ONLY if high common mode noise rejection is necessary, otherwise, do not connect the guard line.



OR

- Discharge the HP 3852A analog backplane to earth ground through 10 kΩ resistors connected to HIGH, LOW, and GUARD on an unused channel.



3852P4_8

Figure 4-8. Discharging the HP 3852A Backplane

Example: Connecting Voltage Sources to the Terminal Module

A voltage source (V0) is connected to Channel 0 on the terminal module as shown in Figure 4-9. Connect the high (+) lead from the voltage source to the HIGH terminal. Connect the low (-) lead from the voltage source to the LOW terminal. If a guarded (3-wire) voltage measurement is being made, connect the shield from the shielded twisted pair to the GUARD terminal. The shielded twisted pair is used to reduce electrical noise in the measurement.

Figure 4-9. Connecting Voltage Sources to the Terminal Module

Connections for Current Measurements

The relay MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across a shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. The relay MUX can be used to switch signals for up to 20 DC or AC current measurements. When making current measurements, HIGH, LOW, and GUARD are switched on each selected channel for maximum common mode noise rejection. Figure 4-10 shows the normal channel configuration and how channels are configured for current sensing measurements.

NOTE

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX is 170 VDC or 120 VAC rms (170V peak). Refer to Table 4-1 for the specifications.

Figure 4-10. Current Sensing Configuration

Example: Installing Shunt Resistors for Current Measurements

A 250Ω shunt resistor (R0) is installed in the shunt position (SHUNT 0) for Channel 0 on the terminal module as shown in Figure 4-11.

NOTE

The SERIES JM (jumper) must be in place on the terminal module for each channel being used for current measurements (see Figure 4-11).

Figure 4-11. Installing Shunt Resistors for Current Measurements

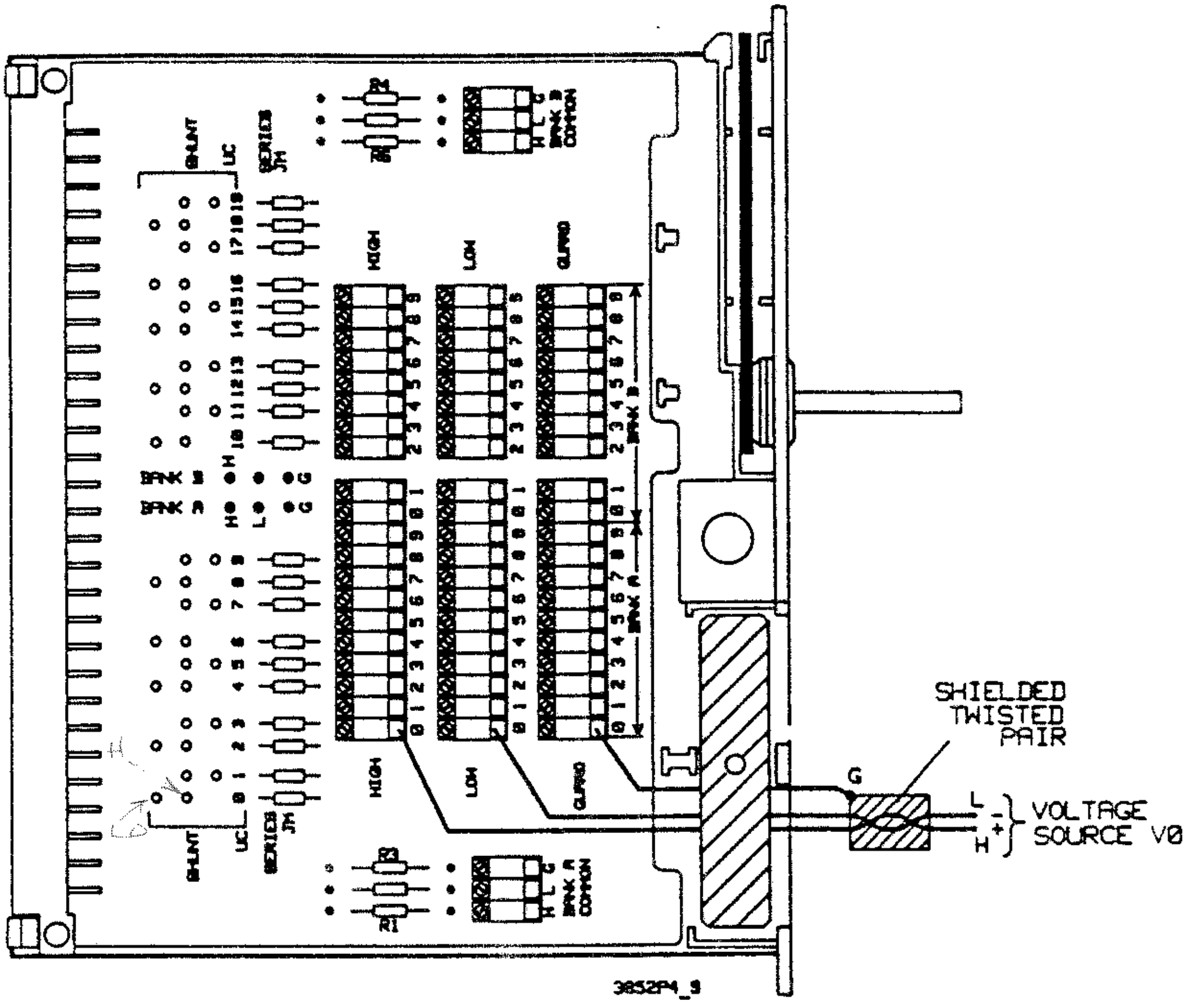


Figure 4-9. Connecting Voltage Sources to the Terminal Module

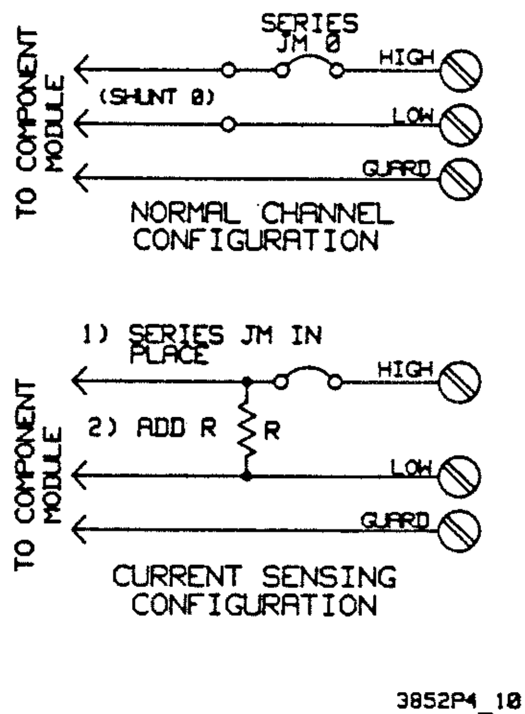


Figure 4-10. Current Sensing Configuration

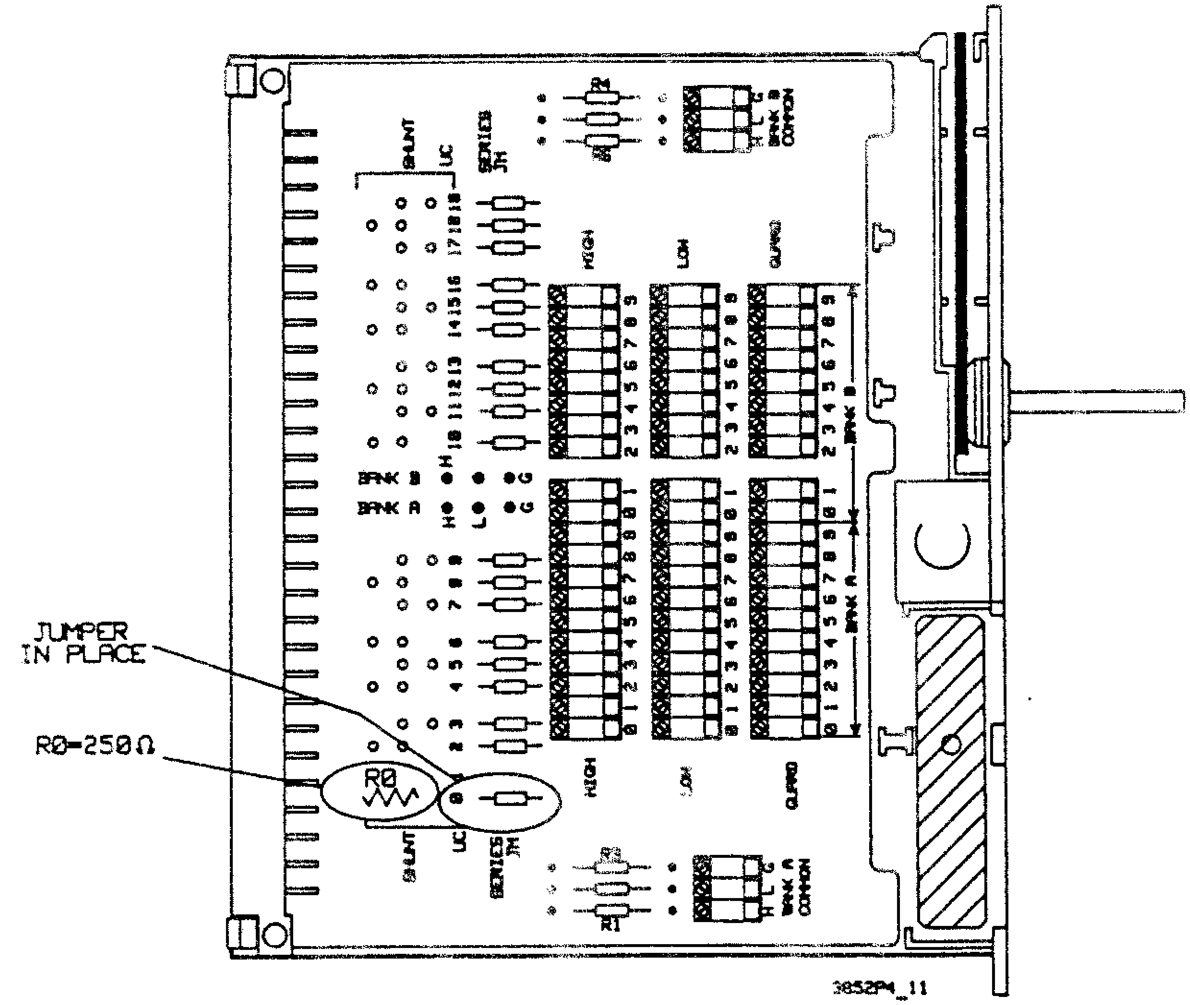


Figure 4-11. Installing Shunt Resistors for Current Measurements

Connections for Resistance Measurements

One of the functions of the relay MUX accessory is to switch signals for resistance measurements. This section contains a 2-wire ohms and a 4-wire ohms configuration example.

Example: Connecting Resistors for 2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to switch signals for up to 20 resistance measurements per relay MUX accessory.

A resistor (R0) is connected to Channel 0 on the terminal module as shown in Figure 4-12. Connect one lead of the resistor to the HIGH terminal. Connect the other lead of the resistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the resistor low lead to the GUARD terminal.

Figure 4-12. Connecting Resistors for 2-Wire Ohms Measurements

Example: Connecting Resistors for 4-Wire Ohms Measurements

The use of the 4-wire ohms measurement virtually eliminates the error caused by the test lead resistances. The current through the unknown resistance is the same regardless of the lead resistance but the voltmeter measures only the voltage across the resistance, not across the combined test lead and the resistance. The 4-wire ohms function is essential when the highest accuracy is required. Since each 4-wire ohms measurement requires two channels, up to 10 resistance measurements can be made per relay MUX accessory.

NOTE

Each 4-wire ohms measurement requires two channels, one from BANK A and one from BANK B. When connecting a resistor to the terminal module for a 4-wire ohms measurement, use two channels that are separated by one decade (i.e., Channels 0 and 10, Channels 1 and 11, etc.).

A resistor (R1) is connected to Channels 0 and 10 on the terminal module for a 4-wire ohms measurement as shown in Figure 4-13. Channel 0 is used as the voltage sense channel for the measurement and Channel 10 is used as the current source channel for the measurement.

Figure 4-13. Connecting Resistors for 4-Wire Ohms Measurements

To make the connections for Channel 0 (the Sense channel), connect one lead of the resistor to the HIGH terminal. Connect the other lead of the resistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the resistor low lead to the GUARD terminal.

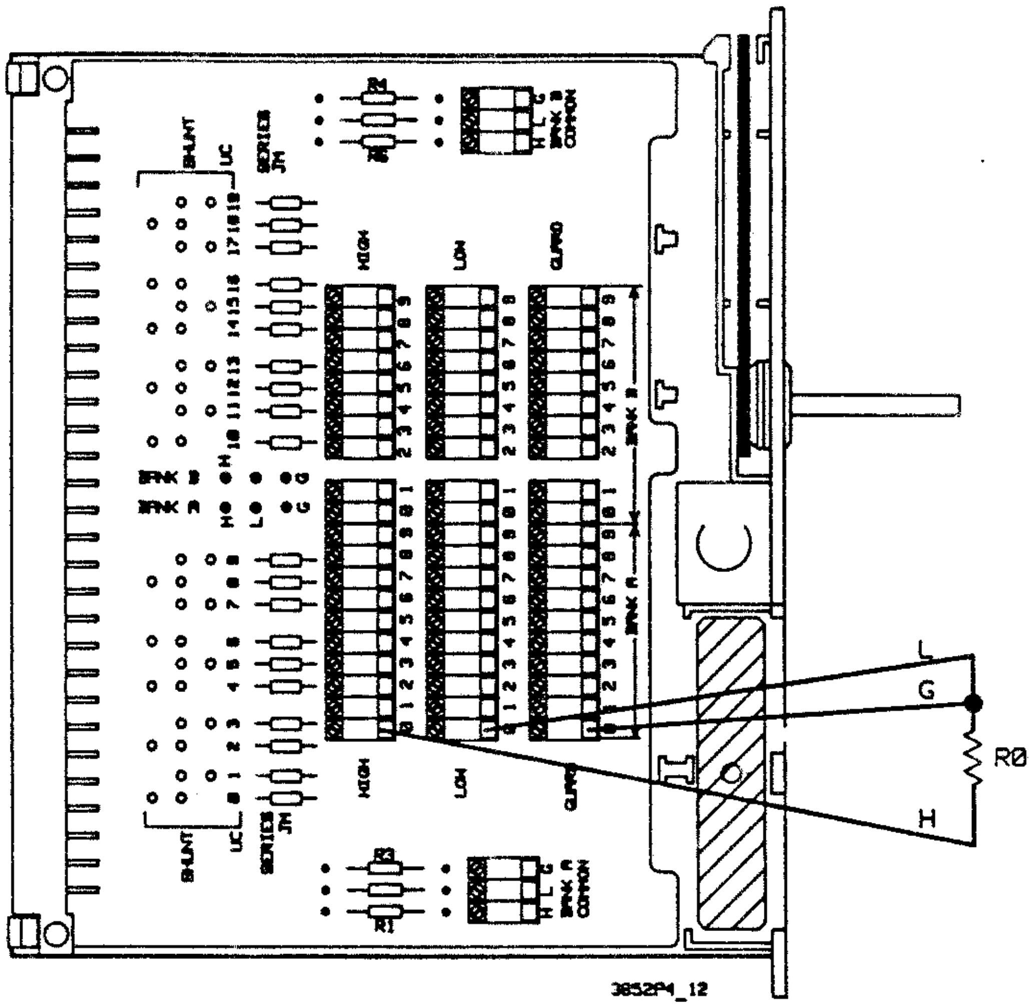


Figure 4-12. Connecting Resistors for 2-Wire Ohms Measurements

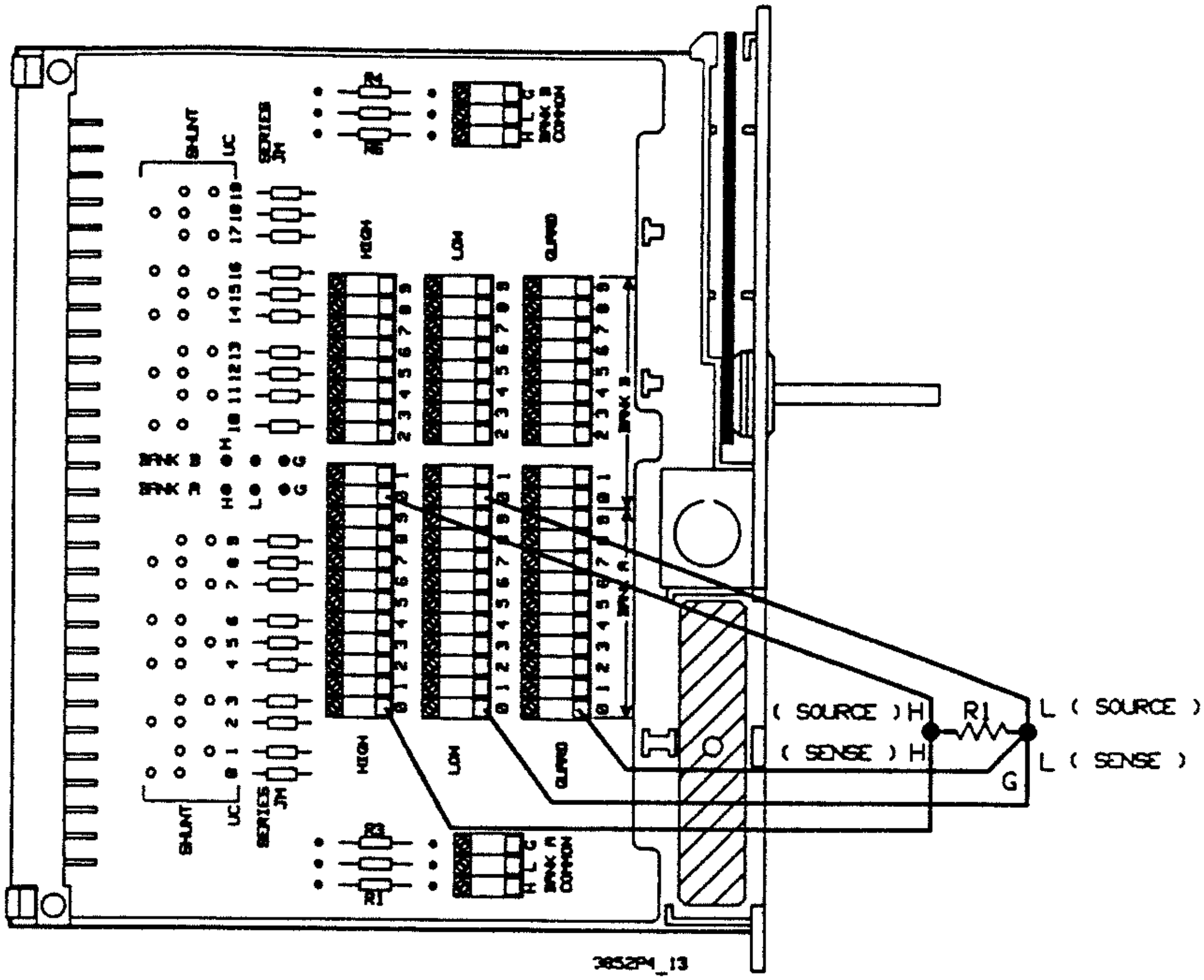


Figure 4-13. Connecting Resistors for 4-Wire Ohms Measurements

To connect the resistor to Channel 10 (the Source channel), repeat the above procedure using the HIGH and LOW terminals for Channel 10. Note that it is not necessary to connect the guard lead to both the sense channel and the source channel.

Connections for Temperature Measurements

One of the functions of the relay MUX accessory is to switch signals for temperature measurements. This section contains examples that show how to connect RTDs and thermistors to the terminal module.

Example: Connecting RTDs for 2-Wire Temperature Measurements

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ and resistance values of 100Ω at 0°C.

An RTD (RTD0) is connected to Channel 0 on the terminal module as shown in Figure 4-14. Connect one lead of the RTD to the HIGH terminal. Connect the other lead of the RTD to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the RTD low lead to the GUARD terminal.

Figure 4-14. Connecting RTDs for 2-Wire Temperature Measurements

Example: Connecting RTDs for 4-Wire Temperature Measurements

The HP 3852A also allows RTDs to be measured using the 4-wire ohms function. Since each measurement 4-wire ohms measurement requires two channels, up to 10 RTD measurements can be made per relay MUX accessory.

NOTE

Each 4-wire RTD measurement requires two channels, one from BANK A and one from BANK B. When connecting an RTD to the terminal module for a 4-wire measurement, use two channels that are separated by one decade (i.e., Channels 0 and 10, Channels 1 and 11, etc.).

An RTD (RTD1) is connected to Channels 0 and 10 for a 4-wire measurement as shown in Figure 4-15. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel for the measurement.

Figure 4-15. Connecting RTDs for 4-Wire Temperature Measurements

To make the connections to Channel 0 (the Sense channel), connect one lead of the RTD to the HIGH terminal. Connect the other lead of the RTD to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the RTD low lead to the GUARD terminal.

To connect the RTD to Channel 10 (the Source channel), repeat the above procedure using the HIGH and LOW terminals for Channel 10. Note that it is not necessary to connect the guard lead to both the sense channel and the source channel.

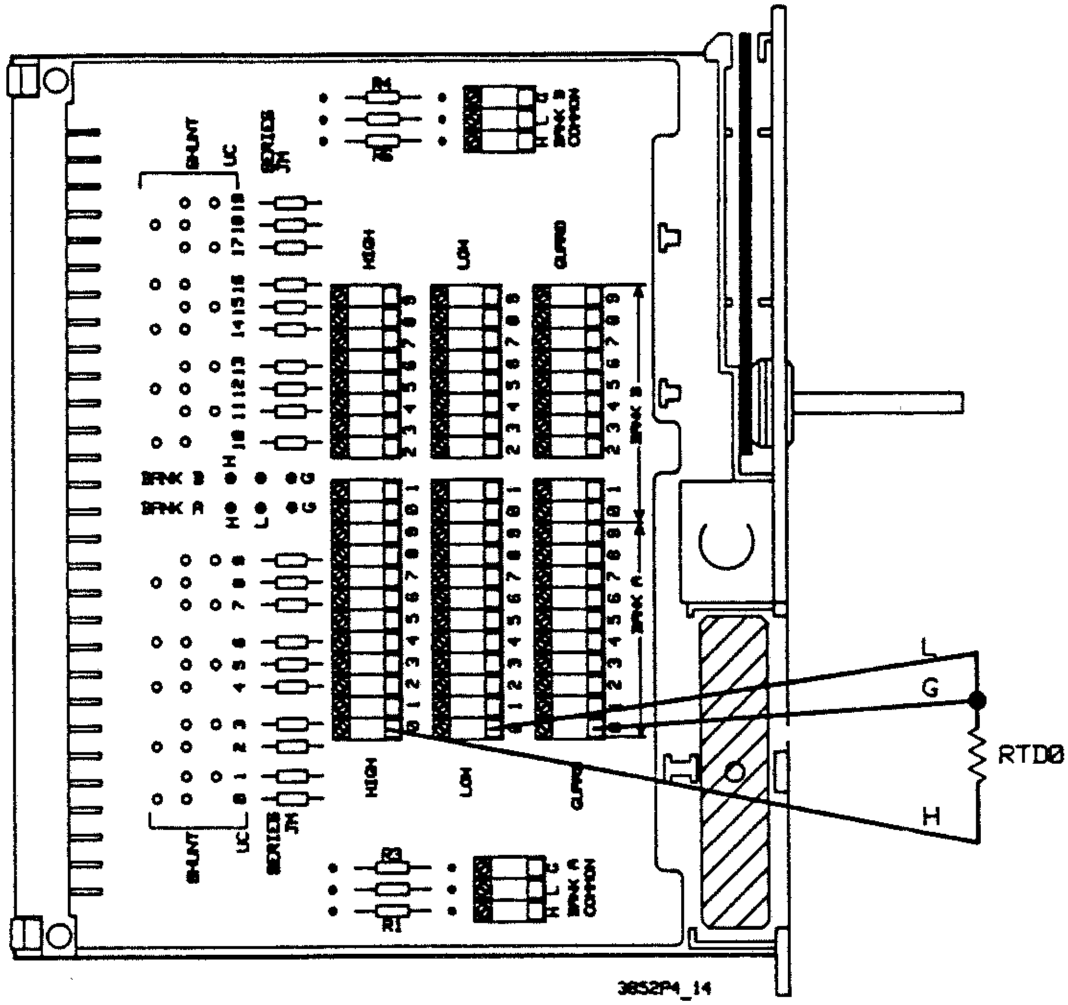


Figure 4-14. Connecting RTDs for 2-Wire Temperature Measurements

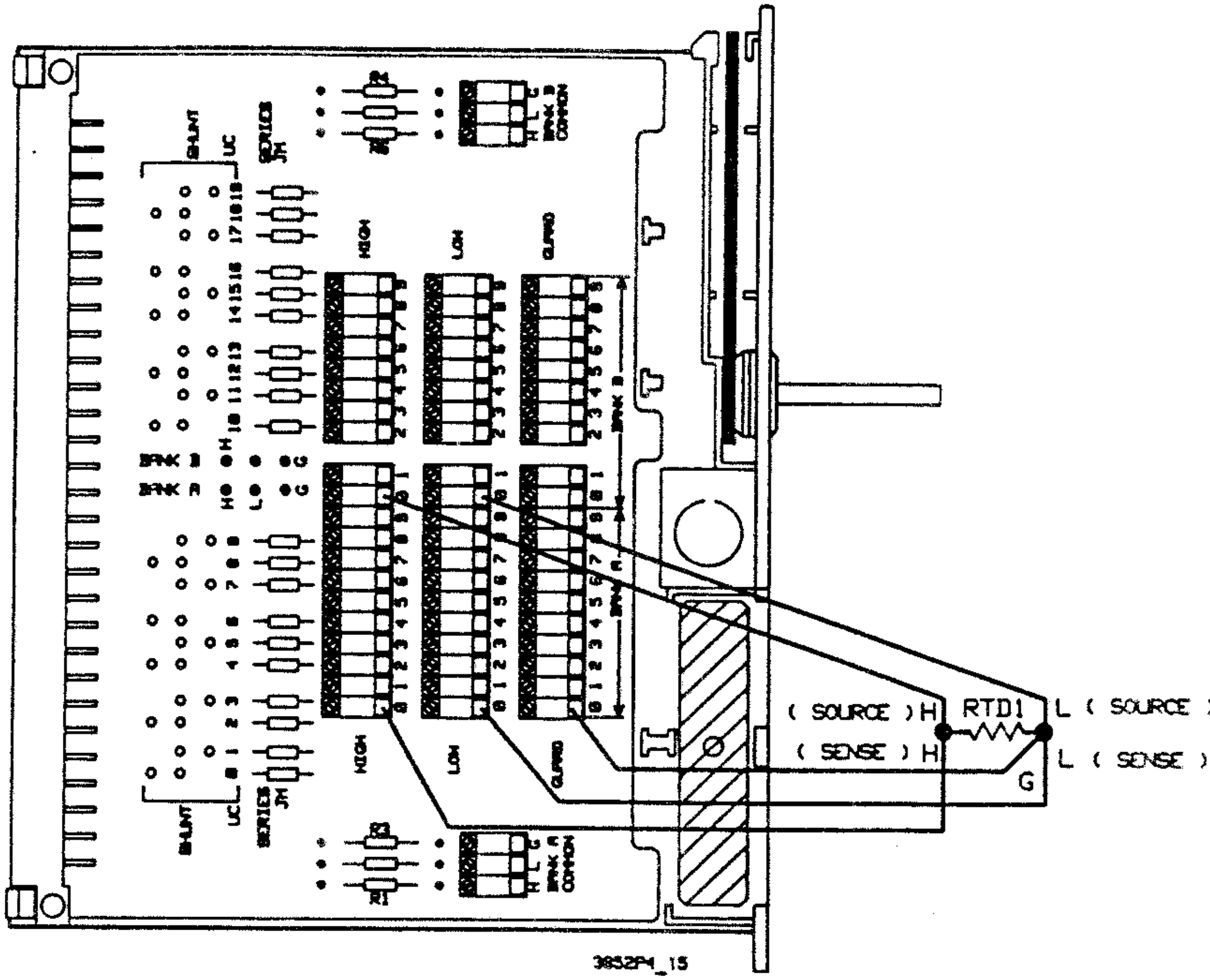


Figure 4-15. Connecting RTDs for 4-Wire Temperature Measurements

Example: Connecting Thermistors for 2-Wire Temperature Measurements

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. Thermistors are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

Up to twenty 2-wire thermistor measurements can be made per relay MUX. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

A thermistor (THM0) is connected to Channel 0 on the terminal module as shown in Figure 4-16. Connect one lead of the thermistor to the HIGH terminal. Connect the other lead of the thermistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the thermistor low lead to the GUARD terminal.

Figure 4-16. Connecting Thermistors for 2-Wire Temperature Measurements

Example: Connecting Thermistors for 4-Wire Temperature Measurements

The HP 3852A also allows thermistors to be measured using the 4-wire function. Since each 4-wire ohms measurement requires two channels, up to 10 temperature measurements can be made per relay MUX accessory.

NOTE

Each 4-wire thermistor measurement require two channels, one from BANK A and one from BANK B. When connecting a thermistor to the terminal module for a 4-wire measurement, use two channels that are separated by one decade (i.e., Channels 0 and 10, Channels 1 and 11, etc.).

A thermistor (THM1) is connected to Channels 0 and 10 for a 4-wire measurement as shown in Figure 4-17. Channel 0 is used as the voltage sense channel for the measurement and Channel 10 is used as the current source channel for the measurement.

Figure 4-17. Connecting Thermistors for 4-Wire Temperature Measurements

To make the connections to Channel 0 (the Sense channel), connect one lead of the thermistor to the HIGH terminal. Connect the other lead of the thermistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the thermistor low lead to the GUARD terminal.

To connect the thermistor to Channel 10 (the Source channel), repeat the above procedure using the HIGH and LOW terminals for Channel 10. Note that it is not necessary to connect the guard lead to both the sense channel and the source channel.

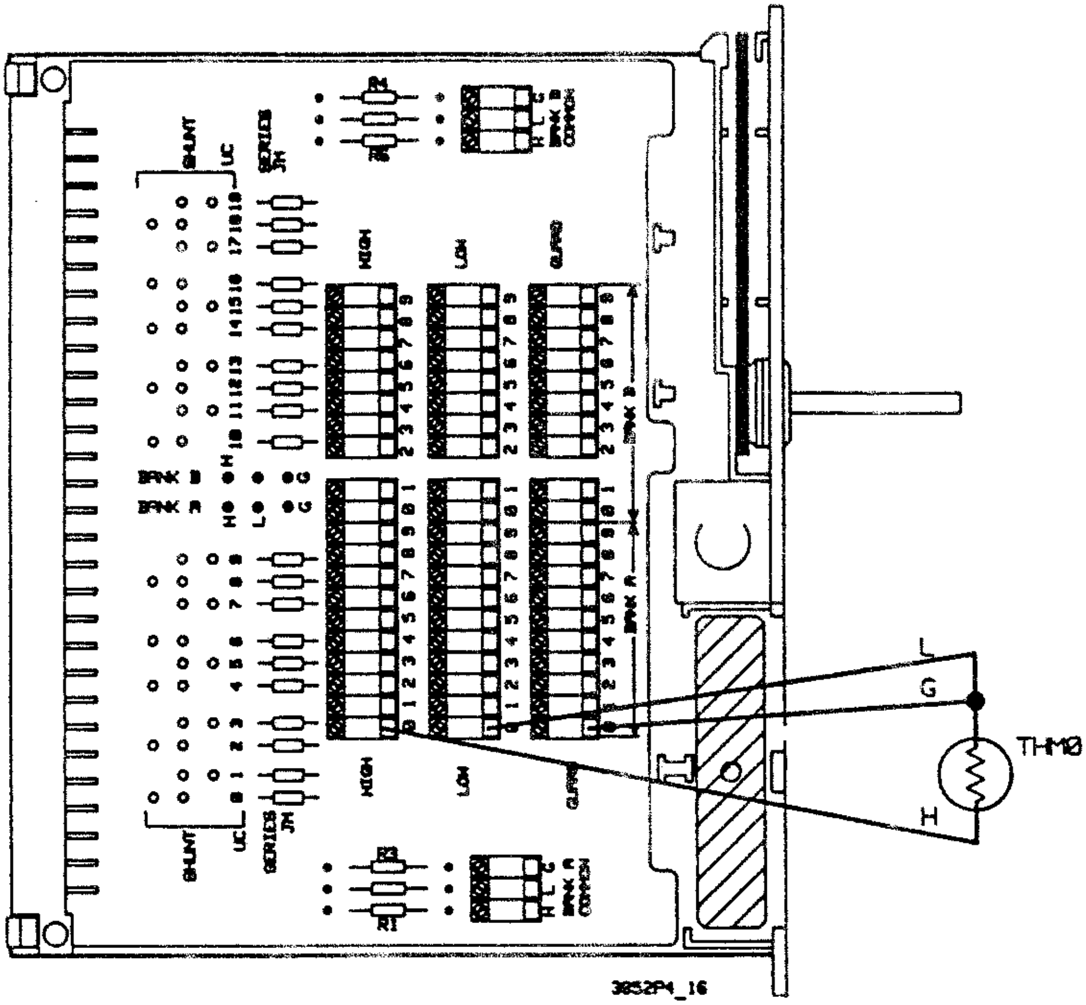


Figure 4-16. Connecting Thermistors for 2-Wire Temperature Measurements

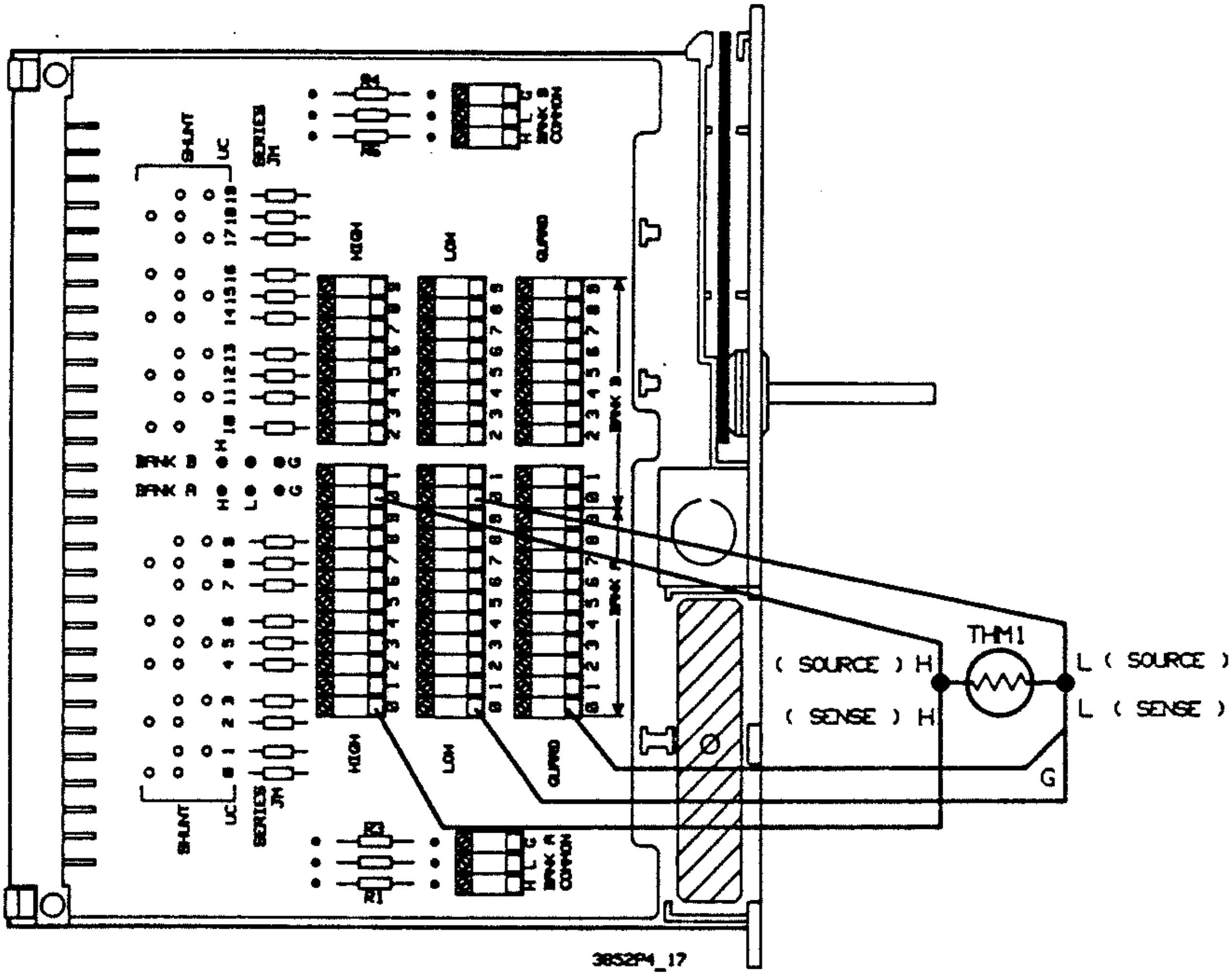


Figure 4-17. Connecting Thermistors for 4-Wire Temperature Measurements

Installation/ Checkout

The following section explains how to check the accessory identity, how to verify the field wiring connections, and how to read the state of the channels.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

Checking the Accessory Identity

After you have connected field wiring from your application to the terminal module, replace the terminal module cover and install the accessory in the desired mainframe or extender slot. Refer to the Mainframe Configuration and Programming Manual to connect the terminal module to the component module and to install the accessory.

To check the accessory identity, you can use the ID? (Identity?) command. The ID? command provides a way to check, from the HP 3852A front panel or from a controller, in what slot an accessory has been installed. The ID? command will return " 44705A" for the 20-Channel Relay MUX and " 447XXX" if the terminal module is not connected to the component module. If the ID? command is sent to a slot with no accessory installed, " 000000" will be returned.

<u>Example: Reading the Accessory Identity</u>

```
10  !
20  !Use the ID? command to read the identity of a
30  !relay MUX installed in slot 2 of the mainframe.
40  !
50  OUTPUT 709; "ID? 200"
60  ENTER 709; Identity$
70  PRINT Identity$
80  END
```

Output with terminal module connected:

```
44705A
```

NOTE

If you have addressed the correct slot and have made sure that the terminal module is connected, but the proper ID number is not returned, refer to the HP 3852A Assembly Level Service Manual for service procedures.

Verifying Wiring Connections

To verify that your field wiring has been properly connected to the terminal module, send the MONMEAS (Monitor/Measure) command from the HP 3852A front panel keyboard or from a controller. This command can be used to check DC and AC voltage connections, 2-wire and 4-wire ohms connections, RTD connections, and thermistor connections.

The following program segment shows how to use the MONMEAS command with a controller to verify DC voltage connections on Channels 200 through 219. The CONF command configures the voltmeter accessory for DC voltage measurements. For this example, a relay MUX is installed in slot 2 of the mainframe and a voltmeter accessory is installed in slot 0 of the mainframe.

```
10  OUTPUT 709; "USE 0"
20  OUTPUT 709; "CONF DCV"
30  OUTPUT 709; "MONMEAS DCV,200-219"
40  END
```

The 20 channels will be scanned and measured one at a time starting with Channel 200. Press "SADV KEY" on the HP 3852A front panel to advance the scanning to the next channel. When the scan is advanced past the last channel (Channel 219 in this example), scanning will stop and the last measurement will remain on the display.

Reading Channel State

The CLOSE? command can be used to determine the state of the relay MUX channels. This command returns one of five numbers for each channel queried. The numbers returned indicate if a channel is open or closed and to which bus the channel is connected. Table 4-3 shows the channel state for each value that can be returned by the CLOSE? command when used with the 20-Channel Relay MUX.

Table 4-3. Values Returned by the CLOSE? Command

Data Returned	Channel State
0	Channel Open
1	Channel Closed
2	Channel Closed - connected to Sense Bus
3	Channel Closed - connected to Source Bus
4	Channel Closed - connected to Both Buses

NOTE

The CLOSE? command will return 2, 3, or 4 only to indicate the state of Channels 0 through 19 (i.e., these values will not be returned for the tree switches).

Example: Reading Channel State

This example shows how to use the CLOSE? command to read the state of Channels 0 through 4 on a relay MUX. The RST command resets the relay MUX to its power-on state where all channels are open. The CLOSE command closes Channel 3 and the BANK A Sense Bus tree switch (Channel 91). The OPEN command is used to open the channels and disconnect them from the backplane. For this example, a relay MUX is installed in slot 2 of the mainframe.

```
10  OUTPUT 709; "RST 200"
20  INTEGER State(4)
30  OUTPUT 709; "CLOSE 203,291"
40  OUTPUT 709; "CLOSE? 200-204"
50  ENTER 709; State(*)
60  PRINT State(*)
70  OUTPUT 709; "OPEN 203,291"
80  END
```

Typical Output (Channel 3 closed - connected to Sense Bus):

```
0   0   0   2   0
```

Programming the 20-Channel Relay MUX

As noted in the Introduction section of this chapter, the relay MUX has four primary functions: voltage measurements, current measurements, resistance measurements, and temperature measurements. This section contains examples that show how to program the accessory for each function. It includes a description of each function, applicable commands for the functions, and programming examples. Each example includes a sample program and (where applicable) typical outputs for the assumed conditions.

This section also summarizes the programming commands used with the relay MUX (refer to "Command Summary") and lists the titles of the example programs (refer to "Program Titles").

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

NOTE

The example programs show how to make typical measurements using the relay MUX with the HP 44701A Integrating Voltmeter Accessory or the HP 44702 High-Speed Voltmeter Accessory (when used on the backplane). Refer to the Mainframe Configuration and Programming Manual for instructions on making measurements using an external voltmeter.

Command Summary

Table 4-4 is an alphabetical listing of commands which apply to the relay MUX accessory. Refer to the HP 3852A Command Reference Manual for a complete description of these commands.

Table 4-4. Commands for the 20-Channel Relay MUX

CLOSE *ch list*

Closes a single multiplexer channel or a list of channels specified by *ch list*. This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

CLOSE? *ch list* [INTO *name*] or [*fmt*]

Queries the state of channels specified by *ch list*.

CONFMEAS *function , ch list* [USE ch] [INTO *name*] or [*fmt*]

Configures the voltmeter accessory and measures a function on the channels specified by *ch list*. This command automatically configures the voltmeter accessory and the tree switches on the multiplexer for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function , ch list* [USE *ch*] [INTO *name*] or [*fmt*]

Scans and measures a function on the channels specified by *ch list*. This command does not configure the voltmeter accessory but it does configure the tree switches on the multiplexer for the measurement.

MONMEAS *function , ch list* [USE *ch*]

Monitors and measures a function on the channels specified by *ch list*. This command is useful to check wiring connections made on the terminal module.

OPEN *ch list*

Opens a single multiplexer channel or a list of channels specified by *ch list*. This command is used to open channels and place them in a safe state after the measurements have been made.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Program Titles

The discussion for each function includes one or two examples that show how to program the relay MUX for that function. Table 4-5 lists the titles of the example programs in this section.

Table 4-5. Program Titles

NOTE

When using more than one relay multiplexer function, it is recommended that similar types of measurements be grouped together in order to maximize relay life and minimize voltmeter function changes.

For example, if you are making DC voltage measurements and 2-wire ohms measurements, group all of the voltage measurements together and all of the resistance measurements together. In this way, the tree switches will be opened and closed fewer times and the voltmeter function won't be changed as often.

Making Voltage Measurements

One of the functions of the relay MUX accessory is to make voltage measurements. This section explains how to program the accessory to make guarded (3-wire) DC and AC voltage measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX is 170 VDC or 120 VAC rms (170V peak). Refer to Table 4-1 for the specifications.

NOTE

The AC voltage function is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC voltage measurements.

Table 4-5. Program Titles

TITLE	DESCRIPTION	COMMANDS
	Voltage Measurements	
Measuring DC and AC Voltage Sources	Measures the outputs from 20 voltage sources using the relay MUX.	CONFMEAS
Measuring Voltage Sources using the CLOSE Command	Measures the output from a voltage source using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	Current Measurements	
Making DC and AC Currents Measurements	Makes a current sensing measurement using a shunt resistor installed on the relay MUX.	CONFMEAS
	Resistance Measurements	
Making Resistance Measurements (2-Wire Function)	Measures 20 resistors using the relay MUX and the 2-wire ohms measurement function.	CONFMEAS
Making 2-Wire Ohms Measurements using the CLOSE Command	Measures a single resistor using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
Making Resistance Measurements (4-Wire Function)	Measures the resistance of a single resistor using the relay MUX and the 4-wire ohms measurement function.	CONFMEAS
	Temperature Measurements	
Measuring Temperature using RTDs (2-Wire Function)	Makes 20 temperature measurements using the relay MUX and the 2-wire RTD measurement function.	CONFMEAS
Measuring Temperature using RTDs (4-Wire Function)	Makes a temperature measurement using the relay MUX and the 4-wire RTD measurement function.	CONFMEAS
Measuring Temperature using Thermistors (2-Wire Function)	Makes 20 temperature measurements using the relay MUX and the 2-wire thermistor measurement function.	CONFMEAS
Measuring Temperature using Thermistors (4-Wire Function)	Makes a temperature measurement using the relay MUX and the 4-wire thermistor measurement function.	CONFMEAS

Example: Measuring DC and AC Voltage Sources

Suppose that you want to measure the outputs from 20 voltage sources using the relay MUX and the guarded voltage function. See Figure 4-9 to connect voltage sources to the terminal module.

The following example program uses the CONFMEAS command to measure 20 DC voltage sources connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the 20 channels once.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70  OUTPUT 709; "CONFMEAS ACV,200-219,USE 0"
```

```
10  !
20  !Use the CONFMEAS command to measure 20 DC voltages
30  !using a relay MUX in slot 2 of the mainframe.  Install
40  !a voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Volts(19)
70  OUTPUT 709; "CONFMEAS DCV,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Volts(I)
100 PRINT "Ch.";I, Volts(I)
110 NEXT I
120 END
```

Typical DC voltage values for the assumed conditions:

```
Ch. 0   4.30300
Ch. 1   4.33350
      .
      .
      .
Ch. 18  4.58580
Ch. 19  3.49490
```

Example: Measuring Voltage Sources using the CLOSE Command

Suppose that you want to measure the output from a voltage source using the CLOSE command to control the tree switches and bank switches. See Figure 4-9 to connect a voltage source to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0 and the BANK A Sense Bus tree switch (Channel 91). The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the DC voltage from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 90:

```
90  OUTPUT 709; "FUNC ACV"
```

```
 10  !
 20  !Use the CLOSE command to make a DC voltage measurement of
 30  !the voltage source connected to Channel 0 on a relay MUX
 40  !in slot 2 of the mainframe.  Install a voltmeter accessory
 50  !in slot 0 of the mainframe.
 60  !
 70  OUTPUT 709; "USE 0"
 80  OUTPUT 709; "CLOSE 200,291"
 90  OUTPUT 709; "FUNC DCV"
100  OUTPUT 709; "TRIG SGL"
110  OUTPUT 709; "CHREAD 0"
120  ENTER 709; Volts
130  PRINT Volts
140  OUTPUT 709; "OPEN 200,291"
150  END
```

Typical DC voltage value for the assumed conditions:

```
3.94940
```

Making Current Measurements

The relay MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across a shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. This section shows how to program the relay MUX to switch signals for DC and AC current measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX is 170 VDC or 120 VAC rms (170V peak). Refer to Table 4-1 for the specifications.

NOTE

The AC voltage function (used for AC current sensing) is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC current measurements.

Example: Making DC and AC Current Measurements

Suppose that you want to make a current measurement using a 250Ω shunt resistor installed on the terminal module. See Figure 4-11 to install a shunt resistor on the terminal module for a current measurement.

The following example program uses the CONFMEAS command to measure a 250Ω shunt resistor installed on Channel 0. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the channel once. The voltage value is returned to the controller which then calculates the current in DC amps.

NOTE

To use the following program to make AC current measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70  OUTPUT 709; "CONFMEAS ACV,200,USE 0"
```

```
10  !
20  !Use the CONFMEAS command to measure a 250Ω shunt resistor
30  !and calculate the DC current on Channel 0.  Use a relay MUX
40  !in slot 2 of the mainframe.  Install a voltmeter accessory
50  !in slot 0 of the mainframe.
60  !
70  OUTPUT 709; "CONFMEAS DCV,200,USE 0"
80  ENTER 709; Volts
90  !
100 !Current = Voltage Measured/Resistance of Shunt
110 !
120 Current = Volts/250
130 PRINT Current
140 END
```

Typical current value (in DC Amps) for the assumed conditions:

```
.03034
```

Making Resistance Measurements

One of the functions of the relay MUX accessory is to make resistance measurements. This section explains how to program the relay MUX for 2-wire and 4-wire ohms measurements.

2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per relay MUX accessory.

When using the relay MUX accessory for 2-wire ohms measurements, the voltmeter accessory is actually configured for a 4-wire ohms measurement. The relay MUX converts the 4-wire function on the voltmeter to a 2-wire function on the component module. It does this by connecting the high voltage sense lead to the high current source lead and the low voltage sense lead to the low current source lead. Therefore, only two leads are used on the relay MUX for the 2-wire ohms measurement.

<u>Example: Making Resistance Measurements (2-Wire Function)</u>

Suppose that you want to measure 20 resistors connected to the relay MUX using the 2-wire ohms function. See Figure 4-12 to connect resistors to the terminal module for 2-wire ohms measurements.

The following example program uses the CONFMEAS command to measure 20 resistors connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for 2-wire ohms measurements and measures the 20 channels once.

```
10  !
20  !Use the CONFMEAS command to measure 20 resistors using a
30  !relay MUX in slot 3 of the mainframe.  Install a voltmeter
40  !accessory in slot 0 of the mainframe.
50  !
60  REAL Ohms(19)
70  OUTPUT 709; "CONFMEAS OHM,300-319,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Ohms(I)
100 PRINT "Ch.";I, Ohms(I)
110 NEXT I
120 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
Ch. 0   4628.340
Ch. 1   5024.900
    .
    .
    .
Ch. 18  4039.400
Ch. 19  6528.380
```

Example: Making 2-Wire Ohms Measurements using the CLOSE Command

Suppose that you want to make a 2-wire ohms measurement of a resistor using the CLOSE command to control the tree switches and bank switches. See Figure 4-12 to connect resistors to the terminal module for a 2-wire ohms measurement.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the BANK A Sense Bus tree switch (Channel 91), and the BANK A Source Bus tree switch (Channel 93). The FUNC command configures the voltmeter accessory for 4-wire ohms measurements (the relay MUX converts the 4-wire function to a 2-wire function on the component module). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance value from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

The following program uses the HP 44701A Integrating Voltmeter Accessory. To use this program with the HP 44702 High-Speed Voltmeter Accessory on the backplane, substitute the following line for the existing line 80:

```
80  OUTPUT 709; "FUNC OHMF100K"
```

```
10  !
20  !Use the CLOSE command to make a 2-wire ohms measurement
30  !of Channel 0 on a relay MUX in slot 3 of the mainframe.
40  !Install a voltmeter accessory in slot 0 of the mainframe.
50  !
60  OUTPUT 709; "USE 0"
70  OUTPUT 709; "CLOSE 300,391,393"
80  OUTPUT 709; "FUNC OHMF"
90  OUTPUT 709; "TRIG SGL"
100 OUTPUT 709; "CHREAD 0"
110 ENTER 709; Ohms
120 PRINT Ohms
130 OUTPUT 709; "OPEN 300,391,393"
140 END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
11623.570
```

4-Wire Ohms Measurements

The use of the 4-wire ohms measurement virtually eliminates the error caused by the test lead resistances. The current through the unknown resistance is the same regardless of the lead resistance but the voltmeter measures only the voltage across the resistance, not across the combined test lead and the resistance. The 4-wire ohms function is essential when the highest accuracy is required. Since each 4-wire ohms measurement requires two channels, up to 10 resistance measurements can be made per relay MUX accessory.

Example: Making Resistance Measurements (4-Wire Function)

Suppose that you want to measure a resistor using the relay MUX and the 4-wire ohms function. See Figure 4-13 to connect resistors to the terminal module for 4-wire ohms measurements.

The following example program uses the CONFMEAS command to measure a resistor using the 4-wire ohms function. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel. Note that the channel specified in the channel list with the CONFMEAS command (Channel 0) is the sense channel (the HP 3852A automatically configures the channel that is one decade from the sense channel as the source channel). The resistor is scanned once by the voltmeter accessory and the result (in Ohms) is returned to the controller.

```
10  !
20  !Use the CONFMEAS command to make a 4-wire ohms measurement
30  !using a relay MUX in slot 3 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
60  OUTPUT 709; "CONFMEAS OHMF,300,USE 0"
70  ENTER 709; Ohms
80  PRINT Ohms
90  END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
205.955
```

Making Temperature Measurements

One of the functions of the relay MUX accessory is to make temperature measurements. This section shows how to program the relay MUX accessory to make RTD measurements and thermistor measurements.

Measuring Temperature using RTDs

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ and resistance values of 100Ω at 0°C.

Most RTDs have small resistance values (typically less than 300Ω) which makes the test lead resistance a significant factor when making resistance measurements. The most accurate method to measure an RTD using the relay MUX is the 4-wire ohms measurement function. The 2-wire ohms function can be used in temperature applications where accuracy is not so important, such as when checking the integrity of your transducers. Up to twenty 2-wire RTD measurements or up to ten 4-wire measurements (each 4-wire ohms measurement requires two channels) can be made per relay MUX accessory.

<u>Example: Measuring Temperature using RTDs (2-Wire Function)</u>

Suppose that you want to make 20 temperature measurements using RTDs and the 2-wire function. See Figure 4-14 to connect RTDs to the terminal module for 2-wire temperature measurements.

The following example program uses the CONFMEAS command to scan and measure 20 RTDs (with $\alpha = 0.00385\ \Omega/\Omega°C$) using the 2-wire function. The program scans Channels 0 through 19 and returns the results (in °C) to the controller.

```
10  !
20  !Use the CONFMEAS command to make twenty 2-wire RTD measurements
30  !using a relay MUX in slot 2 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
```

```
60  REAL Temp(19)
70  OUTPUT 709; "CONFMEAS RTD85,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Temp(I)
100 PRINT "Ch.";I, Temp(I)
110 NEXT I
120 END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0   24.54297
Ch. 1   24.54299
     .
     .
     .
Ch. 18  25.55805
Ch. 19  25.85645
```

Example: Measuring Temperature using RTDs (4-Wire Function)

Suppose that you want to make a temperature measurement using an RTD and the 4-wire function. See Figure 4-15 to connect RTDs to the terminal module for 4-wire temperature measurements.

The following example program uses the CONFMEAS command to scan and measure one RTD (with $\alpha = 0.003916\ \Omega/\Omega°C$) using the 4-wire ohms function. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel. Note that the channel specified in the channel list with the CONFMEAS command (Channel 0) is the sense channel (the HP 3852A configures the channel that is one decade from the sense channel as the source channel). The RTD is scanned once by the voltmeter accessory and the result (in °C) is returned to the controller.

```
10  !
20  !Use the CONFMEAS command to measure an RTD using the 4-wire
30  !ohms function.  Use a relay MUX in slot 2 of the mainframe.
40  !Install a voltmeter accessory in slot 0 of the mainframe.
50  !
60  OUTPUT 709; "CONFMEAS RTDF92,200,USE 0"
70  ENTER 709; Temp
80  PRINT Temp
90  END
```

Typical temperature value (in °C) for the assumed conditions:

```
24.54297
```

Measuring Temperature using Thermistors

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. They are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

The HP 3852A allows thermistors to be measured using either the 2-wire or the 4-wire function. Up to 20 thermistors can be measured per accessory using the 2-wire ohms function. Since each 4-wire measurement requires two channels, up to 10 thermistors can be measured per relay MUX. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

Example: Measuring Temperature using Thermistors (2-Wire Function)

Suppose that you want to make 20 temperature measurements using 5 kΩ thermistors and the 2-wire function. See Figure 4-16 to connect thermistors to the terminal module for 2-wire temperature measurements.

The following example program uses the CONFMEAS command to measure 20 thermistors using the 2-wire function. The program scans and measures Channels 0 through 19 once and returns the results (in °C) to the controller.

```
10  !
20  !Use the CONFMEAS command to measure twenty 5 kΩ
30  !thermistors using a relay MUX in slot 2 of the mainframe.
40  !Install a voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Temp(19)
70  OUTPUT 709; "CONFMEAS THM5K,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Temp(I)
100 PRINT "Ch.";I, Temp(I)
110 NEXT I
120 END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0   24.54297
Ch. 1   24.54299
      .
      .
      .
Ch. 18  25.55800
Ch. 19  25.85645
```

Example: Measuring Temperature using Thermistors (4-Wire Function)

Suppose that you want to make a temperature measurement using a 2252Ω thermistor and you have decided that you will need the accuracy of a 4-wire measurement. See Figure 4-17 to connect a thermistor to the terminal module for a 4-wire temperature measurement.

The following example program uses the CONFMEAS command to scan and measure a 2252Ω thermistor using the 4-wire ohms function. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel. Note that the channel specified in the channel list with the CONFMEAS command (Channel 0) is the sense channel (the HP 3852A configures the channel that is one decade from the sense channel as the source channel). The thermistor is scanned once by the voltmeter accessory and the result (in °C) is returned to the controller.

```
10  !
20  !Use the CONFMEAS command to measure a thermistor (2252Ω) using
30  !the 4-wire function.  Use a relay MUX in slot 2 of the mainframe.
40  !Install a voltmeter accessory in slot 0 of the mainframe.
50  !
60  OUTPUT 709; "CONFMEAS THMF2252,200,USE 0"
70  ENTER 709; Temp
80  PRINT Temp
90  END
```

Typical temperature value (in °C) for the assumed conditions:

```
25.64643
```

Chapter 5
HP 44706A
60-Channel Relay Mux

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HP 44706A 60-Channel Relay MUX

Chapter 5

60-Channel Relay MUX

HP 44706A

Introduction

This chapter shows how to configure and program the HP 44706A 60-Channel Single-Ended Relay Multiplexer (MUX) Accessory. The chapter has four sections: Introduction, Specifications, Configuring the 60-Channel Relay MUX, and Programming the 60-Channel Relay MUX.

- **Introduction** contains a chapter overview, a description of the relay MUX, a description of its functions, and shows suggested steps to get started.
- **Specifications** lists the specifications for the accessory.
- **Configuring the 60-Channel Relay MUX** contains a block diagram description of the accessory and shows how to connect field wiring to the terminal module.
- **Programming the 60-Channel Relay MUX** shows how to program the accessory for voltage, resistance, and temperature measurements.

Description

The relay MUX is an analog signal multiplexer accessory which is used to switch (multiplex) signals from up to 60 single-ended channels for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory provides switching capability for the 60 channels at scanning speeds up to 450 channels per second using an HP 3852A voltmeter accessory. This accessory can switch signals up to 42 VDC or 30 VAC rms (42V peak).

The relay MUX accessory consists of a 60-channel terminal module and a relay MUX component module. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Functions

The relay MUX accessory is used to switch signals in applications that don't require the accuracy of a guarded (3-wire) measurement but high channel count is required. This accessory can be used to switch signals for three primary functions:

- Voltage Measurements.
- 2-Wire Resistance (or Ohms) Measurements.
- Temperature Measurements.

NOTE

Each channel on the relay MUX can be independently configured to allow multiple functions to be measured using the same accessory.

Voltage Measurements

The relay MUX can be used to switch signals for single-ended DC voltage and AC voltage measurements. In the single-ended voltage measurement function, only the HIGH line is switched to allow for more channels at low cost per channel. LOW and GUARD are common to all channels but are not switched. Use this function to make up to 60 single-ended voltage measurements per relay MUX accessory.

2-Wire Ohms Measurements

The relay MUX can be used to switch signals for 2-wire ohms measurements. In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 60 resistance measurements per relay MUX accessory.

NOTE

Four-wire ohms measurements cannot be made using the 60-channel relay MUX accessory.

Temperature Measurements

The relay MUX can be used to switch signals for temperature measurements using resistance temperature detectors (RTDs) and thermistors. RTDs are typically more stable and accurate than thermistors. Thermistors are more sensitive to temperature changes than RTDs. The relay MUX can be used in temperature applications where accuracy is not so important, such as when checking the integrity of your transducers.

Use the 2-wire function to make up to 60 temperature measurements per relay MUX accessory. The HP 3852A resistance-to-temperature conversions support the following RTDs and thermistors:

RTDs Supported:

$\alpha = 0.00385\ \Omega/\Omega°C$ (100Ω at 0°C)
$\alpha = 0.003916\ \Omega/\Omega°C$ (100Ω at 0°C)

Thermistors Supported:

2252Ω at 25°C
5 kΩ at 25°C
10 kΩ at 25°C

NOTE

Other transducers can be measured using the relay MUX but only those listed above are supported by the HP 3852A conversions.

Getting Started

To use the relay MUX for your application, you will need to follow three steps:

- Define your application.
- Configure the accessory for your application.
- Program the accessory for your application.

Define your Application

The first step is to define your application and determine if the accessory can meet the requirements of your application. The relay MUX can switch DC or AC inputs up to 42 VDC or 30 VAC rms (42V peak). Since each of the 60 channels can be independently configured, up to 60 different devices can be connected to the accessory. When selecting devices to be connected, refer to Table 5-1 "60-Channel Relay MUX Specifications" to ensure that the voltage and current requirements of your application are within the specifications for this accessory.

Configure the Accessory

The next step is to configure the accessory for your application. Refer to "Configuring the 60-Channel Relay MUX" for information on hardware configuration (setting jumpers and switches) and connecting field wiring to the terminal module for voltage, 2-wire ohms, and temperature measurements.

Program the Accessory

The third step is to program the relay MUX for your application. Refer to "Programming the 60-Channel Relay MUX" to program the accessory for voltage, 2-wire ohms, and temperature measurements.

Specifications

Table 5-1 lists the specifications for the relay MUX. This table contains four categories: Input Characteristics, Operating Characteristics, RTD Characteristics, and Thermistor Characteristics.

WARNING

The HP 3852A and the HP 3853A internal analog buses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against possible personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the HP 3852A, HP 3853A, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum Allowable Peak Voltage
HP 3852A Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	350V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexer	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extenders, each instrument is considered as a separate circuit.

Table 5-1. 60-Channel Relay MUX Specifications

INPUT CHARACTERISTICS:

Maximum Input Voltage:
Between any two input terminals or to chassis:
42V peak, 42 VDC, 30 VAC rms

Maximum Current: 50 mA per channel non-inductive

Maximum Power: 1 VA per channel

DC Offset: 100 uV (not low-thermal)

Closed Channel Resistance (In Series): 100Ω ±10%

OPERATING CHARACTERISTICS:

Maximum Scan Rate (channels per second):
Using HP 3852A Voltmeter Accessories: 450
Using External Voltmeter: 500

Relay Characteristic Lifetime: [1]

Voltage [2]	Number of Cycles
10V	> 10^8
40V	1.5×10^7

[1] Characteristic lifetime of a single relay on the HP 44706A in the mainframe with one HP 44701A Integrating Voltmeter.

[2] Total peak voltage between one scanned channel and the next or from a scanned channel to 0V (whichever is greater).

Synchronization: Break-Before-Make in scanning operation.

RTD CHARACTERISTICS:

RTD Types Supported:
Type: Platinum, α = 0.00385 Ω/Ω°C
100Ω at 0°C
Type: Platinum, α = 0.003916 Ω/Ω°C
100Ω at 0°C

THERMISTOR CHARACTERISTICS:

Thermistor Types Supported:
Type: 2252Ω at 25°C
Type: 5 kΩ at 25°C
Type: 10 kΩ at 25°C

Configuring the 60-Channel Relay MUX

This section shows how to configure the relay MUX accessory. It contains a block diagram description of the accessory, information on hardware configuring the terminal module, and information on connecting field wiring to the terminal module.

Refer to "Programming the 60-Channel Relay MUX" to program the accessory for voltage, 2-wire ohms, and temperature measurements.

WARNING

⚠ 1

SHOCK HAZARD. Only qualified, service-trained personnel who are aware of the hazards involved should install, remove, or configure any accessory. Before touching any installed accessory, turn off all power to the mainframe, extenders, and to all external devices connected to the mainframe, extenders, or accessories.

WARNING

⚠ 2

POSSIBLE OPERATOR INJURY. Under most conditions of failure, the relays on the relay MUX will remain in whatever state your program has set them. However, for some equipment failures, the relays may not remain in their programmed state. If the relays settle in the closed state, the relay contacts may weld together and the highest voltage present on any one channel may be present on all channels. This condition may cause operator injury if the terminals are touched or equipment damage may result.

For example, see Figure 5-1 which shows the block diagram for the relay MUX. If Channel 0 is at 30 volts and a failure occurs which causes the relay contacts to weld together, the 30 volts may be present on all 60 channels of the accessory.

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers attached.

Block Diagram Description

The relay MUX accessory consists of a 60-channel terminal module and a relay MUX component module as shown in Figure 5-1. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Figure 5-1. 60-Channel Relay MUX Block Diagram

The component module is made up of two types of switches: bank switches and tree switches. There are a total of 60 bank switches which are divided into two groups of 30 channels each: BANK A and BANK B. Unlike the guarded multiplexer accessories, the relay MUX switches only the HIGH line. LOW and GUARD are common to all channels but are not switched.

NOTE

Only one bank switch can be closed at time. Closing a second bank switch will open any previously closed bank switch.

The component module contains four tree switches which are of two types: Source Bus tree switches and Sense Bus tree switches. There are three Sense Bus tree switches and one Source Bus tree switch. The tree switches control signal flow to and from the HP 3852A backplane and also isolate the bank switches from the backplane when they are not in use. The Sense Bus tree switches provides the connections to the backplane for making voltage measurements. The Source Bus tree switches provide the current source connections (+I and -I) to the backplane for making resistance measurements.

Table 5-2 shows the channel definitions for the relay MUX accessory. Channels 0 through 59 control the bank switches and the Sense Bus tree switches (when a command is executed to close a channel, the Sense Bus tree switches are automatically closed). Channel 91 controls the Source Bus tree switch for all 60 channels.

Table 5-2. 60-Channel Relay MUX Channel Definitions

Channel	Definitions
0 - 59	Bank Switches/Source Bus Tree Switch
91	Source Bus Tree Switch

As factory configured, there are two 100Ω protection resistors in series with the LOW and GUARD terminals on the terminal module. Five 100Ω resistors on the component module connect the tree switches to the HP 3852A backplane.

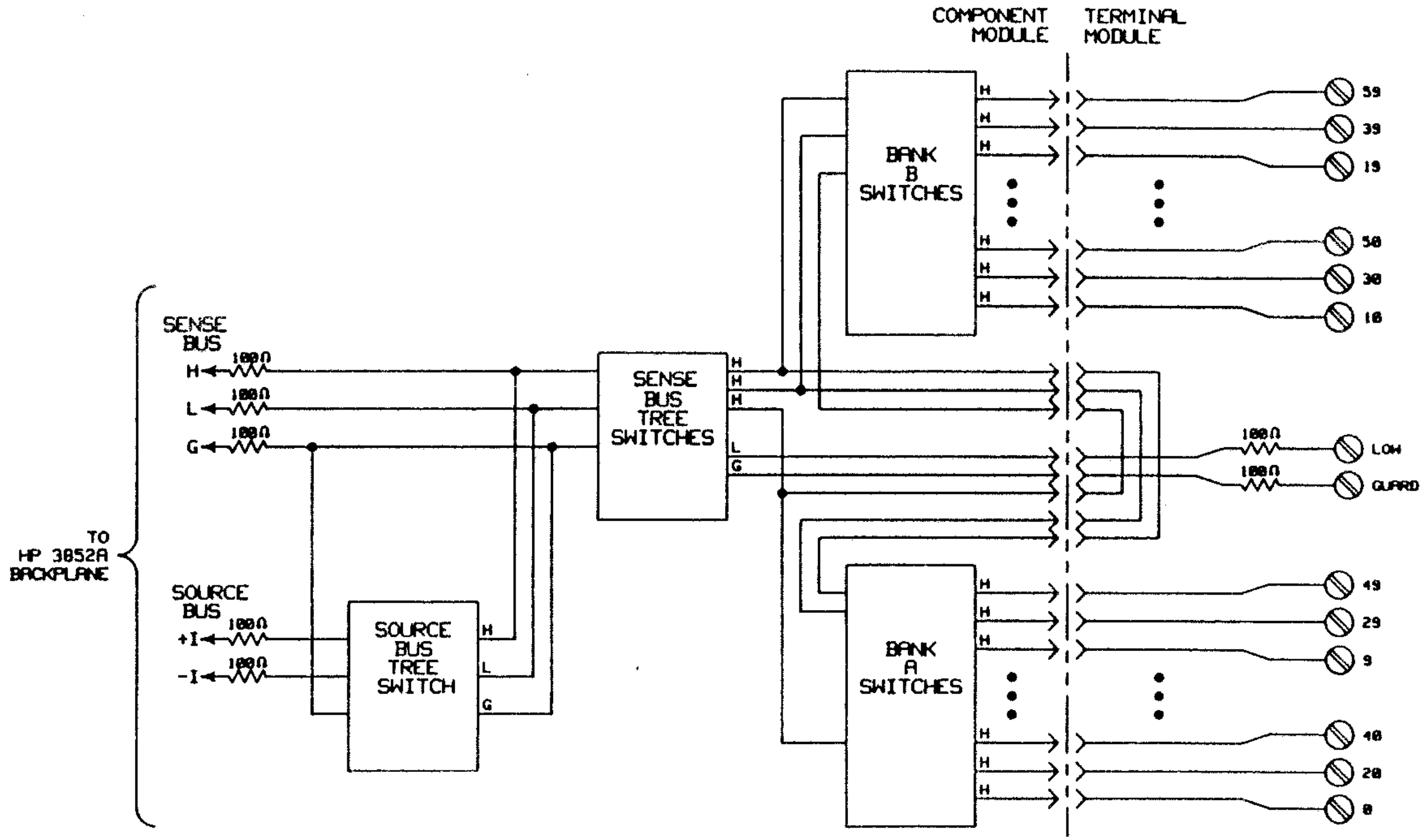


Figure 5-1. 60-Channel Relay MUX Block Diagram

Connecting Field Wiring

The next step is to connect field wiring from your application to the appropriate terminals on the terminal module. The following section contains examples that show how to connect field wiring to the terminal module for voltage, resistance, and temperature measurements.

Figure 5-2 shows the terminal module with the cover removed. There are 60 CHANNEL HIGH terminals (numbered 0 through 59), a common LOW terminal, and a common GUARD terminal.

Figure 5-2. 60-Channel Relay MUX Terminal Module

When connecting field wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make it easier to route the wiring.

NOTE

When connecting components such as resistors, RTDs, or thermistors, the lead length may be too short to route through the strain relief clamp. In this case, the components will have to be stored inside the terminal module. When connecting these components, make sure that no leads are shorted together and bend the leads to allow the terminal module cover to be replaced.

Connections for Voltage Measurements

In the voltage measurement function, the relay MUX accessory can switch signals for up to 60 single-ended DC or AC voltage measurements. When making single-ended voltage measurements, only the HIGH line is switched. LOW and GUARD are common to all channels but are not switched.

CAUTION

The maximum non-destructive voltage which can be applied to the 60-channel relay MUX is 42 VDC or 30 VAC rms (42V peak). Refer to Table 5-1 for the specifications.

Example: Connecting Voltage Sources to the Terminal Module

A voltage source (V0) is connected to Channel 0 on the terminal module as shown in Figure 5-3. Connect the high (+) lead from the voltage source to the CHANNEL HIGH terminal for Channel 0. Connect the low (-) lead from the voltage source to the LOW terminal.

Figure 5-3. Connecting Voltage Sources to the Terminal Module

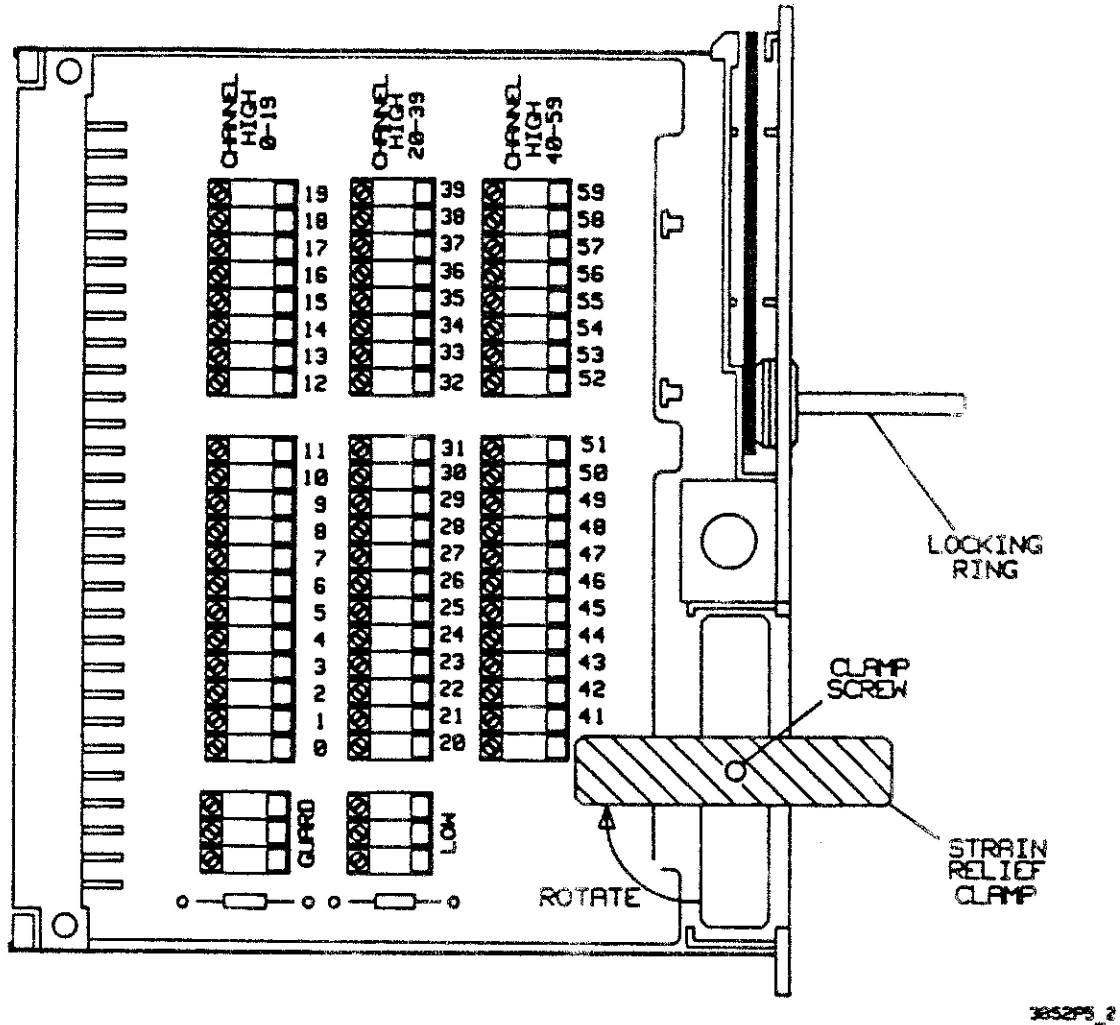


Figure 5-2. 60-Channel Relay MUX Terminal Module

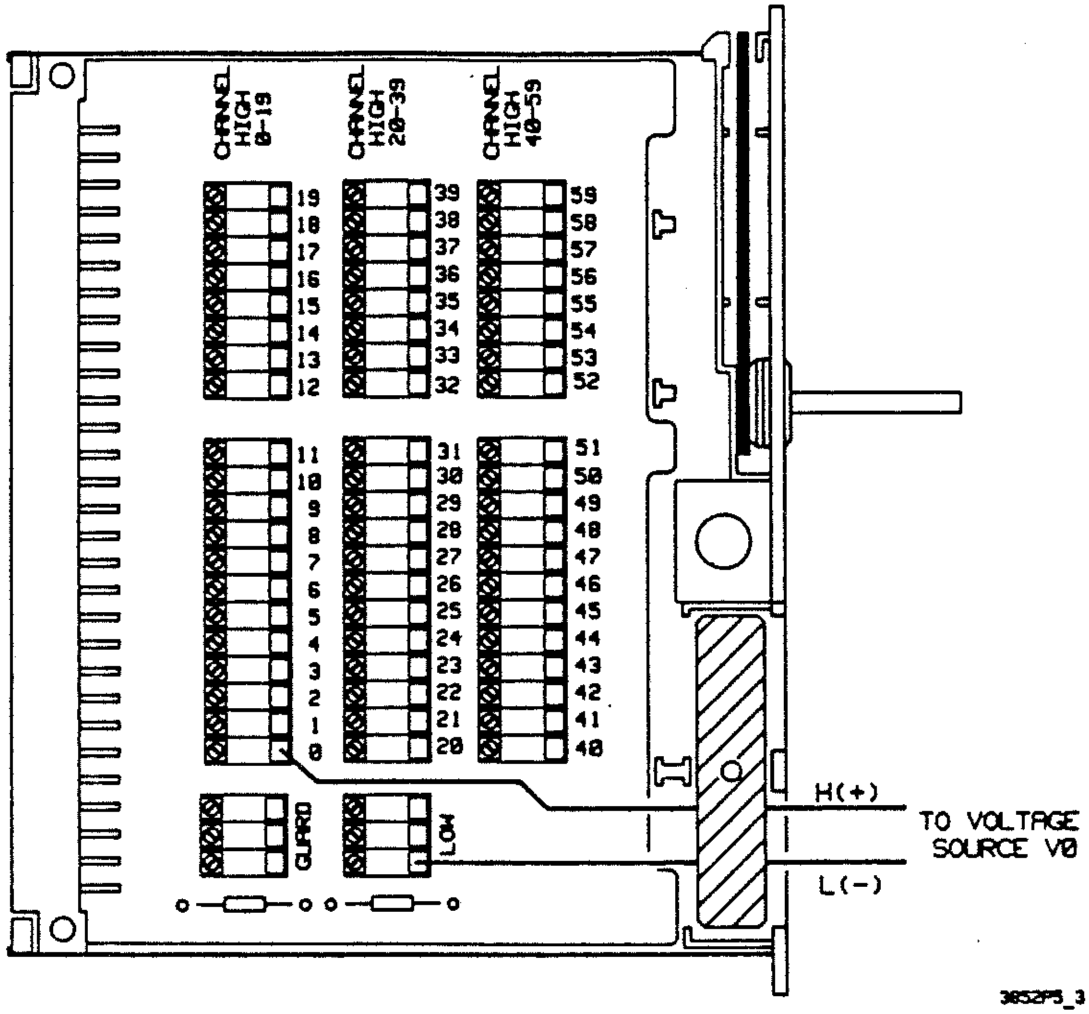


Figure 5-3. Connecting Voltage Sources to the Terminal Module

Connections for Resistance Measurements

One of the functions of the relay MUX accessory is to switch signals for resistance measurements. This section contains a 2-wire ohms configuration example.

Example: Connecting Resistors for 2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to switch signals for up to 60 resistance measurements per relay MUX accessory.

NOTE

There is a 100Ω offset error when making 2-wire ohms measurements using the relay MUX. This offset is due to the 100Ω protection resistor in series with the LOW terminal on the terminal module. The resistor can be shorted out, but this will seriously shorten relay life if high voltages or currents are switched.

A resistor (R0) is connected to Channel 0 on the terminal module as shown in Figure 5-4. Connect one lead of the resistor to the CHANNEL HIGH terminal for Channel 0. Connect the other lead of the resistor to the LOW terminal.

Figure 5-4. Connecting Resistors for 2-Wire Ohms Measurements

Connections for Temperature Measurements

One of the functions of the relay MUX accessory is to switch signals for temperature measurements. This section contains configuration examples that show how to connect RTDs and thermistors to the terminal module.

NOTE

There is a 100Ω offset error when making 2-wire temperature measurements using the relay MUX. This offset is due to the 100Ω protection resistor in series with the LOW terminal on the terminal module. The resistor can be shorted out, but this will seriously shorten relay life if high voltages or currents are switched.

Example: Connecting RTDs for Temperature Measurements

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. Up to sixty 2-wire RTD measurements can be made per relay MUX accessory. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 Ω/Ω°C and 0.003916 Ω/Ω°C and resistance values of 100Ω at 0°C.

An RTD (RTD0) is connected to Channel 0 on the terminal module as shown in Figure 5-5. Connect one lead of the RTD to the CHANNEL HIGH terminal for Channel 0. Connect the other lead of the RTD to the LOW terminal.

Figure 5-5. Connecting RTDs for Temperature Measurements

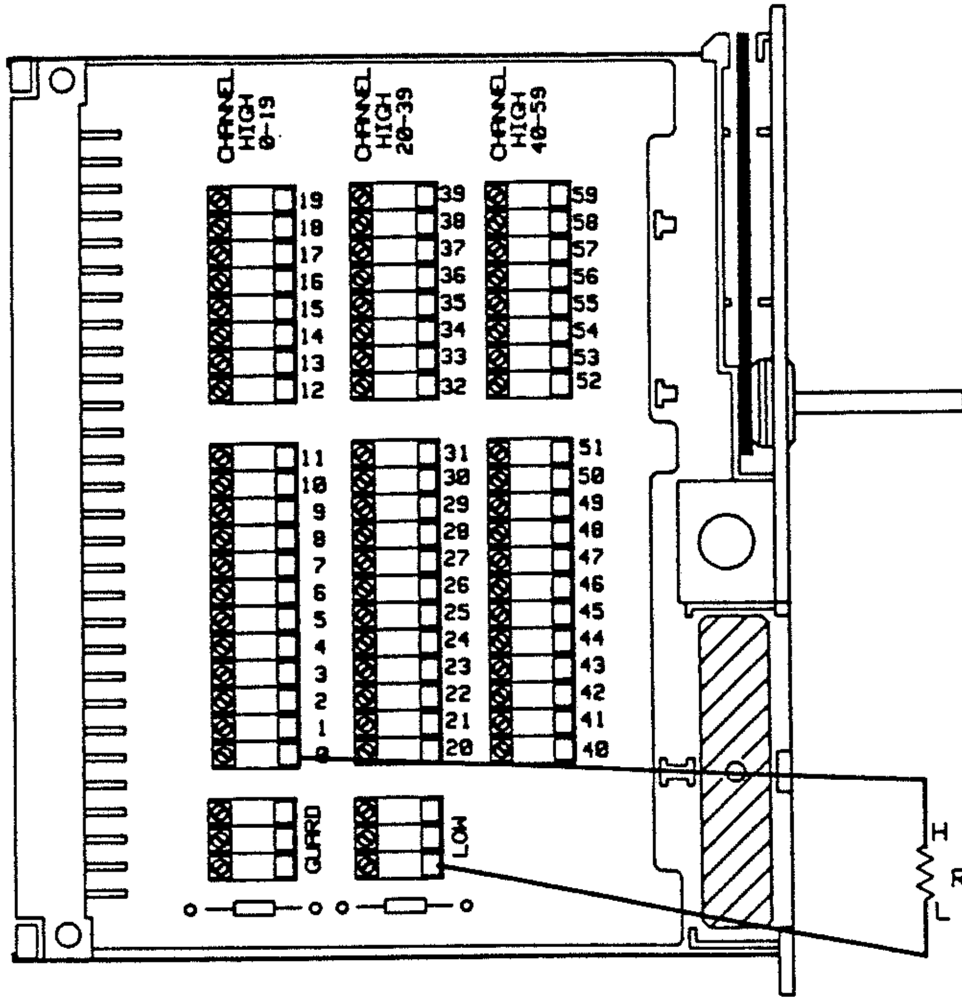


Figure 5-4. Connecting Resistors for 2-Wire Ohms Measurements

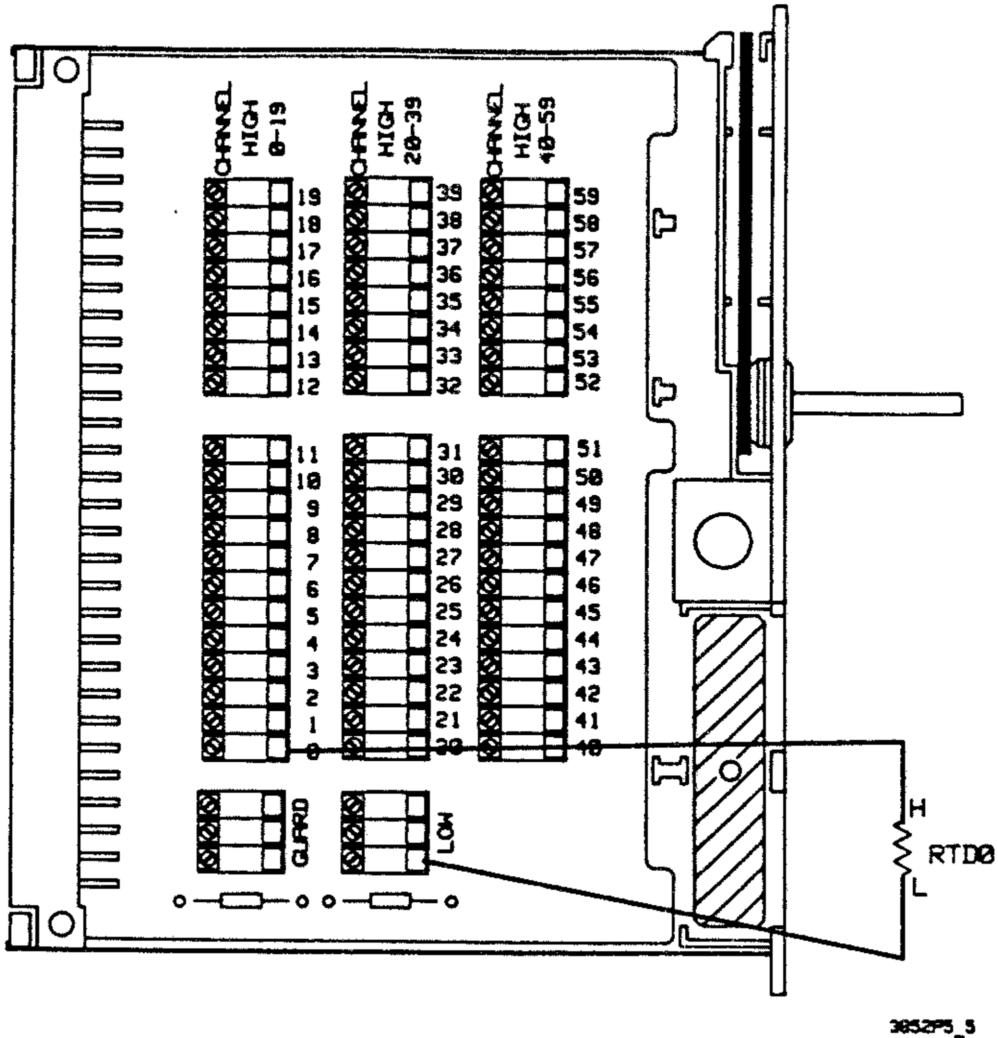


Figure 5-5. Connecting RTDs for Termperature Measurements

Example: Connecting Thermistors for Temperature Measurements

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. Thermistors are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

Up to 60 thermistor measurements can be made using a single relay MUX accessory and the 2-wire ohms function. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

A thermistor (THM0) is connected to Channel 0 on the terminal module as shown in Figure 5-6. Connect one lead of the thermistor to the CHANNEL HIGH terminal for Channel 0. Connect the other lead of the thermistor to the LOW terminal.

Figure 5-6. Connecting Thermistors for 2-Wire Temperature Measurements

Installation/ Checkout

The following section explains how to check the accessory identity, how to verify the field wiring connections, and how to read the state of the channels.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

Checking the Accessory Identity

After you have connected field wiring from your application to the terminal module, replace the terminal module cover and install the accessory in the desired mainframe or extender slot. Refer to the Mainframe Configuration and Programming Manual to connect the terminal module to the component module and to install the accessory.

To check the accessory identity, you can use the ID? (Identity?) command. The ID? command provides a way to check, from the HP 3852A front panel or from a controller, in what slot an accessory has been installed. The ID? command will return " 44706A" for the 60-Channel Relay MUX and " 447XXX" if the terminal module is not connected to the component module. If the ID? command is sent to a slot with no accessory installed, " 000000" will be returned.

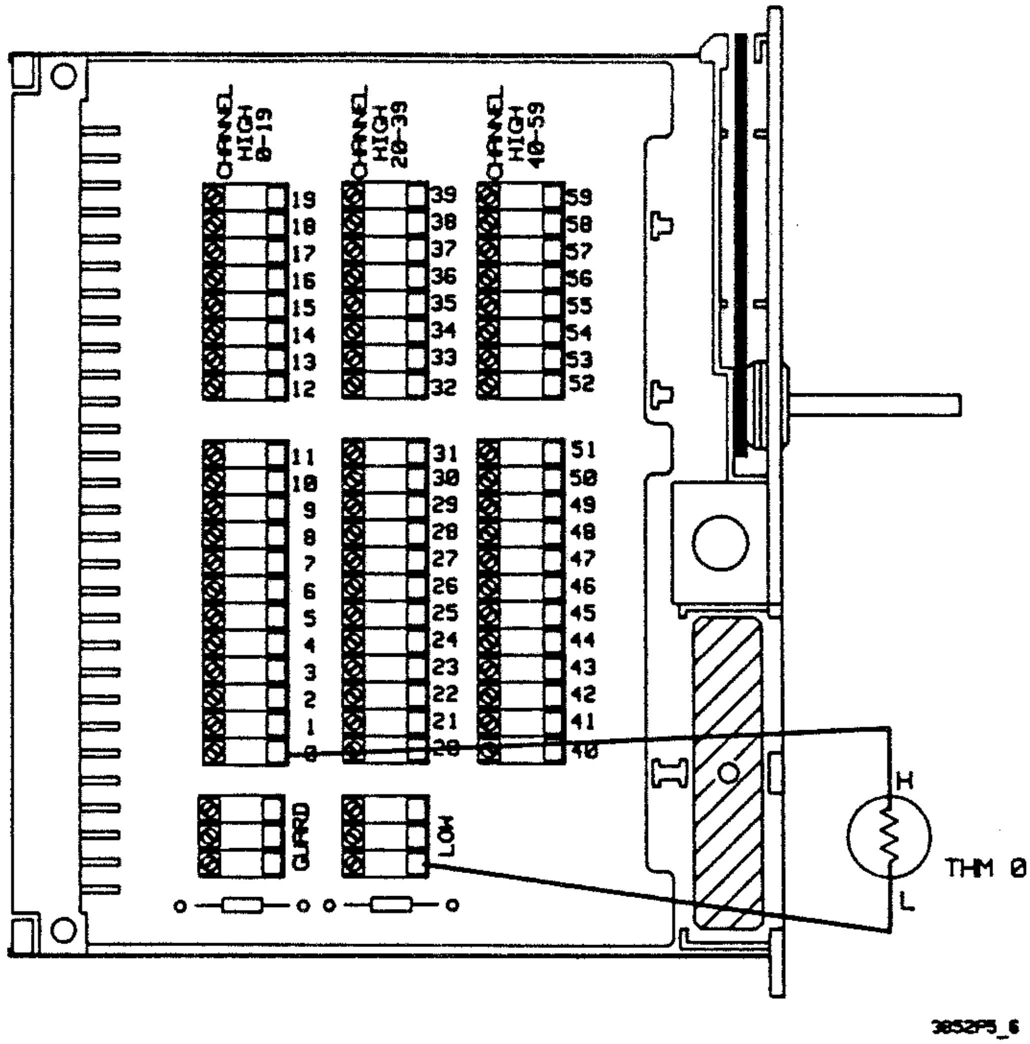


Figure 5-6. Connecting Thermistors for 2-Wire Temperature Measurements

Example: Reading the Accessory Identity

```
10  !
20  !Use the ID? command to read the identity of a
30  !relay MUX installed in slot 2 of the mainframe.
40  !
50  OUTPUT 709; "ID? 200"
60  ENTER 709; Identity$
70  PRINT Identity$
80  END
```

Output with terminal module connected:

```
44706A
```

NOTE

If you have addressed the correct slot and have made sure that the terminal module is connected, but the proper ID number is not returned, refer to the HP 3852A Assembly Level Service Manual for service procedures.

Verifying Wiring Connections

To verify that your field wiring has been properly connected to the terminal module, send the MONMEAS (Monitor/Measure) command from the HP 3852A front panel keyboard or from a controller. This command can be used to check DC and AC voltage, 2-wire ohms, RTD, and thermistor connections.

The following program segment shows how to use the MONMEAS command with a controller to verify DC voltage connections on Channels 200 through 204. The CONF command configures the voltmeter accessory for DC voltage measurements. For this example, a relay MUX is installed in slot 2 of the mainframe and a voltmeter accessory is installed in slot 0 of the mainframe.

```
10  OUTPUT 709; "USE 0"
20  OUTPUT 709; "CONF DCV"
30  OUTPUT 709; "MONMEAS DCV,200-204"
40  END
```

The five channels will be scanned and measured one at a time starting with Channel 200. Press "SADV KEY" on the HP 3852A front panel to advance the scanning to the next channel. When the scan is advanced past the last channel (Channel 204 in this example), scanning will stop and the last measurement will remain on the display.

Reading Channel State

The CLOSE? command can be used to determine the state of the relay MUX channels. This command returns one of four numbers for each channel queried. The numbers returned indicate if a channel is open or closed and to which bus the channel is connected. Table 5-3 shows the channel state for each value that can be returned by the CLOSE? command when used with the 60-Channel Relay MUX.

Table 5-3. Values Returned by the CLOSE? Command

Data Returned	Channel State
0	Channel Open
1	Channel Closed (Valid only for Source Bus Tree Switch - Channel 91)
2	Channel Closed - connected to Sense Bus
4	Channel Closed - connected to Sense Bus and Source Bus

NOTE

The CLOSE? command will return 2 or 4 only to indicate the state of Channels 0 through 59 (i.e., these values will not be returned for the tree switches).

Example: Reading Channel State

This example program shows how to use the CLOSE? command to read the state of Channels 0 through 4 on a relay MUX. The RST command resets the relay MUX to its power-on state where all channels are open. The CLOSE command closes Channel 3 and the Sense Bus tree switch. The OPEN command is used to open the channels and disconnect them from the backplane. For this example, a relay MUX is installed in slot 2 of the mainframe.

```
10  OUTPUT 709; "RST 200"
20  INTEGER State(4)
30  OUTPUT 709; "CLOSE 203"
40  OUTPUT 709; "CLOSE? 200-204"
50  ENTER 709; State(*)
60  PRINT State(*)
70  OUTPUT 709; "OPEN 203"
80  END
```

Typical Output (Channel 3 closed - connected to Sense Bus):

```
0  0  0  2  0
```

Programming the 60-Channel Relay MUX

As noted in the Introduction section of this chapter, the relay MUX has three primary functions: voltage measurements, 2-wire ohms measurements, and temperature measurements. This section contains examples that show how to program the accessory for each function. It includes a description of each function, applicable commands for the functions, and programming examples. Each example includes a sample program and (where applicable) typical outputs for the assumed conditions.

This section also summarizes the programming commands used with the relay MUX (refer to "Command Summary") and lists the titles of the example programs (refer to "Program Titles").

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

NOTE

The example programs show how to make typical measurements using the relay MUX with the HP 44701A Integrating Voltmeter Accessory or the HP 44702 High-Speed Voltmeter Accessory (when used on the backplane). Refer to the Mainframe Configuration and Programming Manual for instructions on making measurements using an external voltmeter.

Command Summary

Table 5-4 is an alphabetical listing of commands which apply to the relay MUX accessory. Refer to the HP 3852A Command Reference Manual for a complete description of these commands.

Table 5-4. Commands for the 60-Channel Relay MUX

CLOSE *ch list*

Closes a single multiplexer channel or a list of channels specified by *ch list*. This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

CLOSE? *ch list* [INTO *name*] or [*fmt*]

Queries the state of channels specified by *ch list*.

CONFMEAS *function* , *ch list* [USE *ch*] [INTO *name*] or [*fmt*]

Configures the voltmeter accessory and measures a function on the channels specified by *ch list*. This command automatically configures the voltmeter accessory and the tree switches on the multiplexer for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function* , *ch list* [USE *ch*] [INTO *name*] or [*fmt*]

Scans and measures a function on the channels specified by *ch list*. This command does not configure the voltmeter accessory but it does configure the tree switches on the multiplexer for the measurement.

MONMEAS *function* , *ch list* [USE *ch*]

Monitors and measures a function on the channels specified by *ch list*. This command is useful to check wiring connections made on the terminal module.

OPEN *ch list*

Opens a single multiplexer channel or a list of channels specified by *ch list*. This command is used to open channels and place them in a safe state after the measurements have been made.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Program Titles

The discussion for each function includes one or two examples that show how to program the relay MUX for that function. Table 5-5 lists the titles of the example programs in this section.

Table 5-5. Program Titles

NOTE

When using more than one relay multiplexer function, it is recommended that similar types of measurements be grouped together in order to maximize relay life and minimize voltmeter function changes.

For example, if you are making DC voltage measurements and 2-wire ohms measurements, group all of the voltage measurements together and all of the resistance measurements together. In this way, the tree switches will be opened and closed fewer times and the voltmeter function won't be changed as often.

Making Voltage Measurements

One of the functions of the relay MUX accessory is to make single-ended voltage measurements. This section explains how to program the accessory to make single-ended DC and AC voltage measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 60-channel relay MUX is 42 VDC or 30 VAC rms (42V peak). Refer to Table 5-1 for the specifications.

NOTE

The AC voltage function is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC voltage measurements.

Example: Measuring DC and AC Voltage Sources

Suppose that you want to measure the outputs from 60 voltage sources using the relay MUX and the single-ended voltage function. See Figure 5-3 to connect voltage sources to the terminal module.

Table 5-5. Program Titles

TITLE	DESCRIPTION	COMMANDS
	Voltage Measurements	
Measuring DC and AC Voltage Sources	Measures the outputs from 60 voltage sources using the relay MUX.	CONFMEAS
Measuring Voltage Sources using the CLOSE Command	Measures the output from a voltage source using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	2-Wire Ohms Measurements	
Measuring Resistors using the 2-Wire Ohms Function	Measures 60 resistors using the relay MUX and the 2-wire ohms measurement function.	CONFMEAS
Making 2-Wire Ohms Measurements using the CLOSE Command	Measures a single resistor using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	Temperature Measurements	
Measuring Temperature using RTDs	Makes 60 temperature measurements using the relay MUX and the 2-wire RTD measurement function.	CONFMEAS
Measuring Temperature using Thermistors	Makes 60 temperature measurements using the relay MUX and the 2-wire thermistor measurement function.	CONFMEAS

The following example program uses the CONFMEAS command to measure 60 DC voltage sources connected to Channels 0 through 59. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the 60 channels once.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70  OUTPUT 709; "CONFMEAS ACV,200-259,USE 0"
```

```
 10  !
 20  !Use the CONFMEAS command to measure 60 DC voltages using a
 30  !relay MUX in slot 2 of the mainframe.  Install a voltmeter
 40  !accessory in slot 0 of the mainframe.
 50  !
 60  REAL Volts(59)
 70  OUTPUT 709; "CONFMEAS DCV,200-259,USE 0"
 80  FOR I = 0 TO 59
 90  ENTER 709; Volts(I)
100  PRINT "Ch.";I, Volts(I)
110  NEXT I
120  END
```

Typical DC voltage values for the assumed conditions:

```
Ch. 0   4.30300
Ch. 1   4.33350
      .
      .
      .
Ch. 58  4.58580
Ch. 59  3.49490
```

Example: Measuring Voltage Sources using the CLOSE Command

Suppose that you want to measure the output from a voltage source using the CLOSE command to control the tree switches and bank switches. See Figure 5-3 to connect a voltage source to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0 and the Sense Bus tree switch. The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the DC voltage from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 90:

```
90  OUTPUT 709; "FUNC ACV"
```

```
 10  !
 20  !Use the CLOSE command to make a DC voltage measurement of
 30  !the voltage source connected to Channel 0 on a relay MUX
 40  !in slot 2 of mainframe.  Install a voltmeter accessory
 50  !in slot 0 of mainframe.
 60  !
 70  OUTPUT 709; "USE 0"
 80  OUTPUT 709; "CLOSE 200"
 90  OUTPUT 709; "FUNC DCV"
100  OUTPUT 709; "TRIG SGL"
110  OUTPUT 709; "CHREAD 0"
120  ENTER 709; Volts
130  PRINT Volts
140  OUTPUT 709; "OPEN 200"
150  END
```

Typical DC voltage value for the assumed conditions:

```
3.94940
```

Making 2-Wire Ohms Measurements

One of the functions of the relay MUX is to make resistance ohms measurements. The section explains how to program the relay MUX for 2-wire ohms measurements.

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 60 resistance measurements per relay MUX.

NOTE

There is a 100Ω offset error when making resistance measurements using the relay MUX. This offset is due to the 100Ω protection resistor in series with the LOW terminal on the terminal module. The resistor can be shorted out, but this will seriously shorten relay life if high voltages or currents are switched.

When using the relay MUX for 2-wire ohms measurements, the voltmeter accessory is actually configured for a 4-wire ohms measurement. The relay MUX converts the 4-wire function on the voltmeter to a 2-wire function on the component module. It does this by connecting the high voltage sense lead to the high current source lead and the low voltage sense lead to the low current source lead. Therefore, only two leads are used on the relay MUX for the 2-wire ohms measurement.

<u>Example: Measuring Resistors using the 2-Wire Ohms Function</u>

Suppose that you want to measure 60 resistors connected to the relay MUX using the 2-wire ohms function. See Figure 5-4 to connect resistors to the terminal module for 2-wire ohms measurements.

The following example program uses the CONFMEAS command to measure 60 resistors connected to Channels 0 through 59. The CONFMEAS command configures the voltmeter accessory for the 2-wire ohms measurement and measures the 60 channels once.

```
 10  !
 20  !Use the CONFMEAS command to measure 60 resistors using
 30  !a relay MUX in slot 3 of the mainframe.  Install a
 40  !voltmeter accessory in slot 0 of the mainframe.
 50  !
 60  REAL Ohms(59)
 70  OUTPUT 709; "CONFMEAS OHM,300-359,USE 0"
 80  FOR I = 0 TO 59
 90  ENTER 709; Ohms(I)
100  PRINT "Ch.";I, Ohms(I)
110  NEXT I
120  END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
Ch. 0    4628.340
Ch. 1    5024.960
      .
      .
      .
Ch. 58   4039.460
Ch. 59   6528.380
```

Example: Making 2-Wire Ohms Measurements using the CLOSE Command

Suppose that you want to make a 2-wire ohms measurement of a resistor using the CLOSE command to control the tree switches and bank switches. See Figure 5-4 to connect a resistor to the terminal module for a 2-wire ohms measurement.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the Sense Bus tree switch, and the Source Bus tree switch (Channel 91). The FUNC command configures the voltmeter accessory for 4-wire ohms measurements (the relay MUX converts the 4-wire function to a 2-wire function on the component module). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance value from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

The following program uses the HP 44701A Integrating Voltmeter Accessory. To use this program with the HP 44702 High-Speed Voltmeter Accessory on the backplane, substitute the following line for the existing line 80:

```
80  OUTPUT 709; "FUNC OHMF10K"
```

```
10  !
20  !Use the CLOSE command to make a 2-wire ohms measurement
30  !of Channel 0 on a relay MUX in slot 3 of the mainframe.
40  !Install a voltmeter accessory in slot 0 of the mainframe.
50  !
60  OUTPUT 709; "USE 0"
70  OUTPUT 709; "CLOSE 300,391"
80  OUTPUT 709; "FUNC OHMF"
```

```
90  OUTPUT 709; "TRIG SGL"
100 OUTPUT 709; "CHREAD 0"
110 ENTER 709; Ohms
120 PRINT Ohms
130 OUTPUT 709; "OPEN 300,391"
140 END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
5623.570
```

Making Temperature Measurements

One of the functions of the relay MUX accessory is to make temperature measurements. This section shows how to program the accessory to make RTD measurements and thermistor measurements.

NOTE

There is a 100Ω offset error when making 2-wire temperature measurements using the relay MUX. This offset is due to the 100Ω protection resistor in series with the LOW terminal on the terminal module. The resistor can be shorted out but this will seriously shorten relay life if high voltages or currents are switched.

Measuring Temperature using RTDs

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 Ω/Ω°C and 0.003916 Ω/Ω°C and resistance values of 100Ω at 0°C.

Most RTDs have small resistance values (typically less than 300Ω) which makes the test lead resistance a significant factor when making measurements. The relay MUX can be used in temperature applications where accuracy is not so important, such as when checking the integrity of your transducers. Up to sixty 2-wire RTD measurements can be made per relay MUX accessory.

Example: Measuring Temperature using RTDs

Suppose that you want to make 60 temperature measurements using RTDs and the 2-wire ohms function. See Figure 5-5 to connect RTDs to the terminal module for 2-wire temperature measurements.

The following example program uses the CONFMEAS command to scan and measure 60 RTDs (with α = 0.00385 Ω/Ω°C) using the 2-wire function. The program scans Channels 0 through 59 once and returns the results (in °C) to the controller.

```
10  !
20  !Use the CONFMEAS command to make sixty 2-wire RTD measurements
30  !using a relay MUX in slot 2 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Temp(59)
70  OUTPUT 709; "CONFMEAS RTD85,200-259,USE 0"
80  FOR I = 0 TO 59
90  ENTER 709; Temp(I)
100 PRINT "Ch.";I, Temp(I)
110 NEXT I
120 END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0   24.54297
Ch. 1   24.54299
      .
      .
      .
Ch. 58  25.55805
Ch. 59  25.85645
```

Measuring Temperature using Thermistors

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. Thermistors are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

Up to sixty 2-wire thermistor measurements can be made per accessory using the relay MUX accessory. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

<u>Example: Measuring Temperature using Thermistors</u>

Suppose that you want to make 60 temperature measurements using 5 kΩ thermistors and the 2-wire function. See Figure 5-6 to connect thermistors to the terminal module for 2-wire temperature measurements.

The following example program uses the CONFMEAS command to measure 60 thermistors using the 2-wire function. The program scans Channels 0 and 59 once and returns the results (in °C) to the controller.

```
10  !
20  !Use the CONFMEAS command to measure 60 5 kΩ thermistors
30  !using a relay MUX in slot 2 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Temp(59)
70  OUTPUT 709; "CONFMEAS THM5K,200-259,USE 0"
80  FOR I = 0 TO 59
90  ENTER 709; Temp(I)
100 PRINT "Ch.";I, Temp(I)
110 NEXT I
120 END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0   24.54297
Ch. 1   24.54299
      .
      .
      .
Ch. 58  25.55805
Ch. 59  25.85645
```

Chapter 6
HP 44708A
20-Channel Relay Mux/TC

Contents

Chapter 6
HP 44708A 20-Channel Relay MUX/TC

Chapter 6

20-Channel Relay MUX/TC

HP 44708A

Introduction

This chapter shows how to configure and program the HP 44708A 20-Channel Relay Multiplexer (MUX) with Thermocouple Compensation Accessory. The chapter has four sections: Introduction, Specifications, Configuring the 20-Channel Relay MUX/TC, and Programming the 20-Channel Relay MUX/TC.

- **Introduction** contains a chapter overview, a description of the relay MUX, a description of its functions, and shows suggested steps to get started.
- **Specifications** lists the specifications for the accessory.
- **Configuring the 20-Channel Relay MUX/TC** contains a block diagram description of the accessory, shows how to hardware configure the terminal module, and shows how to connect field wiring to the terminal module.
- **Programming the 20-Channel Relay MUX/TC** shows how to program the accessory for voltage, current, resistance, and temperature measurements.

Description

The relay MUX is used to switch (multiplex) signals from up to 20 channels for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory provides switching capability for the 20 channels at scanning speeds up to 450 channels per second using an HP 3852A voltmeter accessory. This accessory can switch signals up to 170 VDC or 120 VAC rms (170V peak).

The relay MUX accessory consists of a 20-channel terminal module and a relay MUX component module. This accessory uses the same component module as the HP 44705A 20-Channel Relay MUX Accessory but adds a special isothermal connector block on the terminal module. The isothermal connector block is used to eliminate unwanted measurement errors when making thermocouple measurements.

Functions

The relay MUX accessory is used to switch signals for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory can be used to switch signals for four primary functions:

- Voltage Measurements.
- Current Measurements.
- 2-Wire Resistance (or Ohms) Measurements.
- Temperature Measurements.

NOTE

Each channel on the relay MUX can be independently configured to allow multiple functions to be measured using the same accessory.

Voltage Measurements

The relay MUX can be used to switch signals for guarded (3-wire) DC voltage and AC voltage measurements. In the guarded voltage measurement function, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection. Use this function to make up to 20 voltage measurements per relay MUX accessory.

Current Measurements

The relay MUX can be used to switch signals for DC and AC current measurements using current sensing. Current sensing is a method of determining current using a shunt resistor that you install on the terminal module. Use this function to make up to 20 current measurements per relay MUX accessory.

NOTE

Current sensing measurements are not recommended when making temperature measurements on the same terminal module. The heat produced by the shunt resistor may affect the accuracy of the temperature measurement.

2-Wire Ohms Measurements

The relay MUX can be used to switch signals for 2-wire ohms measurements. In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per relay MUX accessory.

NOTE

Four-wire ohms measurements cannot be made using the 20-Channel Relay MUX/TC accessory.

Temperature Measurements

The relay MUX can be used to switch signals for making temperature measurements using thermocouples, resistance temperature detectors (RTDs), and thermistors. Thermocouples provide simple, durable, inexpensive, and relatively accurate temperature measurements over a wide range of temperatures. RTDs are typically more stable and accurate than thermocouples or thermistors. Thermistors are more sensitive to temperature changes than thermocouples or RTDs.

Use the measurement function to make up to twenty 2-wire temperature measurements per relay MUX accessory. The HP 3852A temperature conversions support the following thermocouples, RTDs, and thermistors:

Thermocouple types supported (Software compensation used):

B, E, J, K, N (awg 14), N (awg 28), R, S, and T

RTDs supported:

$\alpha = 0.00385\ \Omega/\Omega°C$ (100Ω at 0°C)
$\alpha = 0.003916\ \Omega/\Omega°C$ (100Ω at 0°C)

Thermistors supported:

2252Ω at 25°C
5 kΩ at 25°C
10 kΩ at 25°C

NOTE

Other transducers can be measured using the relay MUX but only those listed above are supported by the HP 3852A conversions.

Getting Started

To use the relay MUX accessory for your application, you will need to follow three steps:

- Define your application.
- Configure the accessory for your application.
- Program the accessory for your application.

Define your Application

The first step is to define your application and determine if the accessory can meet the requirements of your application. The relay MUX can switch DC or AC inputs up to 170 VDC or 120 VAC rms (170V peak). Since each of the 20 channels can be independently configured, up to 20 different devices can be connected to the accessory. When selecting devices to be connected, refer to Table 6-1 "20-Channel Relay MUX/TC Specifications" to ensure that the voltage and current requirements of your application are within the specifications for this accessory.

Configure the Accessory

The next step is to configure the accessory for your application. Refer to "Configuring the 20-Channel Relay MUX/TC" for information on hardware configuration (setting jumpers and switches) and connecting field wiring to the terminal module for voltage, current, 2-wire ohms, and temperature measurements.

Program the Accessory

The third step is to program the relay MUX for your application. Refer to "Programming the 20-Channel Relay MUX/TC" to program the accessory for voltage, current, 2-wire ohms, and temperature measurements.

Specifications

Table 6-1 lists the specifications for the relay MUX. This table contains five categories: Input Characteristics, Operating Characteristics, Thermocouple Characteristics, RTD Characteristics, and Thermistor Characteristics.

WARNING

The HP 3852A and the HP 3853A internal analog buses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the HP 3852A, HP 3853A, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum Allowable Peak Voltage
HP 3852A Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	350V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexer	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extenders, each instrument is considered as a separate circuit.

Table 6-1. 20-Channel Relay MUX/TC Specifications

INPUT CHARACTERISTICS:

Maximum Input Voltage:

Between any two input terminals or to chassis:
170V peak, 170 VDC, 120 VAC rms

Maximum Current: 50 mA per channel non-inductive

Injected Current: ±1 nA DC
(Injected currents are sourced by the accessory into HIGH and LOW; RH < 85% @ 28°C or < 60% @ 40°C.)

Maximum Power: 1 VA per channel

DC Offset:

HIGH and LOW Relays: ±1 uV Per Relay
To backplane including tree switches: ±2 uV Differential
Guard Relays (Not low-thermal): ±100 uV

Closed Channel Resistance:

In Series: 100Ω ±10% in HIGH, LOW, and GUARD Lines
Contacts Only: 1Ω per contact

OPERATING CHARACTERISTICS:

Maximum Scan Rate (channels per second):

Using HP 3852A Voltmeter Accessories: 450
Using External Voltmeter: 500

Relay Characteristic Lifetime: [1]

Voltage [2]	Number of Cycles
10V	$> 10^8$
40V	1.5×10^7
100V	10^7

[1] Characteristic lifetime of a single relay on the HP 44705A in the mainframe with one HP 44701A Integrating Voltmeter.

[2] Total peak voltage between one scanned channel and the next or from a scanned channel to 0V (whichever is greater).

Synchronization: Break-Before-Make in scanning operation

Table 6-1. 20-Channel Relay MUX/TC Specifications (cont'd)

THERMOCOUPLE CHARACTERISTICS:

Sense Accuracy (one year): 18-40°C ±0.1°C
0-60°C ±0.2°C

Temperature Gradient (one hour warm-up): ±0.2°C

Thermocouple Types Supported:

Type B: Platinum/6% Rhodium - Platinum/30% Rhodium
Type E: Chromel - Constantan
Type J: Iron - Constantan
Type K: Chromel - Alumel
Type N: Nicrosil - Nisil (14 awg)
Type N: Nicrosil - Nisil (28 awg)
Type R: Platinum - Platinum/13% Rhodium
Type S: Platinum - Platinum/10% Rhodium
Type T: Copper - Constantan

RTD CHARACTERISTICS:

RTD Types Supported:

Type: Platinum, α = 0.00385 Ω/Ω°C,
100Ω at 0°C
Type: Platinum, α = 0.003916 Ω/Ω°C,
100Ω at 0°C

THERMISTOR CHARACTERISTICS:

Thermistor Types Supported:

Type: 2252Ω at 25°C
Type: 5 kΩ at 25°C
Type: 10 kΩ at 25°C

Configuring the 20-Channel Relay MUX/TC

This section shows how to configure the relay MUX accessory. It contains a block diagram description of the accessory, information on hardware configuring the terminal module, and information on connecting field wiring to the terminal module.

Refer to "Programming the 20-Channel Relay MUX/TC" to program the accessory for voltage, current, 2-wire ohms, and temperature measurements.

WARNING

SHOCK HAZARD. Only qualified, service-trained personnel who are aware of
the hazards involved should install, remove, or configure any accessory. Before
1 *touching any installed accessory, turn off all power to the mainframe, extenders,*
and to all external devices connected to the mainframe, extenders, and accessories.

WARNING

POSSIBLE OPERATOR INJURY. Under most conditions of failure, the relays
on the relay MUX will remain in whatever state your program has set them.
However, for some equipment failures, the relays may not remain in their
programmed state. If the relays settle in the closed state, the relay contacts may
weld together and the highest voltage present on any one channel may be present
2 *on all channels. This condition may cause operator injury if the terminals are*
touched or equipment damage may result.

For example, see Figure 6-1 which shows the block diagram for the relay MUX. If Channel 0 (BANK A terminal 0) is at 100 volts and a failure occurs which causes the relay contacts to weld together, the 100 volts may be present on all 20 channels of the accessory.

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers attached.

Block Diagram Description

The relay MUX accessory consists of a 20-channel terminal module and a relay MUX component module as shown in Figure 6-1. Field wiring from your application sensors, such as thermocouples, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Figure 6-1. 20-Channel Relay MUX/TC Block Diagram

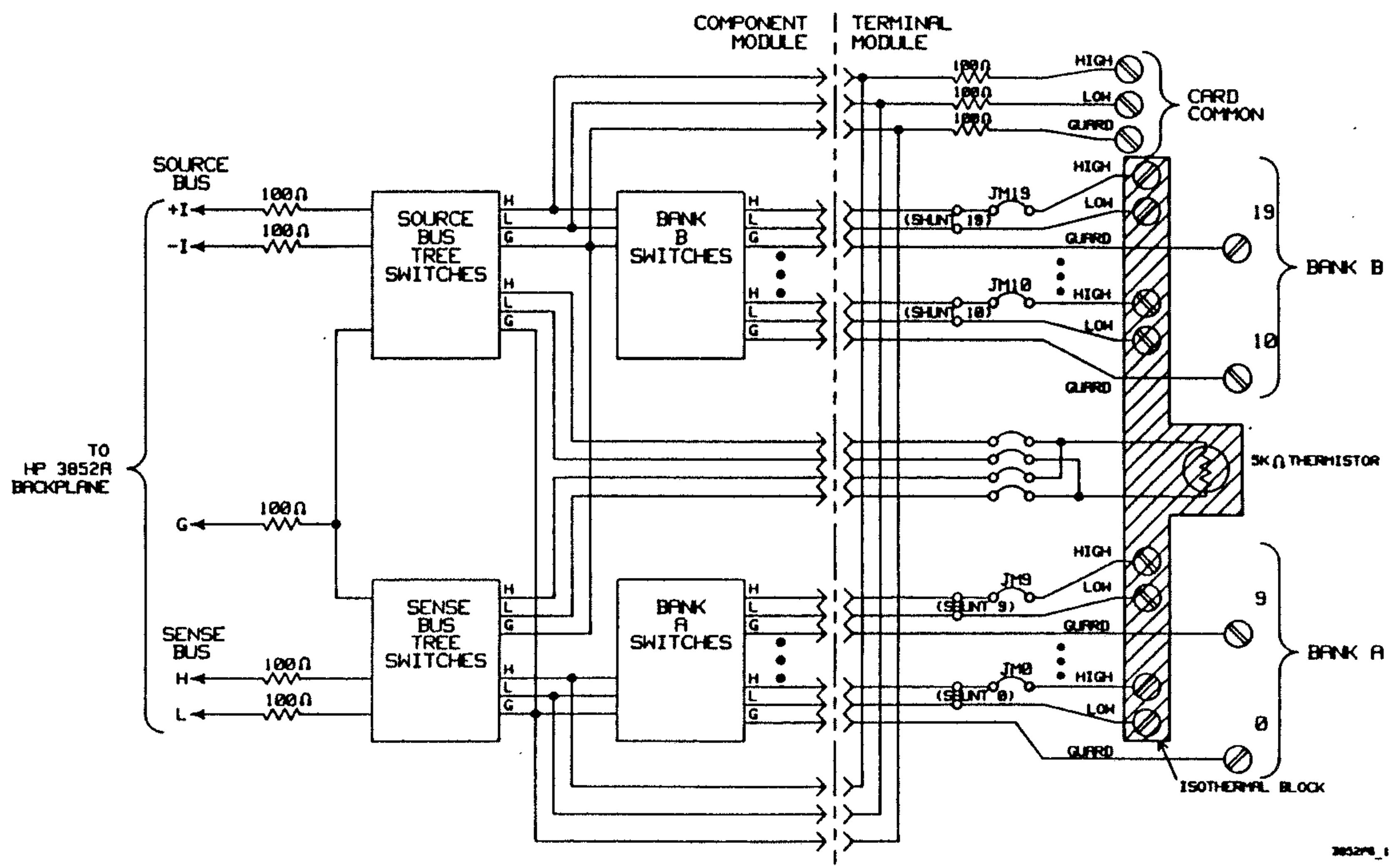


Figure 6-1. 20-Channel Relay MUX/TC Block Diagram

A special isothermal connector block on the terminal module eliminates unwanted measurement errors when making thermocouple measurements. A 5 kΩ thermistor is mounted on the isothermal connector block to measure the reference temperature. The HP 3852A uses software compensation to automatically compensate for the reference temperature when making thermocouple measurements.

The component module is made up of 24 switches which are divided into two categories: bank switches and tree switches. Each of the 24 switches consists of three reed-actuated relays, one each for HIGH, LOW, and GUARD lines. There are a total of 20 bank switches which are divided into two groups of 10 channels each: BANK A and BANK B. The channels in BANK A are numbered 0 through 9 and the channels in BANK B are numbered 10 through 19.

NOTE

Only one channel per bank can be closed at a time. Closing a second channel in a bank will open any previously closed channel in that bank.

The component module contains four tree switches which are of two types: Source Bus tree switches and Sense Bus tree switches. BANK A and BANK B share a Source Bus tree switch and a Sense Bus tree switch. The other Source Bus and Sense Bus tree switches are used to measure the reference temperature when making thermocouple measurements. The tree switches control signal flow to and from the HP 3852A backplane and also isolate the tree switches from the backplane when they are not in use. The Sense Bus tree switches provide the connections to the backplane for making voltage measurements. The Source Bus tree switches provide the current source connections (+I and -I) to the backplane for resistance measurements.

An Isolation Jumper on the component module allows you to disconnect the tree switches from the HP 3852A backplane for special signal routing applications. For more information on the Isolation Jumper, refer to "Setting the Isolation Jumper".

Table 6-2 shows the channel definitions for the relay MUX accessory. Channels 0 through 19 control the bank switches and Channels 91 through 94 control the tree switches. Note that Channels 91 and 94 control the tree switches for BANK A and BANK B. Channels 92 and 93 control the tree switches for the thermistor on the isothermal connector block.

Table 6-2. 20-Channel Relay MUX/TC Channel Definitions

Channel	Definitions
0 - 9	BANK A switches
10 - 19	BANK B switches
91	Sense Bus Tree Switch (bank switches)
92	Sense Bus Tree Switch (thermistor)
93	Source Bus Tree Switch (thermistor)
94	Source Bus Tree Switch (bank switches)

NOTE

Two tree switches of the same type cannot be closed simultaneously (e.g., only one of the two Sense Bus tree switches can be closed at a time). Closing a second tree switch will open any previously closed tree switch of the same type.

The BANK A and BANK B terminals are connected together on the terminal module to form the CARD COMMON terminal. As factory configured, there are three 100Ω current limiting resistors in series with the CARD COMMON terminal.

Five 100Ω resistors on the component module connect the tree switches to the HP 3852A backplane. These resistors provide current limiting protection for the relays on the component module. The resistors do not affect resistance measurements (2-wire ohms error due to contact and trace error < 2Ω). The resistors can be shorted out, but this will seriously shorten relay life if high voltages or currents are switched.

⚠1 Configuring the Terminal Module

This section shows how to hardware configure the terminal module. It shows how to set the Isolation Jumper and how to install low pass filters and attenuators for input signal conditioning.

Setting the Isolation Jumper

The tree switches on the relay MUX can be connected or disconnected from the HP 3852A backplane using the Isolation Jumper. Figure 6-2 shows the location of the Isolation Jumper (J1) on the component module. Note that the jumper has an EN (enable) position and a DIS (disable) position. For normal operation, the Isolation Jumper should be in the enable position to connect the tree switches to the HP 3852A backplane. For applications that require tree switch isolation from the backplane, you can move the Isolation Jumper to the disable position.

NOTE

As factory configured, the Isolation Jumper is in the EN (enable) position.

Figure 6-2. Setting the Isolation Jumper

Installing Low Pass Filters

Space has been provided on the terminal module for you to install one-pole low pass filters for input signal conditioning on each channel. Figure 6-3 shows the normal channel configuration and the low pass filter channel configuration.

Figure 6-3. Low Pass Filter Channel Configuration

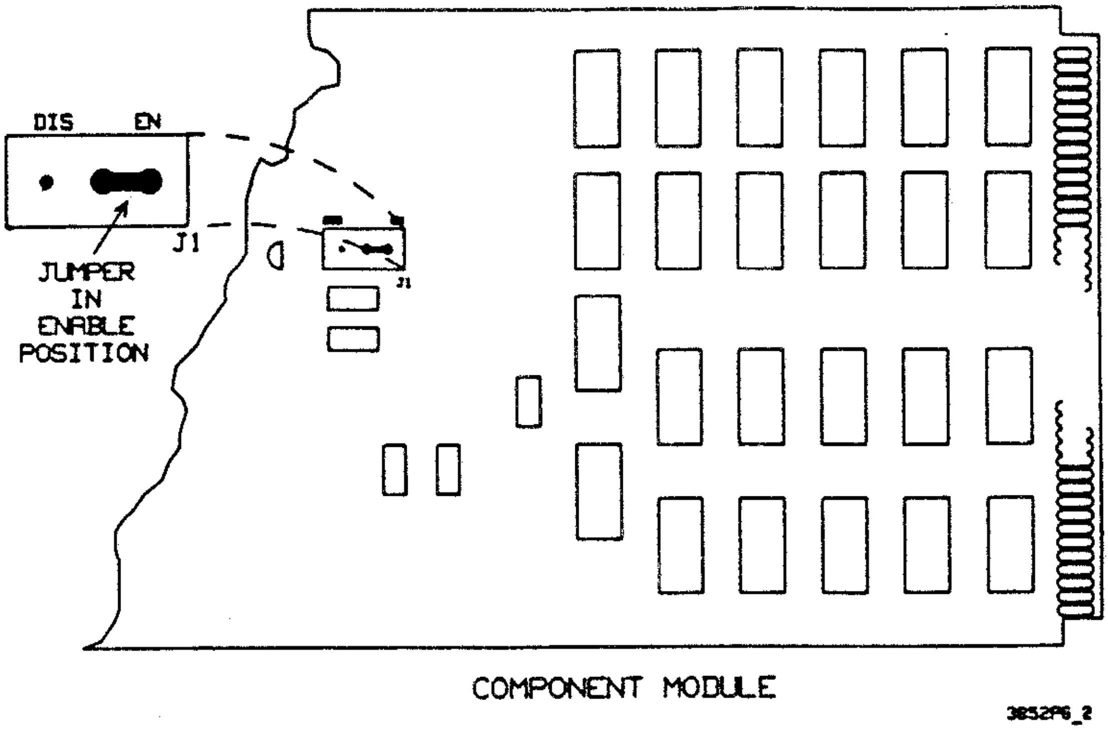


Figure 6-2. Setting the Isolation Jumper

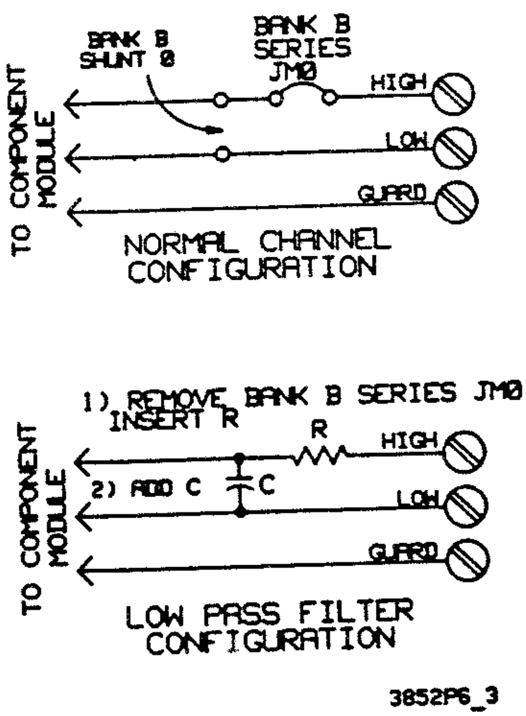


Figure 6-3. Low Pass Filter Channel Configuration

Figure 6-4 shows how to install a low pass filter for Channel 10 on the terminal module. To install the low pass filter, remove the jumper (BANK A SERIES JM 0) and install your resistor in its place. Install your capacitor in the BANK A SHUNT 0 position as shown. Precision components should be used to maintain accuracy.

Figure 6-4. Installing Low Pass Filters

Installing Attenuators

The space for low pass filters on the terminal module can also be used to install attenuators to reduce input signals to a usable level for the relay MUX. Figure 6-5 shows the normal channel configuration and how the channels are configured to attenuate input signals.

Figure 6-5. Attenuator Channel Configuration

Figure 6-6 shows how to install an attenuator for Channel 0 on the terminal module. To install the attenuator, remove the jumper (BANK B SERIES JM 0) and install resistor R1 in its place. Install resistor R2 in the BANK B SHUNT 0 position as shown. Precision components should be used to maintain accuracy.

Figure 6-6. Installing Attenuators

Connecting Field Wiring

The next step is to connect field wiring from your application to the appropriate terminals on the terminal module. The following section contains examples that show how to connect field wiring to the terminal module for voltage, current, 2-wire ohms, and temperature measurements.

Figure 6-7 shows the terminal module with the cover removed. Each of the 20 channels has a HIGH, LOW, and GUARD terminal. Terminals 0 through 9 in BANK A are for Channels 0 through 9, respectively. Terminals 0 through 9 in BANK B are for Channels 10 through 19, respectively.

Figure 6-7. 20-Channel Relay MUX/TC Terminal Module

When connecting field wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make it easier to route the wiring.

NOTE

When connecting components such as resistors, RTDs, or thermistors, the lead length may be too short to route through the strain relief clamp. In this case, the components will have to be stored inside the terminal module. When connecting these components, make sure that no leads are shorted together and bend the leads to allow the terminal module cover to be replaced.

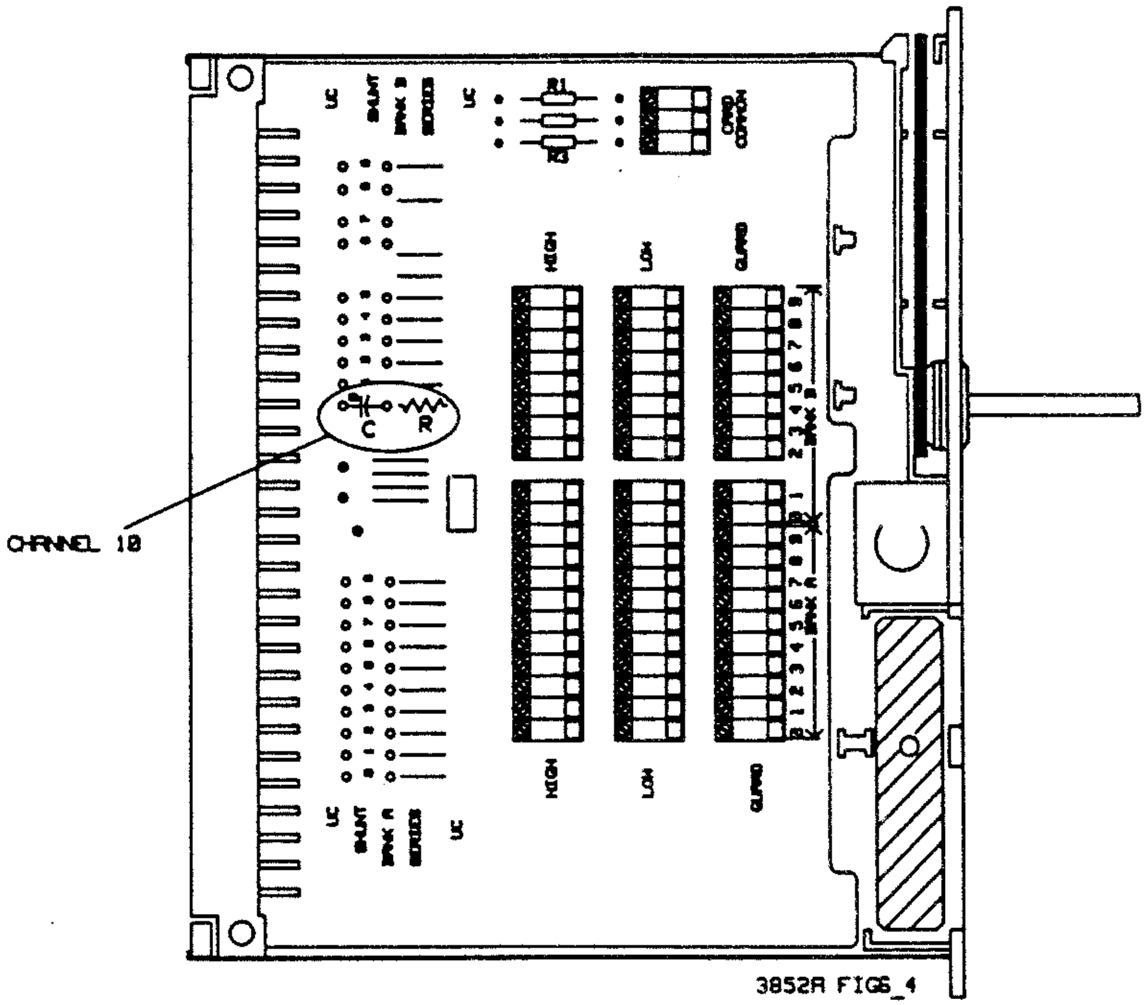


Figure 6-4. Installing Low Pass Filters

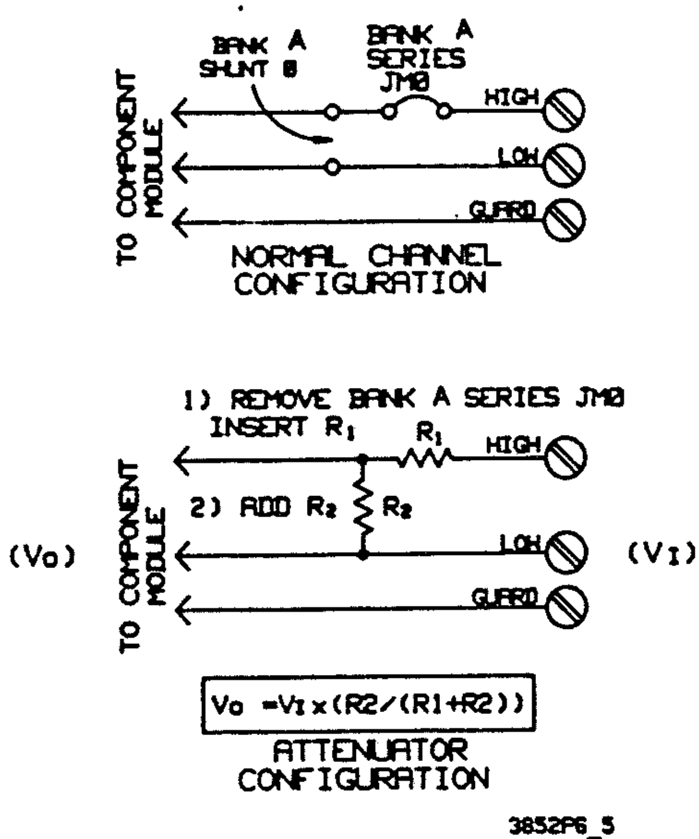


Figure 6-5. Attenuator Channel Configuration

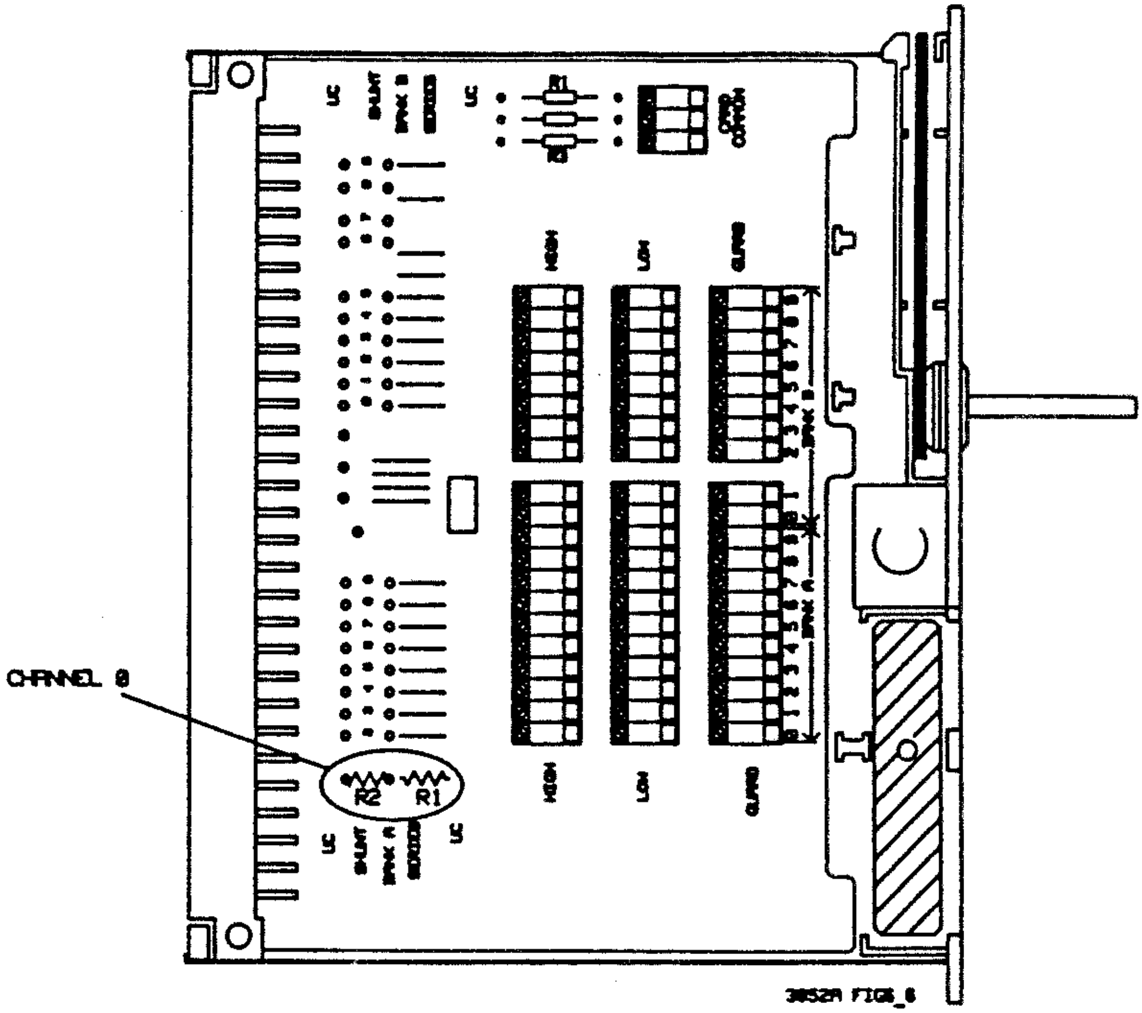


Figure 6-6. Installing Attenuators

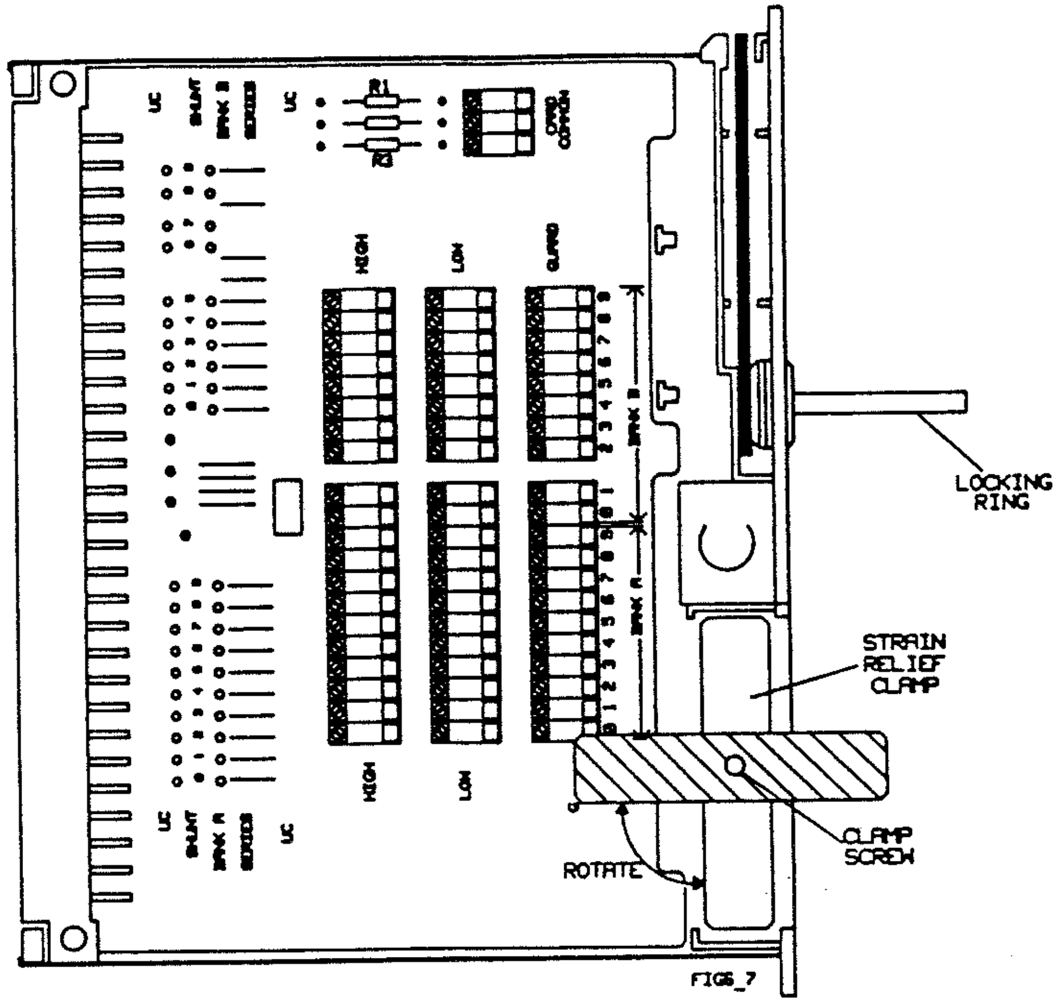


Figure 6-7. 20-Channel Relay MUX/TC Terminal Module

Connections for Voltage Measurements

In the guarded (3-wire) voltage measurement function, the relay MUX accessory can switch signals for up to 20 DC or AC voltage measurements. When making guarded voltage measurements, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX/TC is 170 VDC or 120 VAC rms (170V peak). Refer to Table 6-1 for the specifications.

CAUTION

POSSIBLE EQUIPMENT DAMAGE. When making high-voltage measurements using the relay MUX, the HP 3852A analog backplane becomes charged to the voltage on the last channel connected to it. The next channel that you close may have to absorb all of the stored energy on the backplane.

If the backplane is not discharged after making a high-voltage measurement, the voltage present on the backplane must be added to the voltage being switched on the next channel to determine the total relay contact voltage. To maximize relay life and prevent damage to sensitive transducers by high backplane discharge voltages, see Figure 6-8.

Figure 6-8. Discharging the HP 3852A Backplane

Example: Connecting Voltage Sources to the Terminal Module

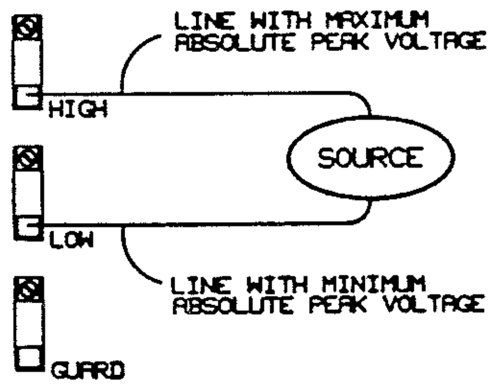
A voltage source (V0) is connected to Channel 0 on the terminal module as shown in Figure 6-9. Connect the high (+) lead from the voltage source to the HIGH terminal. Connect the low (-) lead from the voltage source to the LOW terminal. If a guarded (3-wire) voltage measurement is being made, connect the shield from the shielded twisted pair to the GUARD terminal. The shielded twisted pair is to reduce electrical noise in the measurement.

Figure 6-9. Connecting Voltage Sources to the Terminal Module

Connections for Current Measurements

The relay MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across a shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. The relay MUX can be used to switch signals for up to 20 DC or AC current measurements. When making current measurements, HIGH, LOW, and GUARD are switched on each selected channel for maximum common mode noise rejection. Figure 6-10 shows the normal channel configuration and how channels are configured for current sensing measurements.

- When measuring high-voltages, connect the line which has the highest maximum absolute peak voltage of the source to the HIGH terminal on the terminal module. Connect the line which has the lowest absolute peak voltage of the source to the LOW terminal on the terminal module. Connect the guard line ONLY if high common mode noise rejection is necessary, otherwise, do not connect the guard line.



OR

- Discharge the HP 3852A analog backplane to earth ground through 10 kΩ resistors connected to HIGH, LOW, and GUARD on an unused channel.

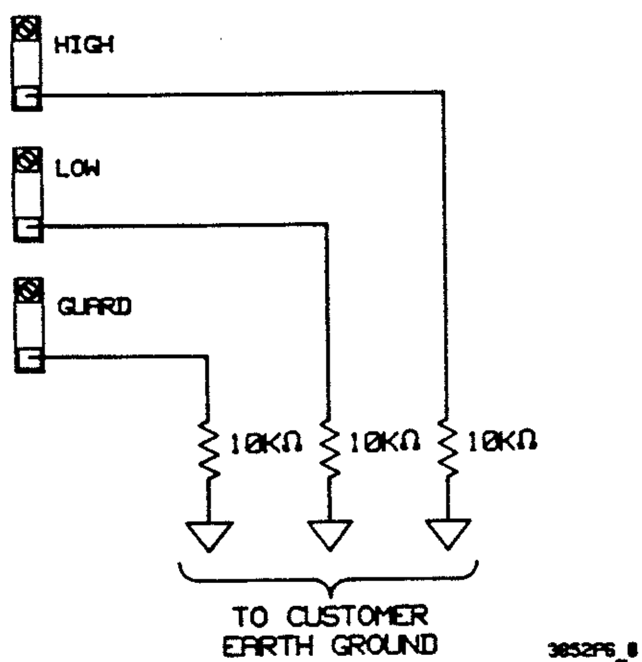


Figure 6-8. Discharging the HP 3852A Backplane

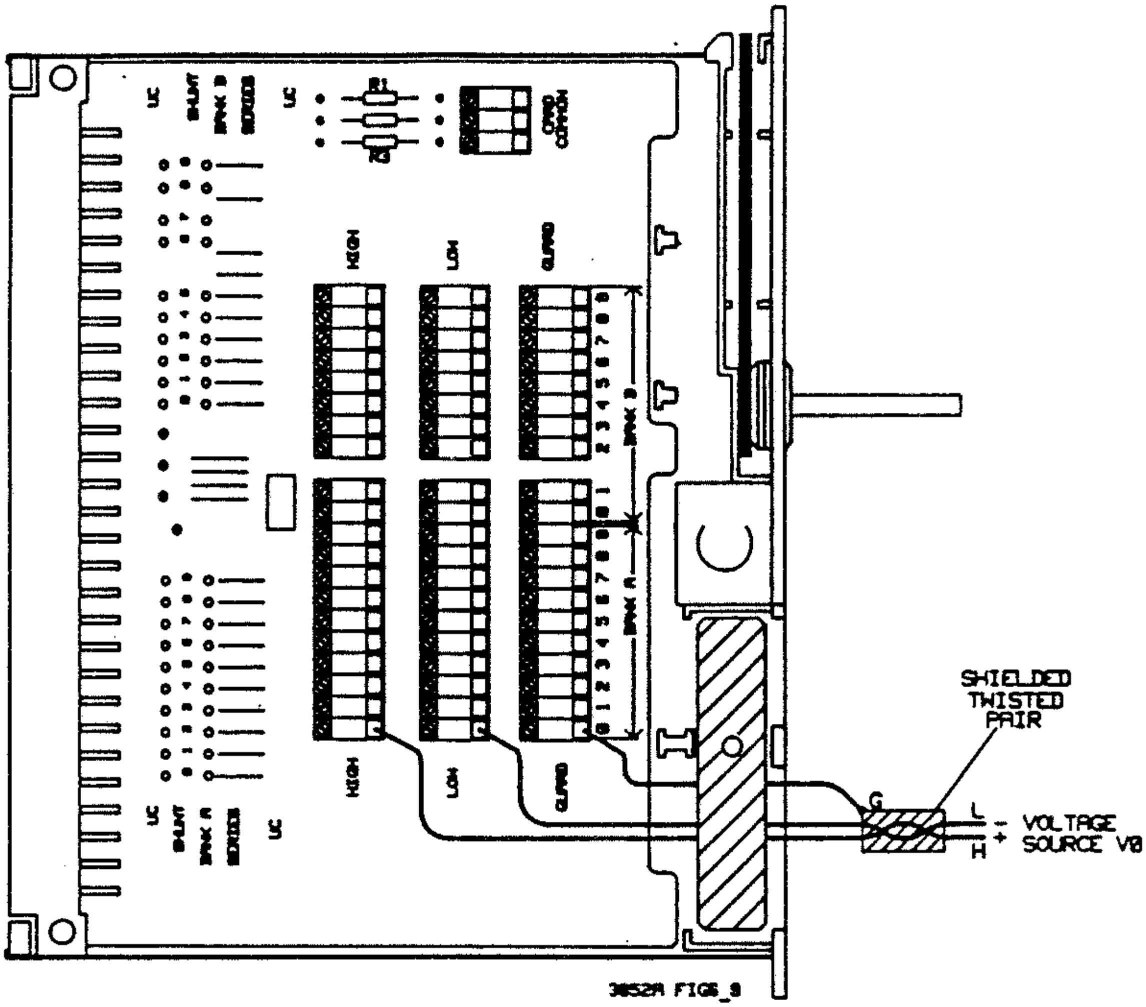


Figure 6-9. Connecting Voltage Sources to the Terminal Module

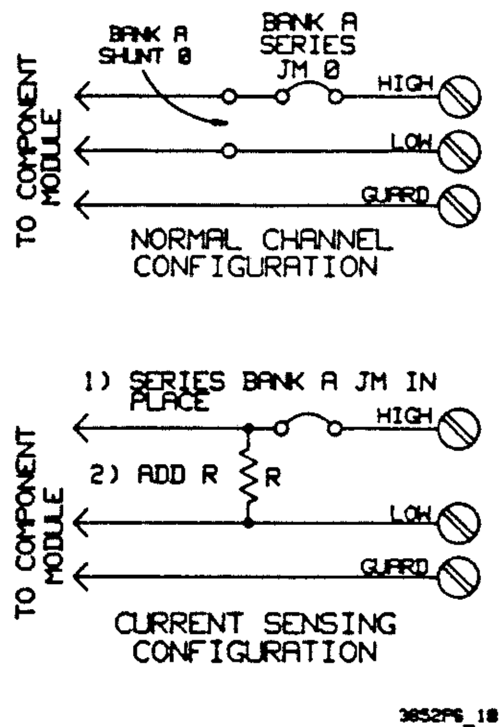


Figure 6-10. Current Sensing Configuration

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX/TC is 170 VDC or 120 VAC rms (170V peak). Refer to Table 6-1 for the specifications.

NOTE

Current sensing measurements are not recommended when making temperature measurements on the same terminal module. The heat produced by the shunt resistor may affect the accuracy of the temperature measurements.

Figure 6-10. Current Sensing Configuration

Example: Installing Shunt Resistors for Current Measurements

A 250Ω shunt resistor (R0) is installed in the shunt position (BANK A SHUNT 0) for Channel 0 on the terminal module as shown in Figure 6-11.

NOTE

The SERIES JM (jumper) must be in place on the terminal module for each channel being used for current measurements (see Figure 6-11).

Figure 6-11. Installing Shunt Resistors for Current Measurements

Connections for Resistance Measurements

One of the functions of the relay MUX accessory is to switch signals for resistance measurements. This section contains a 2-wire ohms configuration example.

Example: Connecting Resistors for 2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to switch signals for up to 20 resistance measurements per relay MUX accessory.

A resistor (R0) is connected to Channel 0 on the terminal module as shown in Figure 6-12. Connect one lead of the resistor to the HIGH terminal. Connect the other lead of the resistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the resistor low lead to the GUARD terminal.

Figure 6-12. Connecting Resistors for 2-Wire Ohms Measurements

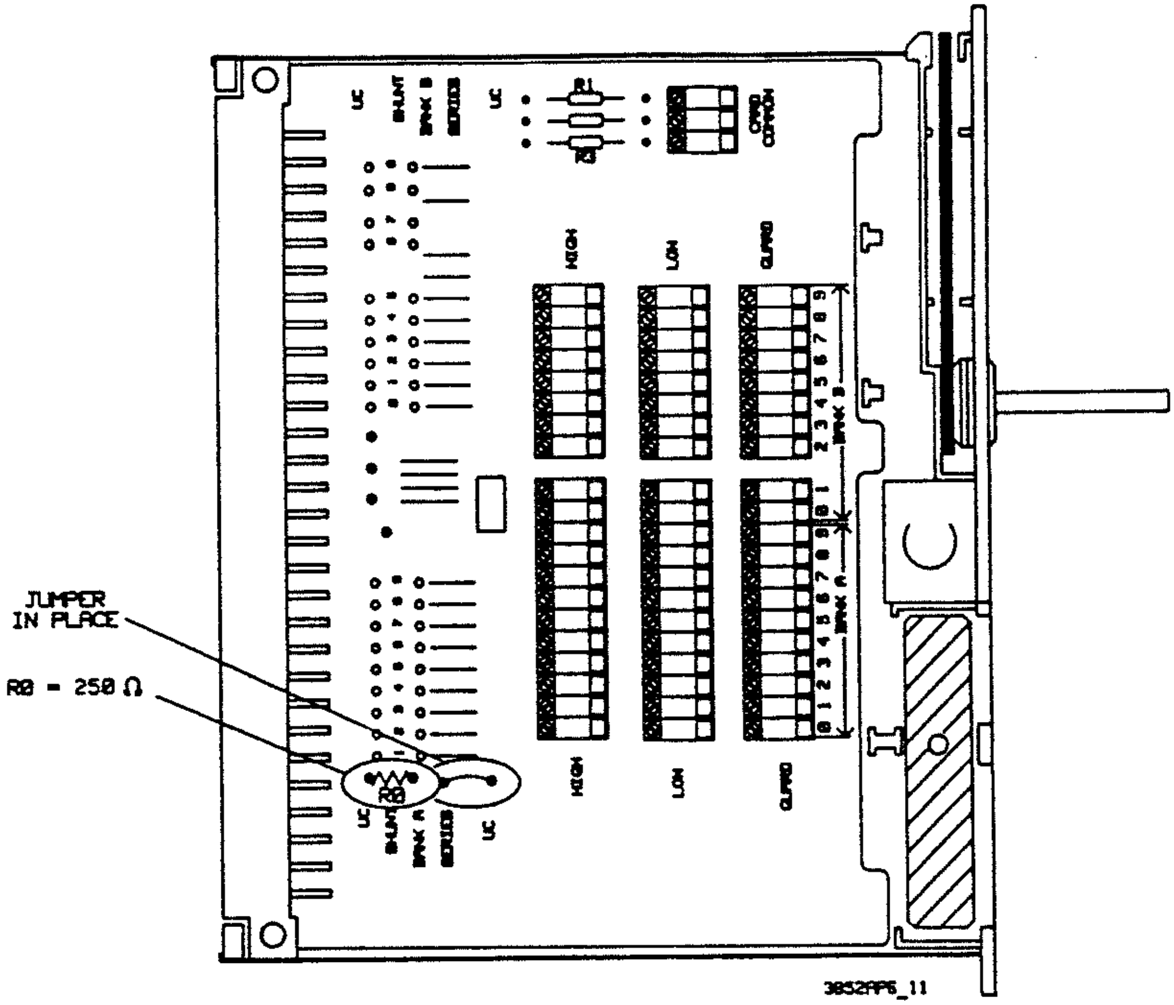


Figure 6-11. Installing Shunt Resistors for Current Measurements

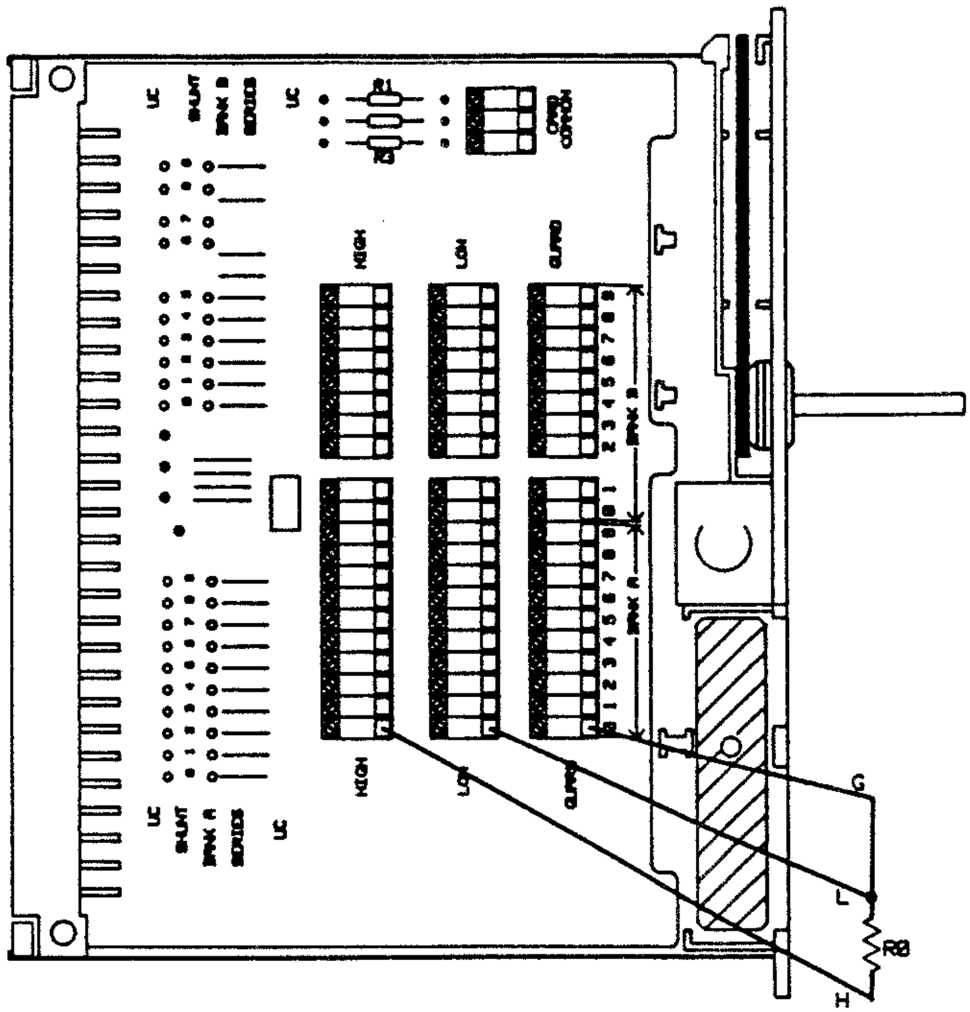


Figure 6-12. Connecting Resistors for 2-Wire Ohms Measurements

Connections for Temperature Measurements

One of the functions of the relay MUX accessory is to switch signals for temperature measurements. This section contains examples that show how to connect thermocouples, RTDs, and thermistors for temperature measurements.

<u>Example: Connecting Thermocouples for Temperature Measurements</u>

Thermocouples provide a simple, durable, inexpensive, and relatively accurate temperature sensor for a wide variety of applications and environmental conditions. The thermocouple is a junction of two unlike metals that produces a voltage related to the junction temperature. Up to 20 thermocouple measurements can be made per relay MUX accessory. The HP 3852A temperature conversions support B, E, J, K, N14, N28, R, S, and T type thermocouples.

Before connecting thermocouples to the terminal module, refer to Table 6-3 for some connection guidelines.

Table 6-3. Guidelines For Connecting Thermocouples

1. Use the largest wire possible that will not shunt heat away from the thermocouple area.
2. Use thermocouple wire that is well within its rating.
3. Avoid mechanical stress and vibration that could strain the wires.
4. For long runs, use a shielded twisted pair and connect the shield to the GUARD terminal on the terminal module.
5. Avoid steep temperature gradients.
6. In hostile environments, use proper sheathing material to reduce adverse effects on thermocouple wires.

NOTE

Since the channels on the relay MUX can be independently configured and software compensation is used, any mixture of thermocouple types can be measured using the relay MUX.

A thermocouple (TC0) is connected to Channel 0 on the terminal module as shown in Figure 6-13. Connect the negative metal lead (red lead) to the LOW terminal. Connect the positive metal lead to the HIGH terminal. Connect the guard lead (if high common mode noise rejection is required) from the thermocouple low lead to the GUARD terminal. Figure 6-14 shows three possible thermocouple wiring configurations.

Figure 6-13. Connecting Thermocouples for Temperature Measurements

Figure 6-14. Thermocouple Wiring Configurations

Example: Connecting RTDs for Temperature Measurements

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. Up to twenty 2-wire RTD measurements can be made per relay MUX accessory. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ and resistance values of 100.0Ω at 0°C.

An RTD (RTD0) is connected to Channel 0 on the terminal module as shown in Figure 6-15. Connect one lead of the RTD to the HIGH terminal. Connect the other lead of the RTD to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the RTD low lead to the GUARD terminal.

Figure 6-15. Connecting RTDs for Temperature Measurements

Example: Connecting Thermistors for Temperature Measurements

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. Thermistors are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

Up to 20 thermistor measurements can be made using a single relay MUX and the 2-wire function. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

A thermistor (THM0) is connected to Channel 0 on the terminal module as shown in Figure 6-16. Connect one lead of the thermistor to the HIGH terminal. Connect the other lead of the thermistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the thermistor low lead to the GUARD terminal.

Figure 6-16. Connecting Thermistors for Temperature Measurements

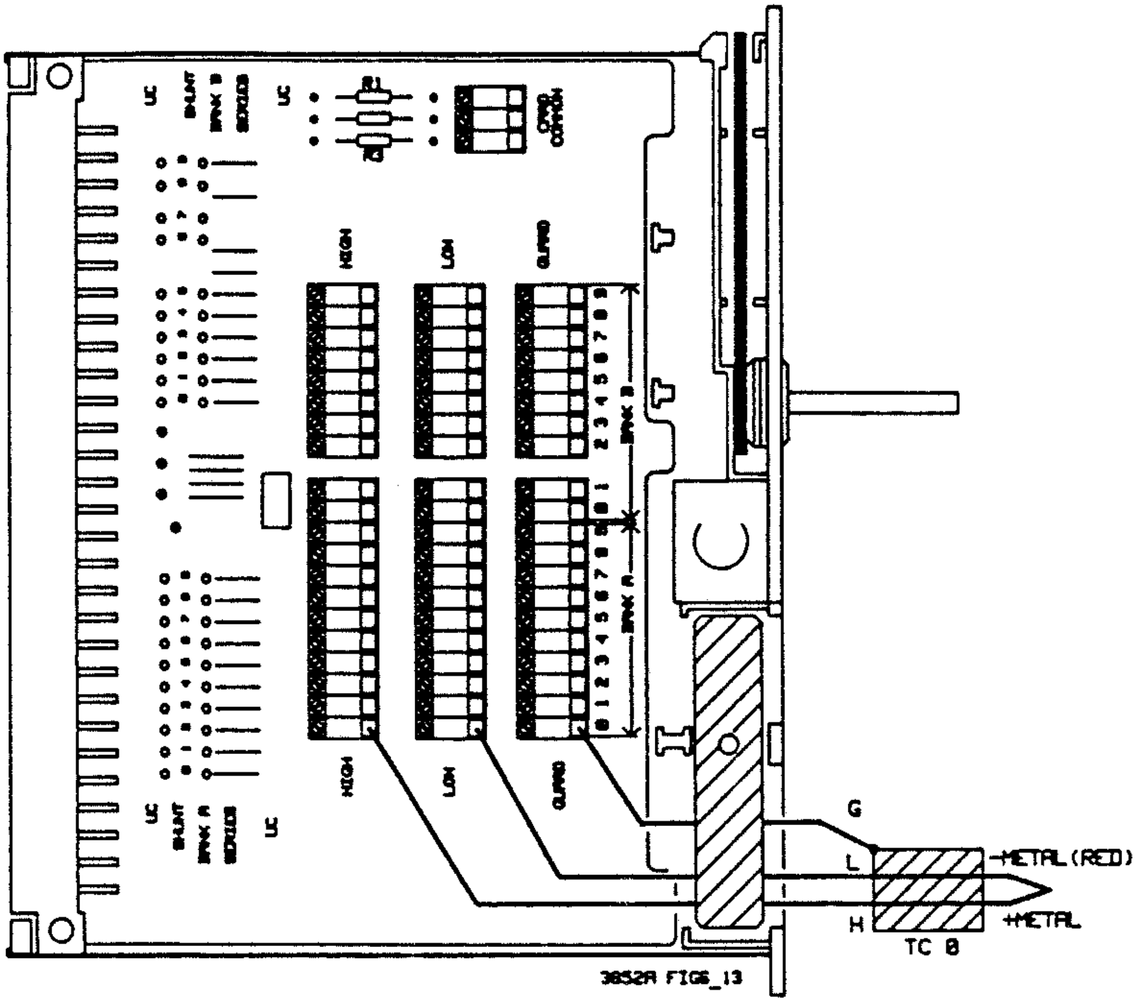


Figure 6-13. Connecting Thermocouples for Temperature Measurements

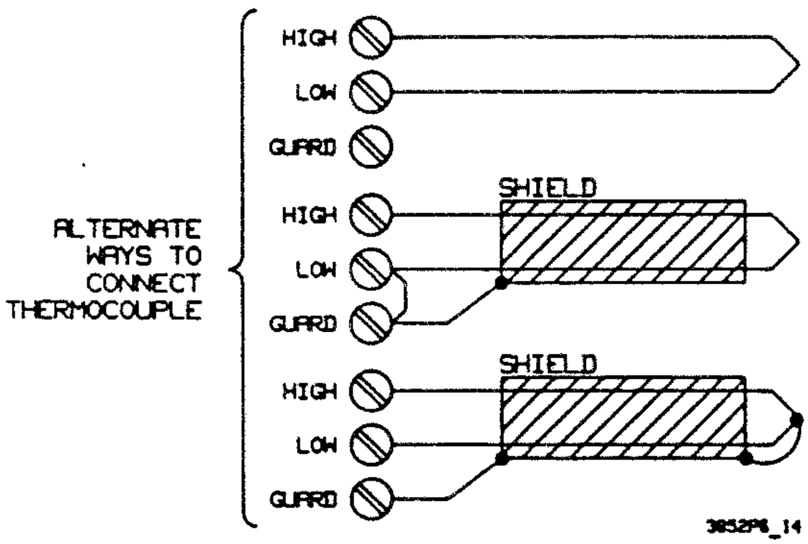


Figure 6-14. Alternate Thermocouple Wiring Configurations

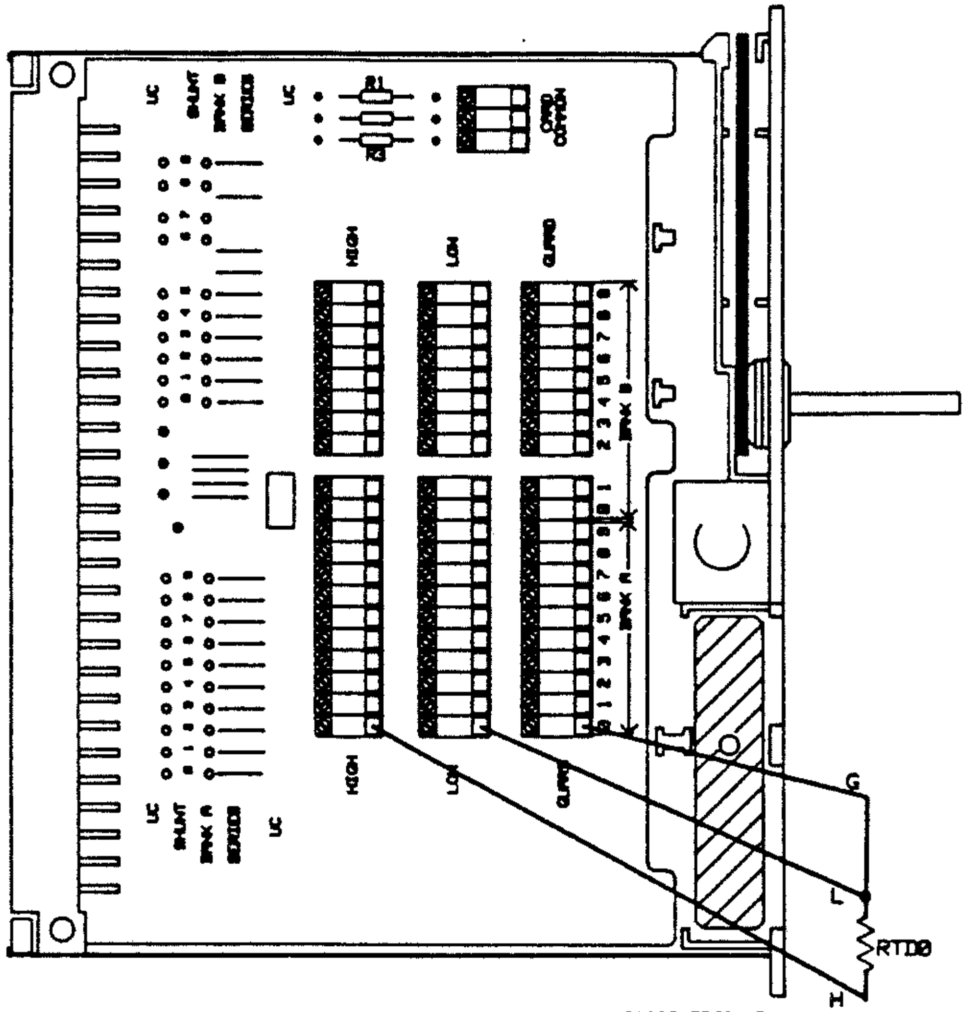


Figure 6-15. Connecting RTDs for Temperature Measurements

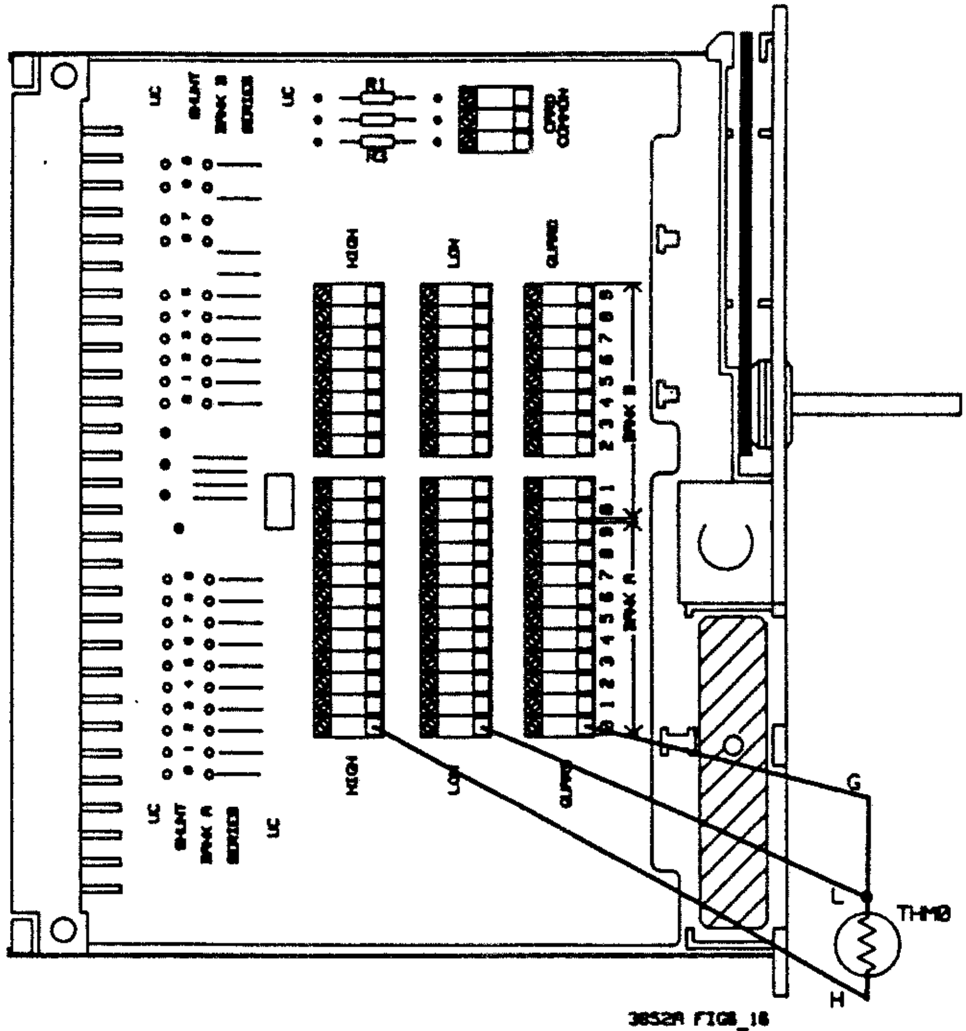


Figure 6-16. Connecting Thermistors for Temperature Measurements

Installation/ Checkout

The following section explains how to check the accessory identity, how to verify the field wiring connections, and how to read the state of the channels.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

Checking the Accessory Identity

After you have connected field wiring from your application to the terminal module, replace the terminal module cover and install the accessory in the desired mainframe or extender slot. Refer to the Mainframe Configuration and Programming Manual to connect the terminal module to the component module and to install the accessory.

To check the accessory identity, you can use the ID? (Identity?) command. The ID? command provides a way to check, from the HP 3852A front panel or from a controller, in what slot an accessory has been installed. The ID? command will return " 44708A" for the 20-Channel Relay MUX/TC and " 447XXX" if the terminal module is not connected to the component module. If the ID? command is sent to a slot with no accessory installed, " 000000" will be returned.

<u>Example: Reading the Accessory Identity</u>

```
10  !
20  !Use the ID? command to read the identity of a relay
30  !MUX installed in slot 2 of the mainframe.
40  !
50  OUTPUT 709; "ID? 200"
60  ENTER 709; Identity$
70  PRINT Identity$
80  END
```

Output with terminal module connected:

```
44708A
```

NOTE

If you have addressed the correct slot and have made sure that the terminal module is connected, but the proper ID number is not returned, refer to the HP 3852A Assembly Level Service Manual for service procedures.

Verifying Wiring Connections

To verify that your field wiring has been properly connected to the terminal module, send the MONMEAS (Monitor/Measure) command from the HP 3852A front panel keyboard or from a controller. This command can be used to check DC and AC voltage connections, 2-wire ohms connections, RTD connections, and thermistor connections.

The following program segment shows how to use the MONMEAS command with a controller to verify DC voltage connections on Channels 200 through 219. The CONF command configures the voltmeter accessory for DC voltage measurements. For this example, a relay MUX is installed in slot 2 of the mainframe and a voltmeter accessory is installed in slot 0 of the mainframe.

```
10 OUTPUT 709; "USE 0"
20 OUTPUT 709; "CONF DCV"
30 OUTPUT 709; "MONMEAS DCV,200-219"
40 END
```

The 20 channels will be scanned and measured one at a time starting with Channel 200. Press "SADV KEY" on the HP 3852A front panel to advance the scanning to the next channel. When the scan is advanced past the last channel (Channel 219 in this example), scanning will stop and the last measurement will remain on the display.

Reading Channel State

The CLOSE? command can be used to determine the state of the relay MUX channels. This command returns one of five numbers for each channel queried. The numbers returned indicate if a channel is open or closed and to which bus the channel is connected. Table 6-4 shows the channel state for each value that can be returned by the CLOSE? command when used with the 20-Channel Relay MUX/TC.

Table 6-4. Values Returned by the CLOSE? Command

Data Returned	Channel State
0	Channel Open
1	Channel Closed
2	Channel Closed - connected to Sense Bus
3	Channel Closed - connected to Source Bus
4	Channel Closed - connected to Both Buses

NOTE

The CLOSE? command will return 2, 3, or 4 only to indicate the state of Channels 0 through 19 (i.e., these values will not be returned for the tree switches).

Example: Reading Channel State

This example shows how to use the CLOSE? command to read the state of Channels 0 through 4 on a relay MUX. The RST command resets the relay MUX to its power-on state where all channels are open. The CLOSE command closes Channel 3 and the Sense Bus tree switch (Channel 91). The OPEN command is used to open the channels and disconnect them from the backplane. For this example, a relay MUX accessory is installed in slot 2 of the mainframe.

```
10  OUTPUT 709; "RST 200"
20  INTEGER State(4)
30  OUTPUT 709; "CLOSE 203,291"
40  OUTPUT 709; "CLOSE? 200-204"
50  ENTER 709; State(*)
60  PRINT State(*)
70  OUTPUT 709; "OPEN 203,291"
80  END
```

Typical Output (Channel 3 closed - connected to Sense Bus):

```
0  0  0  2  0
```

Programming the 20-Channel Relay MUX/TC

As noted in the Introduction section of this chapter, the relay MUX has four primary functions: voltage measurements, current measurements, 2-wire ohms measurements, and temperature measurements. This section contains examples that show how to program the accessory for each function. It includes a description of each function, applicable commands for the functions, and programming examples. Each example includes a sample program and (where applicable) typical outputs for the assumed conditions.

This section also summarizes the programming commands used with the relay MUX (refer to "Command Summary") and lists the titles of the example programs (refer to "Program Titles").

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

NOTE

The example programs show how to make typical measurements using the relay MUX with the HP 44701A Integrating Voltmeter Accessory or the HP 44702 High-Speed Voltmeter Accessory (when used on the backplane). Refer to the Mainframe Configuration and Programming Manual for instructions on making measurements using an external voltmeter.

Command Summary

Table 6-5 is an alphabetical listing of commands which apply to the relay MUX accessory. Refer to the HP 3852A Command Reference Manual for a complete description of these commands.

Table 6-5. Commands for the 20-Channel Relay MUX/TC

CLOSE *ch list*

Closes a single multiplexer channel or a list of channels specified by *ch list*. This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

CLOSE? *ch list* [INTO *name*] or [*fmt*]

Queries the state of channels specified by *ch list*.

CONFMEAS *function* , *ch list* [USE ch] [INTO *name*] or [*fmt*]

Configures the voltmeter accessory and measures a function on the channels specified by *ch list*. This command automatically configures the voltmeter accessory and the tree switches on the multiplexer for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function* , *ch list* [USE *ch*] [INTO *name*] or [*fmt*]

Scans and measures a function on the channels specified by *ch list*. This command does not configure the voltmeter accessory but it does configure the tree switches on the multiplexer for the measurement.

MONMEAS *function*, *ch list* [USE *ch*]

Monitors and measures a function on the channels specified by *ch list*. This command is useful to check wiring connections made on the terminal module.

OPEN *ch list*

Opens a single multiplexer channel or a list of channels specified by *ch list*. This command is used to open channels and place them in a safe state after the measurements have been made.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Program Titles

The discussion for each function includes one or two examples that show how to program the relay MUX for that function. Table 6-6 lists the titles of the example programs in this section.

Table 6-6. Program Titles

NOTE

When using more than one relay multiplexer function, it is recommended that similar types of measurements be grouped together in order to maximize relay life and minimize voltmeter function changes.

For example, if you are making DC voltage measurements and 2-wire ohms measurements, group all of the voltage measurements together and all of the resistance measurements together. In this way, the tree switches will be opened and closed fewer times and the voltmeter function won't be changed as often.

Making Voltage Measurements

One of the functions of the relay MUX accessory is to make voltage measurements. This section explains how to program the accessory to make guarded (3-wire) DC and AC voltage measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX/TC is 170 VDC or 120 VAC rms (170V peak). Refer to Table 6-1 for the specifications.

NOTE

The AC voltage function is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC voltage measurements.

Example: Measuring DC and AC Voltage Sources

Suppose that you want to measure the outputs from 20 voltage sources using the relay MUX and the guarded voltage function. See Figure 6-9 to connect voltage sources to the terminal module.

Table 6-6. Program Titles

TITLE	DESCRIPTION	COMMANDS
	Voltage Measurements	
Measuring DC and AC Voltage Sources	Measures the outputs from 20 voltage sources using the relay MUX.	CONFMEAS
Measuring Voltage Sources using the CLOSE Command	Measures the output from a voltage source using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	Current Measurements	
Making DC and AC Currents Measurements	Makes a current sensing measurement using a shunt resistor installed on the relay MUX.	CONFMEAS
	2-Wire Ohms Measurements	
Measuring Resistors using the 2-Wire Ohms Function.	Measures 20 resistors using the relay MUX and the 2-wire ohms measurement function.	CONFMEAS
Making 2-Wire Ohms Measurements using the CLOSE Command	Measures a single resistor using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	Temperature Measurements	
Measuring Temperature using Thermocouples	Makes 20 temperature measurements using the relay MUX and J-type thermocouples.	CONFMEAS
Measuring the Isothermal Reference Temperature	Measures the reference temperature of the isothermal connector block and also the compensated temperature of a B-type thermocouple.	CONFMEAS
Measuring Temperature using RTDs	Makes 20 temperature measurements using the relay MUX and the 2-wire RTD measurement function.	CONFMEAS
Measuring Temperature using Thermistors	Makes 20 temperature measurements using the relay MUX and the 2-wire thermistor measurement function.	CONFMEAS

The following example program uses the CONFMEAS command to measure 20 DC voltage sources connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the 20 channels once.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70  OUTPUT 709; "CONFMEAS ACV,200-219,USE 0"
```

```
10  !
20  !Use the CONFMEAS command to measure 20 DC voltages using
30  !a relay MUX in slot 2 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Volts(19)
70  OUTPUT 709; "CONFMEAS DCV,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Volts(I)
100 PRINT "Ch.";I, Volts(I)
110 NEXT I
120 END
```

Typical DC voltage values for the assumed conditions:

```
Ch. 0   4.30300
Ch. 1   4.33350
      .
      .
      .
Ch. 18  4.58580
Ch. 19  3.49470
```

<u>Example: Measuring Voltage Sources using the CLOSE Command</u>

Suppose that you want to measure the output from a voltage source using the CLOSE command to control the tree switches and bank switches. See Figure 6-9 to connect a voltage source to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0 and the Sense Bus tree switch (Channel 91). The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the DC voltage from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 90:

```
90  OUTPUT 709; "FUNC ACV"
```

```
 10  !
 20  !Use the CLOSE command to make a DC voltage measurement of
 30  !the voltage source connected to Channel 0 on a relay
 40  !MUX in slot 2 of the mainframe.  Install a voltmeter accessory
 50  !in slot 0 of the mainframe.
 60  !
 70  OUTPUT 709; "USE 0"
 80  OUTPUT 709; "CLOSE 200,291"
 90  OUTPUT 709; "FUNC DCV"
100  OUTPUT 709; "TRIG SGL"
110  OUTPUT 709; "CHREAD 0"
120  ENTER 709; Volts
130  PRINT Volts
140  OUTPUT 709; "OPEN 200,291"
150  END
```

Typical DC voltage value for the assumed conditions:

```
3.94940
```

Making Current Measurements

The relay MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across a shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. This section shows how to program the relay MUX to switch signals for DC and AC current measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel relay MUX/TC is 170 VDC or 120 VAC rms (170V peak). Refer to Table 6-1 for the specifications.

NOTE

Current sensing measurements are not recommended when making temperature measurements on the same terminal module. The heat produced by the shunt resistor may affect the accuracy of the temperature measurements.

NOTE

The AC voltage function (used for AC current sensing) is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC current measurements.

Example: Making DC and AC Current Measurements

Suppose that you want to make a current measurement using a 250Ω shunt resistor installed on the terminal module. See Figure 6-11 to install a shunt resistor on the terminal module for a current measurement.

The following example program uses the CONFMEAS command to measure a 250Ω shunt resistor installed on Channel 0. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the channel once. The voltage value is returned to the controller which then calculates the current in DC amps.

NOTE

To use the following program to make AC current measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70   OUTPUT 709; "CONFMEAS ACV,200,USE 0"
```

```
 10  !
 20  !Use the CONFMEAS command to measure a 250Ω shunt
 30  !resistor and calculate the DC current on Channel 0.
 40  !Use a relay MUX in slot 2 of the mainframe.  Install a
 50  !voltmeter accessory in slot 0 of the mainframe.
 60  !
 70  OUTPUT 709; "CONFMEAS DCV,200,USE 0"
 80  ENTER 709; Volts
 90  !
100  !Current = Voltage Measured/Resistance of Shunt
110  !
120  Current = Volts/250
130  PRINT Current
140  END
```

Typical current value (in DC Amps) for the assumed conditions:

```
.03034
```

Making 2-Wire Ohms Measurements

One of the functions of the relay MUX accessory is to make resistance measurements. This section explains how to program the relay MUX for 2-wire ohms measurements.

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per relay MUX.

When using the relay MUX accessory for 2-wire ohms measurements, the voltmeter accessory is actually configured for a 4-wire ohms measurement. The relay MUX converts the 4-wire function on the voltmeter to a 2-wire function on the component module. It does this by connecting the high voltage sense lead to the high current source lead and the low voltage sense lead to the low current source lead. Therefore, only two leads are used on the relay MUX for the 2-wire ohms measurement.

Example: Measuring Resistors using the 2-Wire Ohms Function

Suppose that you want to measure 20 resistors connected to the relay MUX using the 2-wire ohms function. See Figure 6-12 to connect resistors to the terminal module for a 2-wire ohms measurement.

The following example program uses the CONFMEAS command to measure 20 resistors connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for 2-wire ohms measurements and measures the 20 channels once.

```
 10  !
 20  !Use the CONFMEAS command to measure 20 resistors using a
 30  !relay MUX in slot 3 of the mainframe.  Install a voltmeter
 40  !accessory in slot 0 of the mainframe.
 50  !
 60  REAL Ohms(19)
 70  OUTPUT 709; "CONFMEAS OHM,300-319,USE 0"
 80  FOR I = 0 TO 19
 90  ENTER 709; Ohms(I)
100  PRINT "Ch.";I, Ohms(I)
110  NEXT I
120  END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
Ch. 0   4628.340
Ch. 1   5024.900
          .
          .
          .
Ch. 18  4039.400
Ch. 19  6528.380
```

Example: Making 2-Wire Ohms Measurements using the CLOSE Command

Suppose that you want to make a 2-wire ohms measurement of a resistor using the CLOSE command to control the tree switches and bank switches. See Figure 6-12 to connect a resistor to the terminal module for 2-wire ohms measurements.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the Sense Bus tree switch (Channel 91), and the Source Bus tree switch (Channel 94). The FUNC command configures the voltmeter accessory for 4-wire ohms measurements (the relay MUX converts the 4-wire function to a 2-wire function on the component module). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance value from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

The following program uses the HP 44701A Integrating Voltmeter Accessory. To use this program with the HP 44702 High-Speed Voltmeter Accessory on the backplane, substitute the following line for the existing line 80:

```
80  OUTPUT 709; "FUNC OHMF100K"
```

```
 10  !
 20  !Use the CLOSE command to make a 2-wire ohms measurement
 30  !of Channel 0 on a relay MUX in slot 3 of the mainframe.
 40  !Install a voltmeter accessory in slot 0 of the mainframe.
 50  !
 60  OUTPUT 709; "USE 0"
 70  OUTPUT 709; "CLOSE 300,391,394"
 80  OUTPUT 709; "FUNC OHMF"
 90  OUTPUT 709; "TRIG SGL"
100  OUTPUT 709; "CHREAD 0"
110  ENTER 709; Ohms
120  PRINT Ohms
130  OUTPUT 709; "OPEN 300,391,394"
140  END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
11623.57
```

Making Temperature Measurements

One of the functions of the relay MUX accessory is to switch signals for temperature measurements. This section shows how to program the relay MUX accessory to make thermocouple measurements, RTD measurements, and thermistor measurements.

Measuring Temperature using Thermocouples

Thermocouples provide a simple, durable, inexpensive, and relatively accurate temperature sensor for a wide variety of applications and environmental conditions. The thermocouple is a junction of two unlike metals that produces a voltage that is related to the junction temperature. Up to 20 thermocouple measurements can be made per relay MUX accessory. The HP 3852A temperature conversions support B, E, J, K, N14, N28, R, S, and T type thermocouples.

The HP 3852A does not directly measure the temperature of thermocouples but rather, it measures the voltages generated by the thermocouples. The measured voltage is a function of the actual temperature of the thermocouples. The problem with this approach is that the voltage measured by the HP 3852A is different from the actual thermocouple voltage (due to junction voltages on the terminal module) unless some compensating technique is used. The relay MUX uses a technique called software compensation. In performing software compensated thermocouple measurements, the following steps occur:

1. Measure the resistance of the thermistor mounted on the isothermal connector block and compute the isothermal block reference temperature.

2. Measure the voltage produced by the thermocouple.

3. Convert the isothermal block reference temperature to a thermocouple reference voltage. Since the thermocouple voltage depends upon the type of thermocouple being compensated, this allows different types of thermocouples to be used on an accessory.

4. Add the thermocouple voltage measured in step 2 to the voltage computed in step 3.

5. Convert the total voltage in step 4 to a temperature in °C.

NOTE

When used with the scanning commands (CONFMEAS for example), the HP 3852A automatically performs the compensation steps when making thermocouple measurements.

When using low-level commands such as CLOSE and OPEN, the compensation steps are not performed automatically.

NOTE

Since the channels on the relay MUX can be independently configured and software compensation is used, any mixture of thermocouple types can be measured. However, separate commands will have to be executed for each type of thermocouple.

<u>Example: Measuring Temperature using Thermocouples</u>

Suppose that you want to make 20 temperature measurements using thermocouples and the relay MUX. See Figure 6-13 to connect thermocouples to the terminal module for temperature measurements.

The following example program uses the CONFMEAS command to measure 20 J-type thermocouples connected to Channels 0 through 19. The program scans the 20 channels once and returns the results (in °C) to the controller.

```
10  !
20  !Use the CONFMEAS command to measure 20 J-type thermocouples
30  !using a relay MUX in slot 2 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Temp(19)
70  OUTPUT 709; "CONFMEAS TEMPJ,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Temp(I)
100 PRINT "Ch.";I, Temp(I)
110 NEXT I
120 END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0    24.54297
Ch. 1    24.54200
       .
       .
       .
Ch. 18   25.55800
Ch. 19   25.85600
```

Example: Measuring the Isothermal Reference Temperature

Suppose that you want to measure the temperature (the reference temperature) of the thermistor mounted on the isothermal connector block. The following program uses the CONFMEAS command to measure the reference temperature and also the compensated temperature of a B-type thermocouple connected to Channel 0. See Figure 6-13 to connect thermocouples to the terminal module.

```
10  !
20  !Use the CONFMEAS command to measure the reference temperature and
30  !the compensated temperature of a B-type thermocouple.  Use a
40  !relay MUX in slot 2 of the mainframe.  Install a voltmeter
50  !accessory in slot 0 of the mainframe.
60  !
70  !Measure isothermal reference temperature.
80  !
90  OUTPUT 709; "CONFMEAS REFT,200,USE 0"
100 ENTER 709; Reftemp
110 !
120 !Measure compensated temperature of B-type thermocouple on Channel 0.
130 !
140 OUTPUT 709; "CONFMEAS TEMPB,200,USE 0"
150 ENTER 709; Temp
160 !
```

```
170  !Print results.
180  !
190  PRINT "Isothermal Reference Temperature = ";Reftemp
200  PRINT
210  PRINT "Compensated Temperature = ";Temp
220  END
```

Typical Output:

```
Isothermal Reference Temperature = 24.43848

Compensated Temperature = 24.55176
```

Measuring Temperature using RTDs

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ and resistance values of 100Ω at 0°C.

Most RTDs have small resistance values (typically less than 300Ω) which makes the test lead resistance a significant factor when making resistance measurements. The relay MUX can be used in RTD applications where accuracy is not so important, such as when checking the integrity of your transducers. Up to twenty 2-wire RTD measurements can be made per relay MUX accessory.

<u>Example: Measuring Temperature using RTDs</u>

Suppose that you want to make 20 temperature measurements using RTDs and the 2-wire function. See Figure 6-15 to connect RTDs to the terminal module for 2-wire temperature measurements.

The following example program uses the CONFMEAS command to scan and measure 20 RTDs (with $\alpha = 0.00385\ \Omega/\Omega°C$) using the 2-wire function. The program scans Channels 0 through 19 and returns the results (in °C) to the controller.

```
10  !
20  !Use the CONFMEAS command to make twenty 2-wire RTD measurements
30  !using a relay MUX in slot 2 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Temp(19)
70  OUTPUT 709; "CONFMEAS RTD85,200-219,USE 0"
80  FOR I = 0 TO 19

90  ENTER 709; Temp(I)
100 PRINT "Ch.";I, Temp(I)
110 NEXT I
120 END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0   24.54297
Ch. 1   24.54299
      .
      .
      .
Ch. 18  25.55805
Ch. 19  25.85645
```

Measuring Temperature using Thermistors

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. They are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

Up to 20 thermistors can be measured per accessory using the relay MUX. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

Example: Measuring Temperature using Thermistors

Suppose that you want to make 20 temperature measurements using 5 kΩ thermistors and the 2-wire function. See Figure 6-16 to connect thermistors to the terminal module for 2-wire temperature measurements.

The following example program uses the CONFMEAS command to measure 20 thermistors using the 2-wire function. The program scans and measures Channels 0 through 19 once and returns the results (in °C) to the controller.

```
10  !
20  !Use the CONFMEAS command to measure twenty 5 kΩ thermistors
30  !using a relay MUX in slot 2 of the mainframe.  Install a voltmeter
40  !accessory in slot 0 of the mainframe.
50  !
60  REAL Temp(19)
70  OUTPUT 709; "CONFMEAS THM5K,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Temp(I)
100 PRINT "Ch.";I, Temp(I)
110 NEXT I
120 END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0   24.54297
Ch. 1   24.54299
      .
      .
      .
Ch. 18  25.55800
Ch. 19  25.85645
```

Chapter 7
HP 44709A
20-Channel FET Mux

Contents

Chapter 7
HP 44709A 20-Channel FET MUX

Chapter 7

20-Channel FET MUX

HP 44709A

Introduction

This chapter shows how to configure and program the HP 44709A 20-Channel FET Multiplexer (MUX) Accessory. The chapter has four sections: Introduction, Specifications, Configuring the 20-Channel FET MUX, and Programming the 20-Channel FET MUX.

- **Introduction** contains a chapter overview, a description of the FET MUX, a description of its functions, and shows suggested steps to get started.
- **Specifications** lists the specifications for the accessory.
- **Configuring the 20-Channel FET MUX** contains a block diagram description of the accessory, shows how to hardware configure the terminal module, and shows how to connect field wiring to the terminal module.
- **Programming the 20-Channel FET MUX** shows how to program the accessory for voltage, current, resistance, and temperature measurements.

Description

The FET MUX is used to switch (multiplex) signals from up to 20 channels for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory is designed to perform high-speed switching of low signal-level devices with input voltages less than 10.24 VDC or 7.24 VAC RMS (10.24V peak). The 20 channels can be switched at speeds up to 600 channels per second using an HP 3852A voltmeter accessory.

The FET MUX accessory consists of a 20-channel terminal module and a FET MUX component module. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Functions

The FET MUX accessory is used to switch signals for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory can be used to switch signals for four primary functions:

- Voltage Measurements.
- Current Measurements.
- Resistance Measurements.
- Temperature Measurements.

NOTE

Each channel on the FET MUX can be independently configured to allow multiple functions to be measured using the same accessory.

Voltage Measurements

The FET MUX can be used to switch signals for guarded (3-wire) DC voltage and AC voltage measurements. In the guarded voltage measurement function, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection. Use this function to make up to 20 voltage measurements per FET MUX accessory.

Current Measurements

The FET MUX can be used to switch signals for DC and AC current measurements using current sensing. Current sensing is a method of determining current using a shunt resistor that you install on the terminal module. Use this function to make up to 20 current measurements per FET MUX accessory.

Resistance Measurements

The FET MUX can be used to switch signals for 2-wire and 4-wire resistance (or ohms) measurements. The primary difference between the two types of resistance measurements is the accuracy. In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per FET MUX accessory.

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

The use of the 4-wire ohms measurement virtually eliminates the error caused by the test lead resistances. The current through the unknown resistance is the same regardless of the lead resistance but the voltmeter measures only the voltage across the resistance, not across the combined test lead and the resistance. The 4-wire ohms function is essential when the highest accuracy is required. Since each 4-wire ohms measurement requires two channels, up to 10 resistance measurements can be made per FET MUX accessory.

Temperature Measurements

The FET MUX can be used to switch signals for temperature measurements using resistance temperature detectors (RTDs) and thermistors. RTDs are typically more stable and accurate than thermistors. Thermistors are more sensitive to temperature changes than RTDs. Because of the low resistance values of RTDs and thermistors and the high "on" resistance of the FET switches, the only temperature measurement technique available for this accessory is the 4-wire ohms function. Since each 4-wire ohms measurements requires two channels, up to 10 temperature measurements can be made per FET MUX accessory.

The HP 3852A resistance-to-temperature conversions support the following RTDs and thermistors:

RTDs supported:

$\alpha = 0.00385\ \Omega/\Omega{}^\circ C$ (100Ω at $0^\circ C$)
$\alpha = 0.003916\ \Omega/\Omega{}^\circ C$ (100Ω at $0^\circ C$)

Thermistors supported:

2252Ω at $25^\circ C$
5 $k\Omega$ at $25^\circ C$
10 $k\Omega$ at $25^\circ C$

NOTE

Other transducers can be measured using the FET MUX but only those listed above are supported by the HP 3852A conversions.

Getting Started

To use the FET MUX accessory for your application, you will need to follow three steps:

- Define your application.
- Configure the accessory for your application.
- Program the accessory for your application.

Define your Application

The first step is to define your application and determine if the accessory can meet the requirements of your application. The FET MUX can switch DC or AC inputs up to 10.24 VDC or 7.24 VAC RMS (10.24V peak). Since each of the 20 channels can be independently configured, up to 20 different devices can be connected to the accessory. When selecting devices to be connected, refer to Table 7-1 "20-Channel FET MUX Specifications" to ensure that the voltage and current requirements of your application are within the specifications for this accessory.

Configure the Accessory

The next step is to configure the accessory for your application. Refer to "Configuring the 20-Channel FET MUX" for information on hardware configuration and connecting field wiring to the terminal module for voltage, current, resistance, and temperature measurements.

Program the Accessory

The third step is to program the FET MUX for your application. Refer to "Programming the 20-Channel FET MUX" to program the accessory for voltage, current, resistance, and temperature measurements.

Specifications

Table 7-1 lists the specifications for the FET MUX. This table contains six categories: Input Characteristics, Channel Specifications, Operating Characteristics, AC Performance, RTD Characteristics, and Thermistor Characteristics.

WARNING

The HP 3852A and the HP 3853A internal analog buses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the HP 3852A, HP 3853A, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum Allowable Peak Voltage
HP 3852A Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	350V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexer	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extenders, each instrument is considered as a separate circuit.

Table 7-1. 20-Channel FET MUX Specifications

INPUT CHARACTERISTICS:

Maximum Signal Voltage:

Between any two input terminals or to chassis:
10.24V peak, 10.24 VDC, 7.24 VAC RMS

Input Voltage Protection Limit:

Channel Inputs: ±12V peak maximum
Backplane with isolation relays open: ±42V peak maximum

CHANNEL SPECIFICATIONS:

Bias Currents:

(Channel at 0V with respect to Chassis)
Currents are sourced by the accessory from HIGH or LOW to Chassis.

	Into Transducer or Backplane (0-28°C/0-55°C)	
	Channel Closed	Channel Open
HIGH or LOW	5 nA/45 nA	2 nA/11 nA
GUARD	65 nA/770 nA	6 nA/110 nA

	Into Backplane (0-28°C/0-55°C)	
	Channel Open Isolation Relay Closed[1]	Maximum Differential Offset Voltage[2]
HIGH or LOW	2 nA/11 nA	20 uV/120 uV
GUARD	65 nA/670 nA	—

[1]All channels open, isolation relay closed.

[2]Differential offset voltage between HIGH and LOW with a source resistance < 1 kΩ; RH < 85% @ 28°C or RH < 60% @ 40°C.

Maximum Signal Current: ±1 mA per channel

Isolation:

HIGH to LOW, HIGH to Chassis:
Channel On or Off: $10^8\Omega$
Power Off: Vin ≤ 10V 1 kΩ
Vin > 10V 200Ω

Low to Chassis: 100Ω

Closed Channel "On" Resistance:
HIGH or LOW: 3.0 kΩ
GUARD: 3.2 kΩ

OPERATING CHARACTERISTICS:

Maximum Scan Rate (channels per second):
Using HP 3852A Voltmeter Accessories: 600
Using External Voltmeter: 8,000

Synchronization: Break-Before-Make in scanning operation.

AC PERFORMANCE:

Frequency Response relative to 1 kHz:
(50Ω source, 1 MΩ termination)

50 kHz: -0.6 dB
200 kHz: -3.0 dB

Capacitance with Channel On:
HIGH to LOW: 200 pF
HIGH, LOW to Chassis: 200 pF

Crosstalk, Channel-to-Channel:
(50Ω source, 1 MΩ load); ≤ 5 Vrms

10 kHz: -50 dB
100 kHz: -35 dB

RTD CHARACTERISTICS:

RTD Types Supported:
Type: Platinum, α = 0.00385 Ω/Ω°C, (100.0Ω at 0°C)
Type: Platinum, α = 0.003916 Ω/Ω°C, (100.0Ω at 0°C)

THERMISTOR CHARACTERISTICS:

Thermistor Types Supported:
Type: 2252Ω at 25°C
Type: 5 kΩ at 25°C
Type: 10 kΩ at 25°C

Configuring the 20-Channel FET MUX

This section shows how to configure the FET MUX accessory. It contains a block diagram description of the accessory, information on hardware configuring the terminal module, and information on connecting field wiring to the terminal module.

Refer to "Programming the 20-Channel FET MUX" to program the accessory for voltage, current, resistance, and temperature measurements.

WARNING

⚠ 1 *SHOCK HAZARD. Only qualified, service-trained personnel who are aware of the hazards involved should install, remove, or configure any accessory. Before touching any installed accessory, turn off all power to the mainframe, extenders, and to all external devices connected to the mainframe, extenders, or accessories.*

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers attached.

Block Diagram Description

⚠ 2

The FET MUX accessory consists of a 20-channel terminal module and a FET MUX component module as shown in Figure 7-1. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Figure 7-1. 20-Channel FET MUX Block Diagram

The component module is made up of 24 switches which are divided into two categories: bank switches and tree switches. Each of the 24 switches consists of three Field Effect Transistors (FETs), one each for HIGH, LOW, and GUARD lines. There are a total of 20 bank switches which are divided into two groups of 10 channels each: BANK A and BANK B. The channels in BANK A are numbered 0 through 9 and the channels in BANK B are numbered 10 through 19.

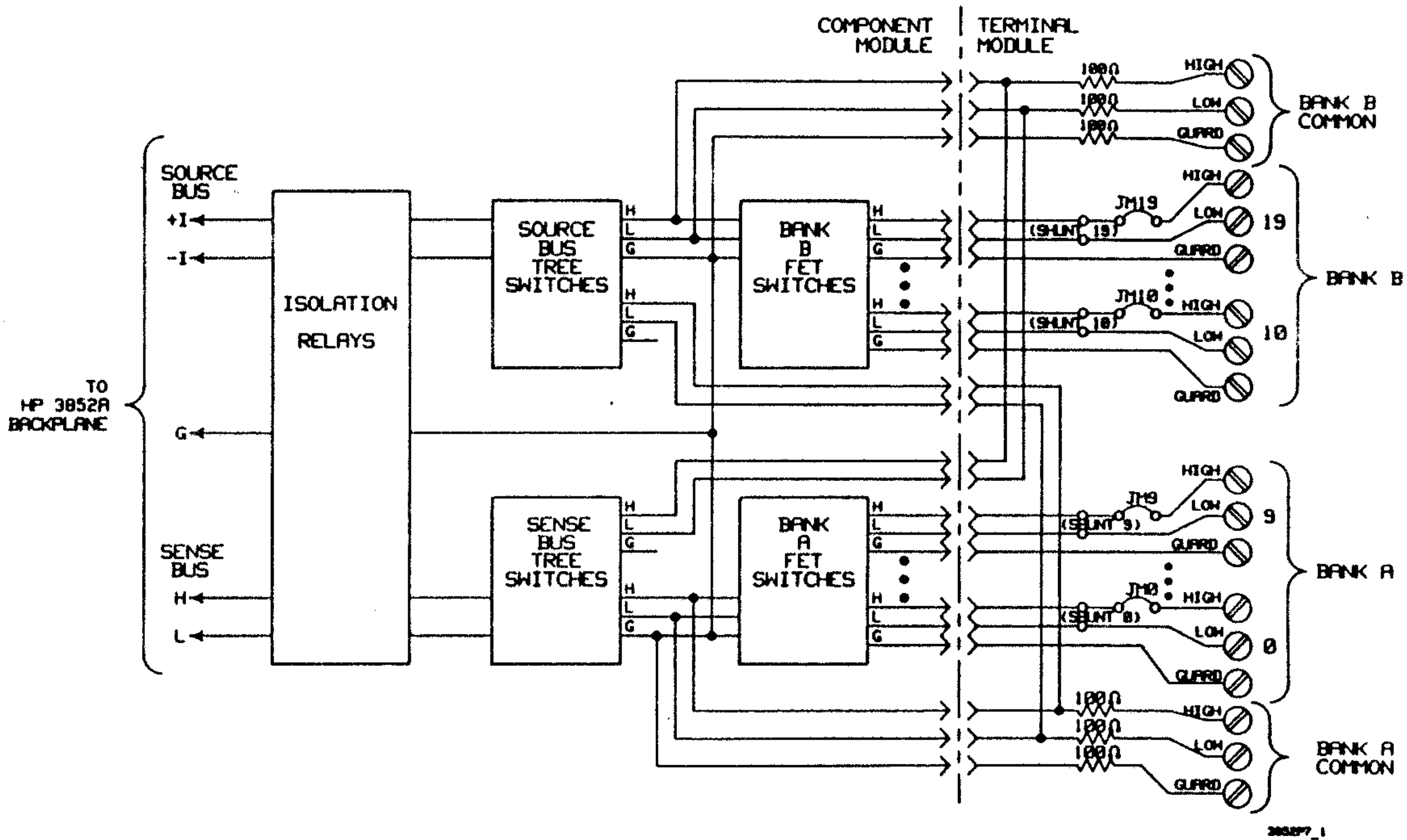


Figure 7-1. 20-Channel FET MUX Block Diagram

NOTE

Only one channel per bank can be closed at a time. Closing a second channel in a bank will open any previously closed channel in that bank.

The component module contains four tree switches which are of two types: Source Bus tree switches and Sense Bus tree switches. Each of the two banks has one Source Bus tree switch and one Sense Bus tree switch. The tree switches control signal flow to and from the HP 3852A backplane and also isolate the bank switches from the backplane when they are not in use. The Sense Bus tree switches provide the connections to the backplane for making voltage measurements. The Source Bus tree switches provide the connections (+I and -I) to the backplane for making resistance measurements.

The component module also includes isolation relays which allow the accessory to be isolated from the HP 3852A backplane. The isolation relays are used to reduce the leakage current on the backplane for critical measurements or for using the backplane at voltages greater than the FET MUX voltage specification. The FET MUX has overvoltage protection circuitry which will automatically open the isolation relays when voltages greater than ±15V peak are detected on the HP 3852A backplane.

Table 7-2 shows the channel definitions for the FET MUX accessory. Channels 0 through 19 control the bank switches, Channel 90 controls the isolation relays, and Channels 91 through 94 control the tree switches.

Table 7-2. 20-Channel FET MUX Channel Definitions

Channel	Definitions
0 - 9	BANK A switches
10 - 19	BANK B switches
90	Isolation relays
91	Sense Bus Tree Switch (BANK A)
92	Sense Bus Tree Switch (BANK B)
93	Source Bus Tree Switch (BANK A)
94	Source Bus Tree Switch (BANK B)

NOTE

Two tree switches of the same type cannot be closed simultaneously (e.g., only one of the two Sense Bus tree switches can be closed at a time). Closing a second tree switch will open any previously closed tree switch of the same type.

The BANK A COMMON and BANK B COMMON terminals on the terminal module can be used to connect an external voltmeter or for diagnostic procedures. As factory configured, there are three 100Ω current limiting resistors in series with the BANK A COMMON terminal and three 100Ω current limiting resistors in series with the BANK B COMMON terminal.

⚠ 1 Configuring the Terminal Module

This section explains how to hardware configure the terminal module. It shows how to install low pass filters and attenuators on the terminal module for input signal conditioning.

Installing Low Pass Filters

Space has been provided on the terminal module for you to install one-pole low pass filters for input signal conditioning on each channel. Figure 7-2 shows the normal channel configuration and the low pass filter channel configuration.

Figure 7-2. Low Pass Filter Channel Configuration

Figure 7-3 shows how to install a low pass filter on Channel 10 of the terminal module. To install the low pass filter, remove the jumper (SERIES JM 10) and install your resistor in its place. Install your capacitor in the SHUNT 10 position as shown. Precision components should be used to maintain accuracy.

Figure 7-3. Installing Low Pass Filters

Installing Attenuators

The space for low pass filters on the terminal module can also be used to install attenuators to reduce input signals to a usable level for the FET MUX. Figure 7-4 shows the normal channel configuration and how the channels are configured to attenuate input signals.

Figure 7-4. Attenuator Channel Configuration

Figure 7-5 shows how to install an attenuator on Channel 0 of the terminal module. To install the attenuator, remove the jumper (SERIES JM 0) and install resistor R1 in its place. Install resistor R2 in the SHUNT 0 position as shown. Precision components should be used to maintain accuracy.

Figure 7-5. Installing Attenuators

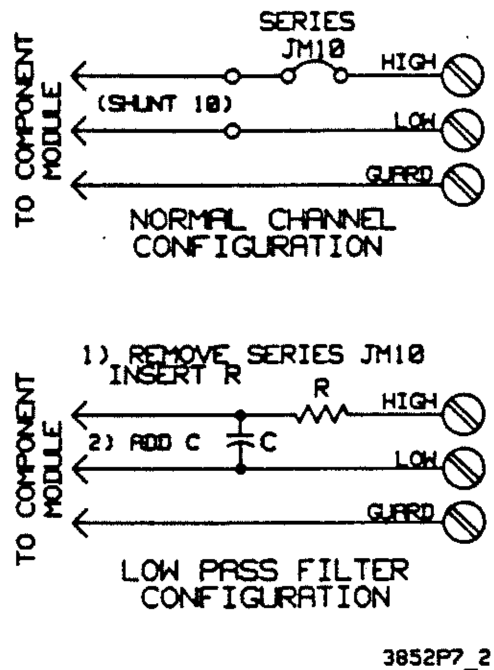


Figure 7-2. Low Pass Filter Channel Configuration

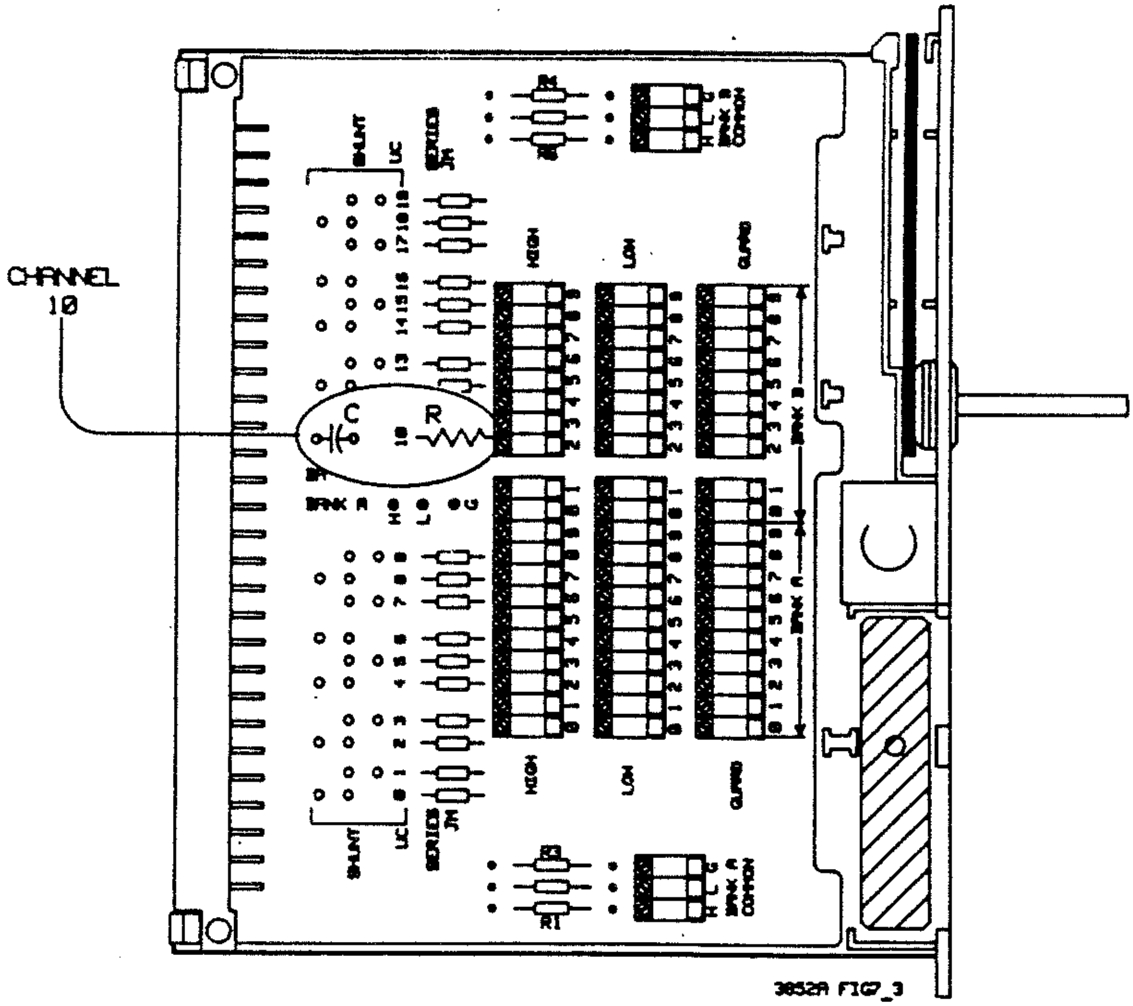


Figure 7-3. Installing Low Pass Filters

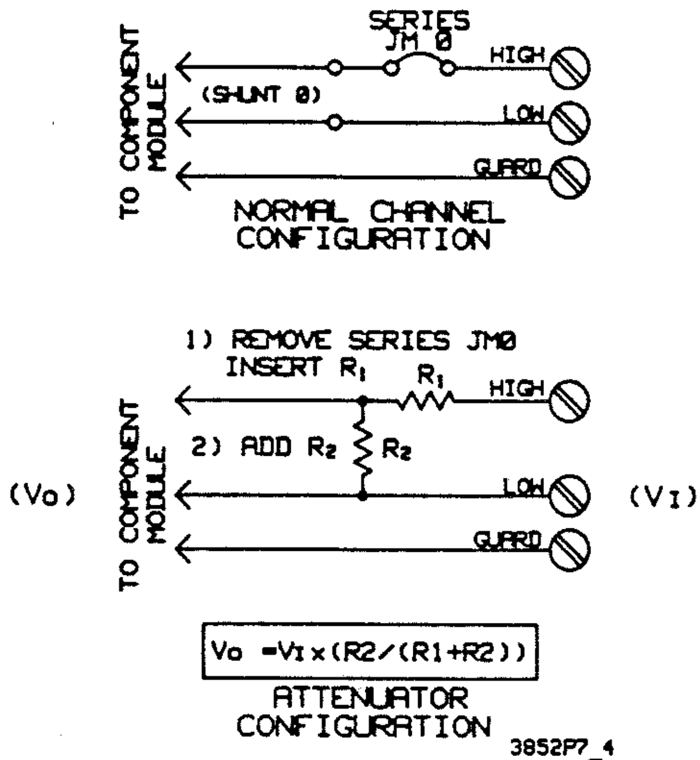


Figure 7-4. Attenuator Channel Configuration

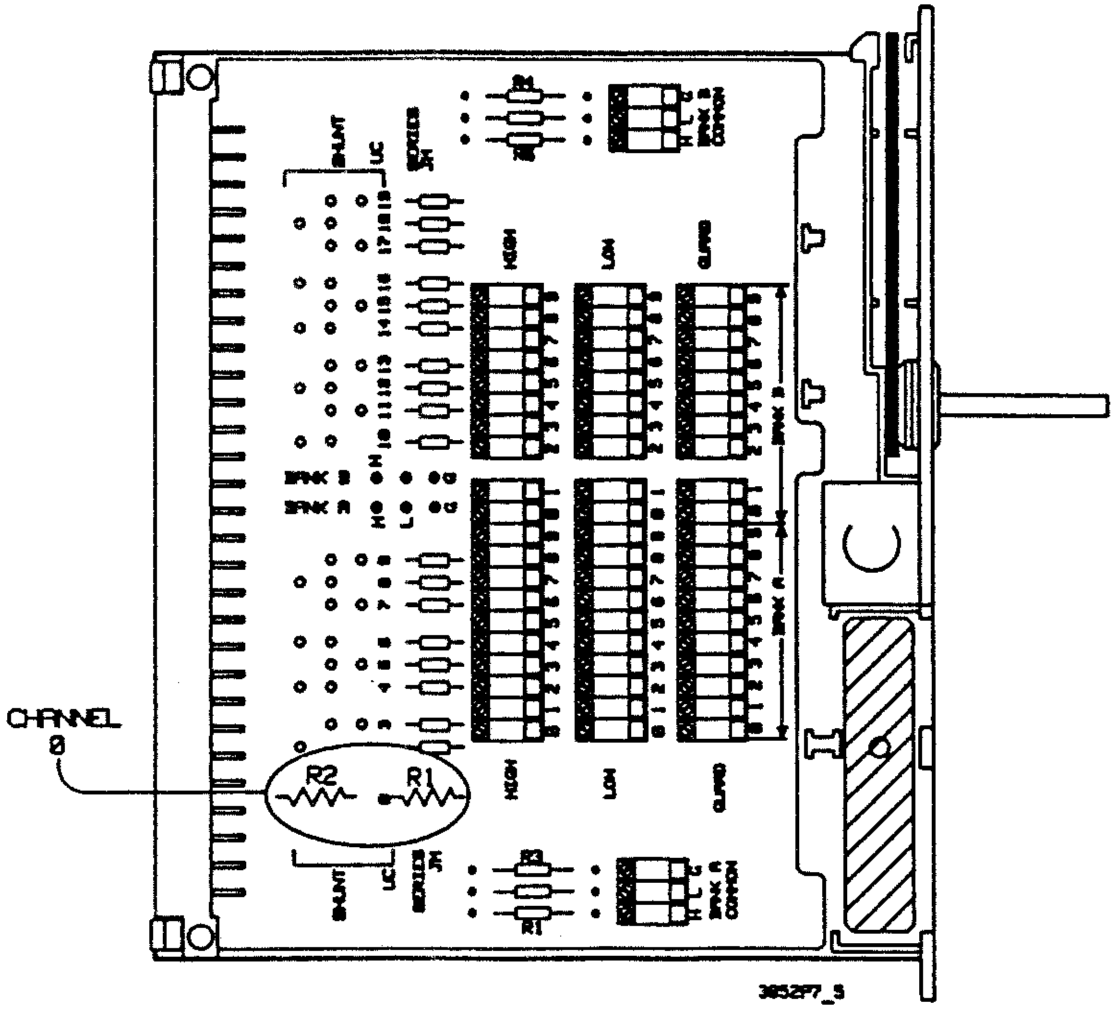


Figure 7-5. Installing Attenuators

Connecting Field Wiring

The next step is to connect field wiring from your application to the appropriate terminals on the terminal module. The following section contains examples that show how to connect field wiring to the terminal module for voltage, current, resistance, and temperature measurements.

Figure 7-6 shows the terminal module with the cover removed. Each of the 20 channels has a HIGH, LOW, and GUARD terminal. Terminals 0 through 9 in BANK A are for Channels 0 through 9, respectively. Terminals 0 through 9 in BANK B are for Channels 10 through 19, respectively.

Figure 7-6. 20-Channel FET MUX Terminal Module

When connecting field wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make it easier to route the wiring.

NOTE

When connecting components such as resistors, RTDs, or thermistors, the lead length may be too short to route through the strain relief clamp. In this case, the components will have to be stored inside the terminal module. When connecting these components, make sure that no leads are shorted together and bend the leads to allow the terminal module cover to be replaced.

Connections for Voltage Measurements

In the guarded (3-wire) voltage measurement function, the FET MUX accessory can switch signals for up to 20 DC or AC voltage measurements. When making guarded voltage measurements, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 7-1 for the specifications.

Example: Connecting Voltage Sources to the Terminal Module

A voltage source (V0) is connected to Channel 0 on the terminal module as shown in Figure 7-7. Connect the high (+) lead from the voltage source to the HIGH terminal. Connect the low (-) lead from the voltage source to the LOW terminal. If a guarded (3-wire) voltage measurement is being made, connect the shield from the shielded twisted pair to the GUARD terminal. The shielded twisted pair is used to reduce electrical noise in the measurements.

Figure 7-7. Connecting Voltage Sources to the Terminal Module

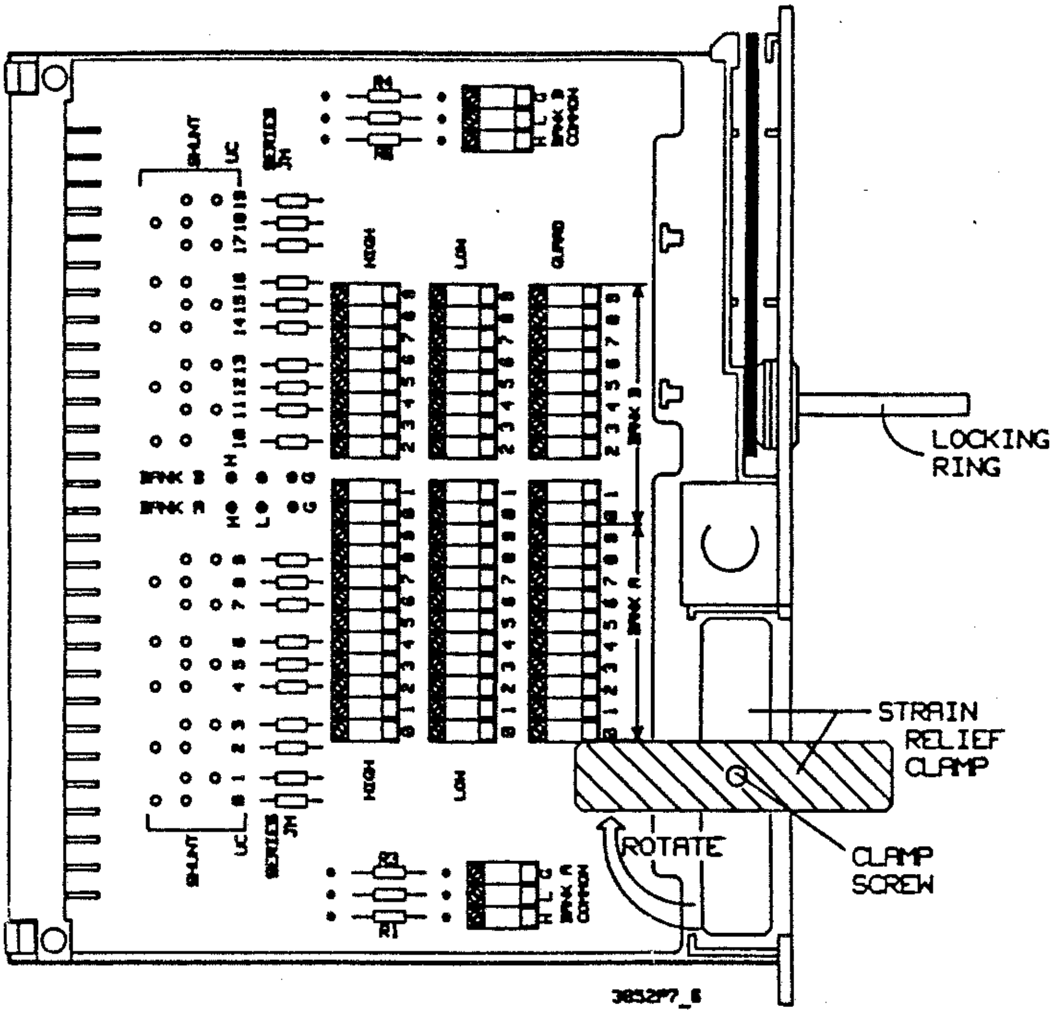


Figure 7-6. 20-Channel FET MUX Terminal Module

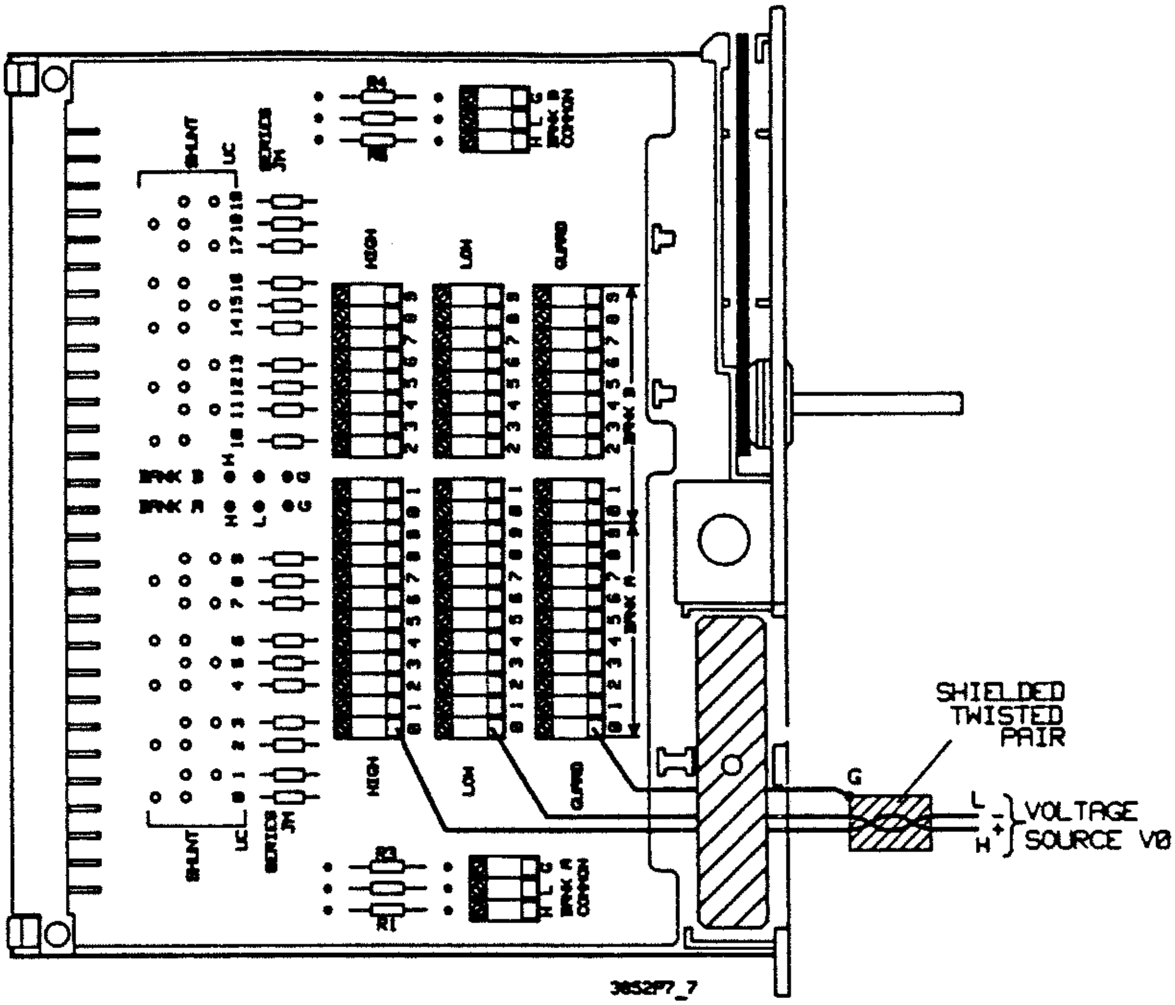


Figure 7-7. Connecting Voltage Sources to the Terminal Module

Connections for Current Measurements

The FET MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across a shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. The FET MUX can be used to switch signals for up to 20 DC or AC current measurements. When making current measurements, HIGH, LOW, and GUARD are switched on each selected channel for maximum common mode noise rejection. Figure 7-8 shows the normal channel configuration and how channels are configured for current sensing measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 7-1 for the specifications.

Figure 7-8. Current Sensing Configuration

Example: Installing Shunt Resistors for Current Measurements

A 250Ω shunt resistor (R0) is installed in the shunt position (SHUNT 0) for Channel 0 on the terminal module as shown in Figure 7-9.

NOTE

The SERIES JM (jumper) must be in place on the terminal module for each channel being used for current measurements (see Figure 7-9).

Figure 7-9. Installing Shunt Resistors for Current Measurements

Connections for Resistance Measurements

One of the functions of the FET MUX accessory is to switch signals for resistance measurements. This section contains a 2-wire ohms and a 4-wire ohms configuration example.

Example: Connecting Resistors for 2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to switch signals for up to 20 resistance measurements per FET MUX accessory.

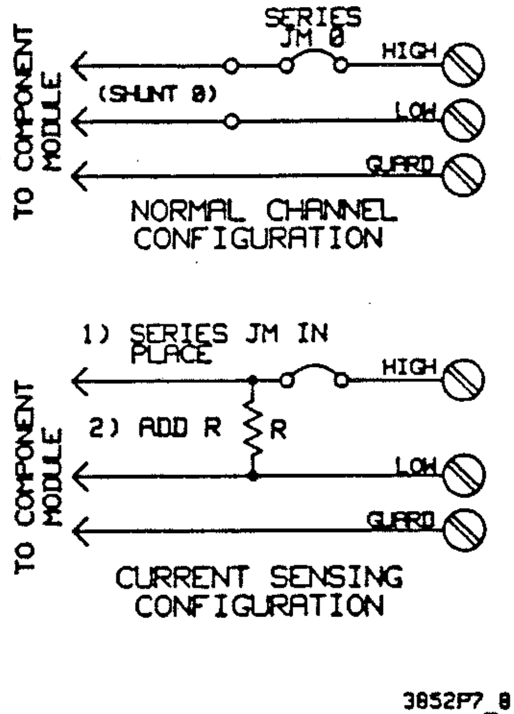


Figure 7-8. Current Sensing Configuration

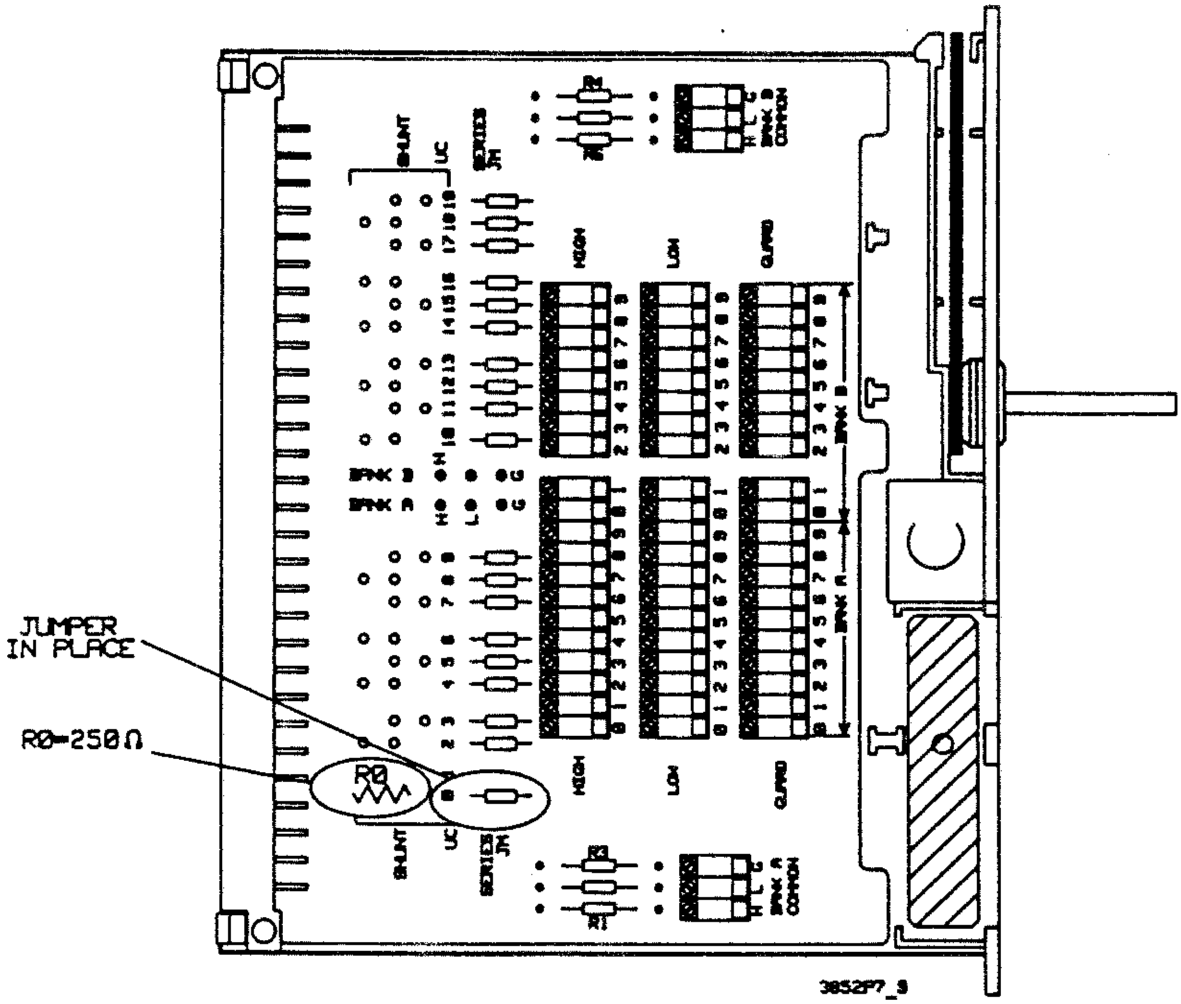


Figure 7-9. Installing Shunt Resistors for Current Measurements

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

A resistor (R0) is connected to Channel 0 on the terminal module as shown in Figure 7-10. Connect one lead of the resistor to the HIGH terminal. Connect the other lead of the resistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the resistor low lead to the GUARD terminal.

Figure 7-10. Connecting Resistors for 2-Wire Ohms Measurements

Example: Connecting Resistors for 4-Wire Ohms Measurements

The use of the 4-wire ohms measurement virtually eliminates the error caused by the test lead resistances. The current through the unknown resistance is the same regardless of the lead resistance but the voltmeter measures only the voltage across the resistance, not across the combined test lead and the resistance. The 4-wire ohms function is essential when the highest accuracy is required. Since each 4-wire ohms measurement requires two channels, up to 10 resistance measurements can be made per FET MUX accessory.

NOTE

Each 4-wire ohms measurement requires two channels, one from BANK A and one from BANK B. When connecting a resistor to the terminal module for a 4-wire ohms measurement, use two channels that are separated by one decade (i.e., Channels 0 and 10, Channels 1 and 11, etc.).

A resistor (R1) is connected to Channels 0 and 10 on the terminal module for a 4-wire ohms measurement as shown in Figure 7-11. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel for the measurement.

Figure 7-11. Connecting Resistors for 4-Wire Ohms Measurements

To make the connections to Channel 0 (the Sense channel), connect one lead of the resistor to the HIGH terminal. Connect the other lead of the resistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the resistor low lead to the GUARD terminal.

To connect the resistor to Channel 10 (the Source channel), repeat the above procedure using the HIGH and LOW terminals for Channel 10. Note that it is not necessary to connect the guard lead to both the sense channel and the source channel.

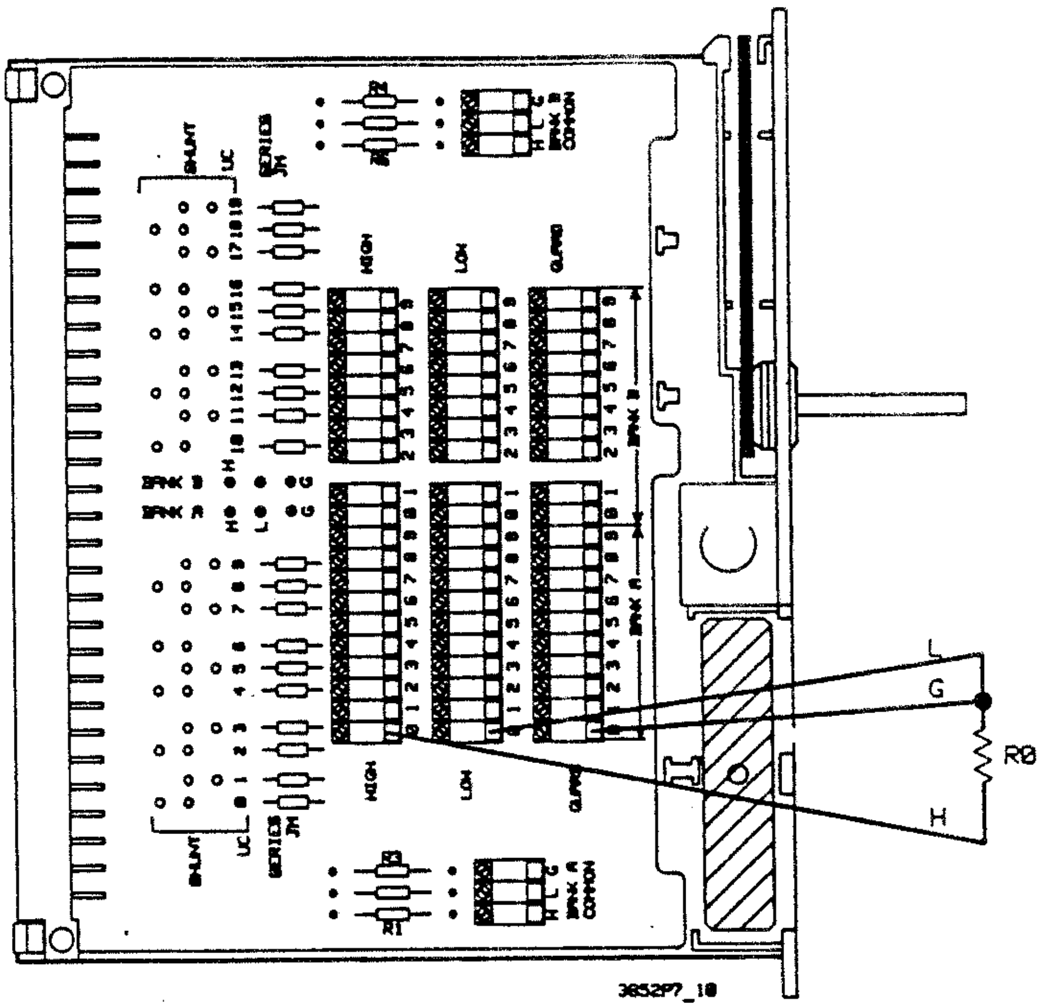


Figure 7-10. Connecting Resistors for 2-Wire Ohms Measurements

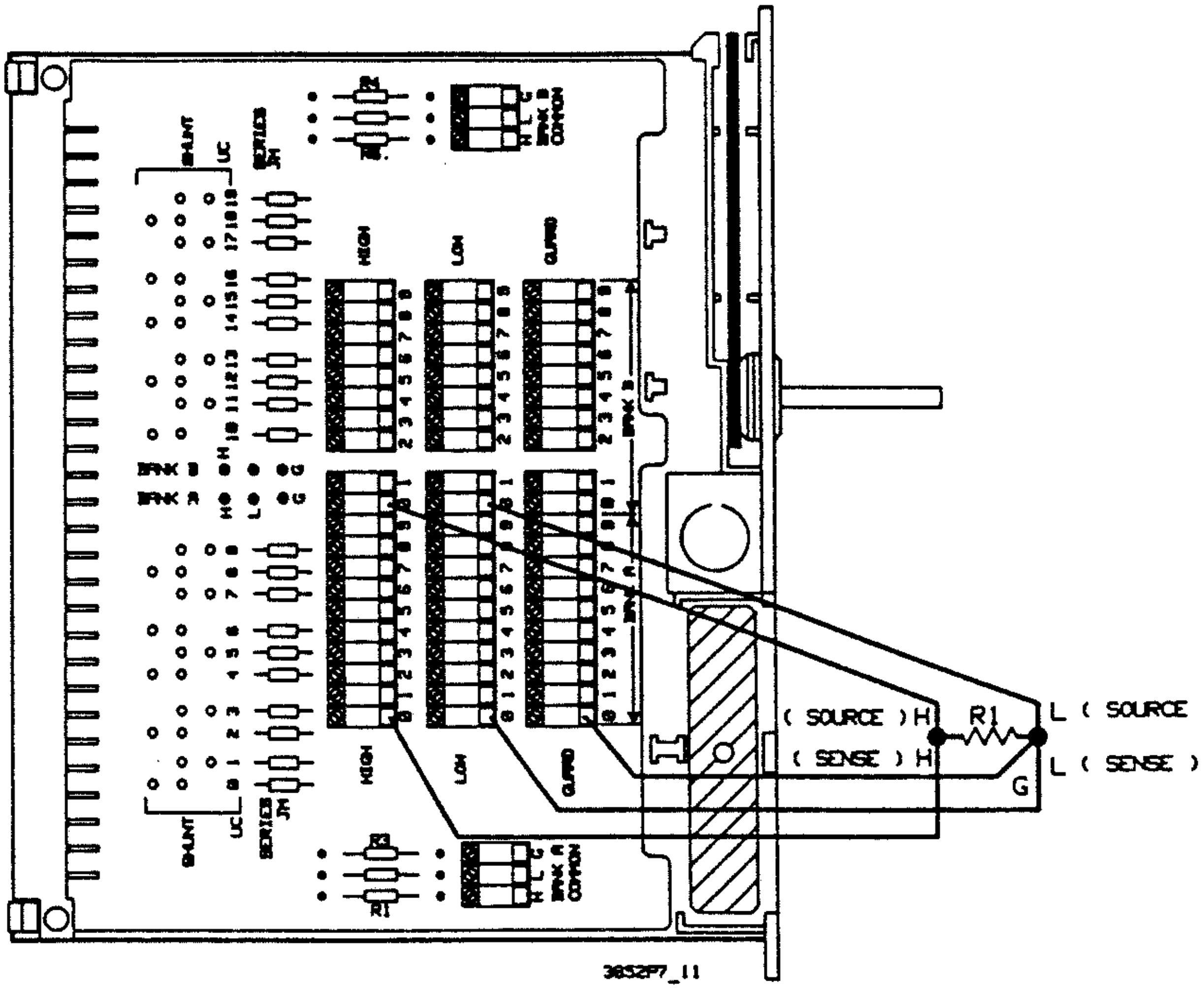


Figure 7-11. Connecting Resistors for 4-Wire Ohms Measurements

Connections for Temperature Measurements

One of the functions of the FET MUX accessory is to switch signals for temperature measurements. This section contains examples that show how to connect RTDs and thermistors to the terminal module.

NOTE

Because of the low resistance values of RTDs and thermistors and the high "on" resistance of the FET switches on the FET MUX, the only temperature measurement technique available for this accessory is the 4-wire ohms function.

Example: Connecting RTDs for 4-Wire Temperature Measurements

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. Since each 4-wire measurement requires two channels, up to 10 RTD measurements can be made per FET MUX accessory. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ and resistance values of 100Ω at 0°C.

NOTE

Each 4-wire RTD measurement requires two channels, one from BANK A and one from BANK B. When connecting an RTD to the terminal module for a 4-wire measurement, use two channels that are separated by one decade (i.e., Channels 0 and 10, Channels 1 and 11, etc.).

An RTD (RTD1) is connected to Channels 0 and 10 for a 4-wire measurement as shown in Figure 7-12. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel for the measurement.

Figure 7-12. Connecting RTDs for 4-Wire Temperature Measurements

To make the connections to Channel 0 (the Sense channel), connect one lead of the RTD to the HIGH terminal. Connect the other lead of the RTD to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the RTD low lead to the GUARD terminal.

To connect the RTD to Channel 10 (the Source channel), repeat the above procedure using the HIGH and LOW terminals for Channel 10. Note that it is not necessary to connect the guard lead to both the sense channel and the source channel.

Example: Connecting Thermistors for 4-Wire Temperature Measurements

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. Thermistors are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

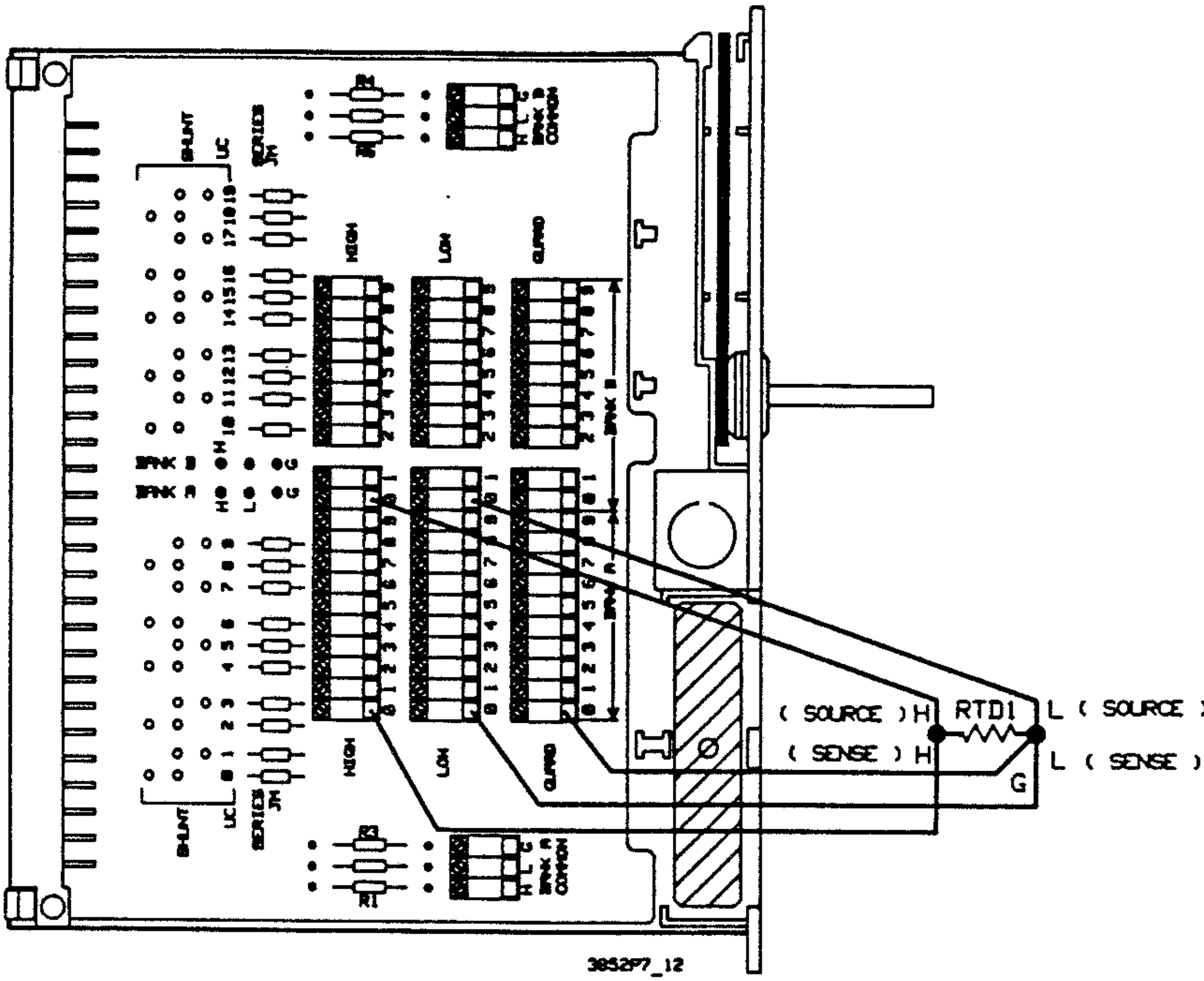


Figure 7-12. Connecting RTDs for 4-Wire Temperature Measurements

Since each 4-wire measurement requires two channels, up to 10 temperature measurements can be made per FET MUX. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

NOTE

Each 4-wire thermistor measurement requires two channels, one from BANK A and one from BANK B. When connecting a thermistor to the terminal module for a 4-wire measurement, use two channels that are separated by one decade (i.e., Channels 0 and 10, Channels 1 and 11, etc.).

A thermistor (THM1) is connected to Channels 0 and 10 for a 4-wire measurement as shown in Figure 7-13. Channel 0 is used as the voltage sense channel for the measurement and Channel 10 is used as the current source channel for the measurement.

Figure 7-13. Connecting Thermistors for 4-Wire Temperature Measurements

To make the connections to Channel 0 (the Sense channel), connect one lead of the thermistor to the HIGH terminal. Connect the other lead of the thermistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the thermistor low lead to the GUARD terminal.

To connect the thermistor to Channel 10 (the Source channel), repeat the above procedure using the HIGH and LOW terminals for Channel 10. Note that it is not necessary to connect the guard lead to both the sense channel and the source channel.

Installation/ Checkout

The following section explains how to check the accessory identity, how to verify the field wiring connections, and how to read the state of the channels.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

Checking the Accessory Identity

After you have connected field wiring from your application to the terminal module, replace the terminal module cover and install the accessory in the desired mainframe or extender slot. Refer to the Mainframe Configuration and Programming Manual to connect the terminal module to the component module and to install the accessory.

To check the accessory identity, you can use the ID? (Identity?) command. The ID? command provides a way to check, from the HP 3852A front panel or from

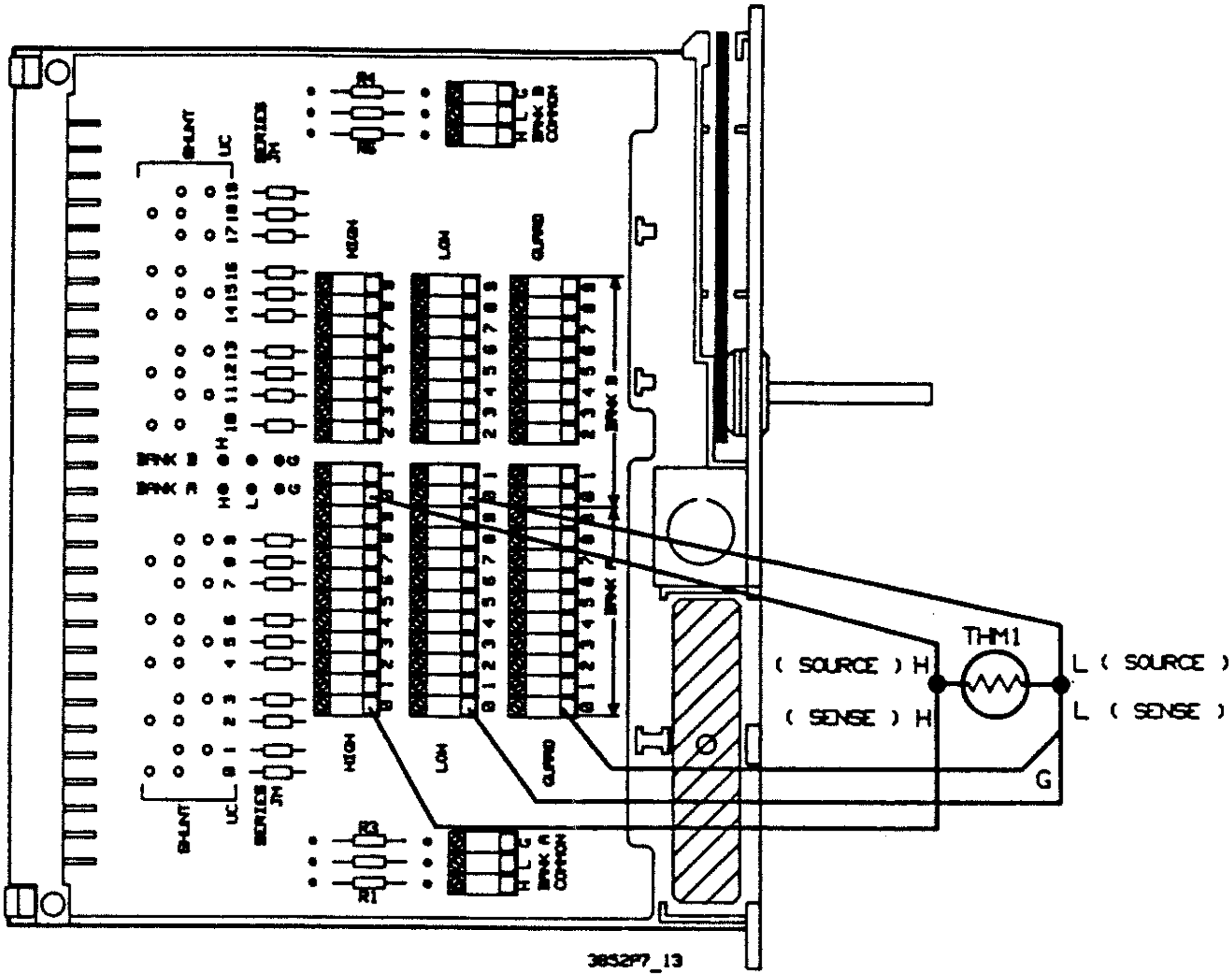


Figure 7-13. Connecting Thermistors for 4-Wire Temperature Measurements

a controller, in what slot an accessory has been installed. The ID? command will return " 44709A" for the 20-Channel FET MUX and " 447XXX" if the terminal module is not connected to the component module. If the ID? command is sent to a slot with no accessory installed, " 000000" will be returned.

Example: Reading the Accessory Identity

```
10  !
20  !Use the ID? command to read the identity of a
30  !FET MUX installed in slot 2 of the mainframe.
40  !
50  OUTPUT 709; "ID? 200"
60  ENTER 709; Identity$
70  PRINT Identity$
80  END
```

Output with terminal module connected:

```
44709A
```

NOTE

If you have addressed the correct slot and have made sure that the terminal module is connected, but the proper ID number is not returned, refer to the HP 3852A Assembly Level Service Manual for service procedures.

Verifying Wiring Connections

To verify that your field wiring has been properly connected to the terminal module, send the MONMEAS (Monitor/Measure) command from the HP 3852A front panel keyboard or from a controller. This command can be used to check DC and AC voltage connections, 2-wire and 4-wire ohms connections, RTD connections, and thermistor connections.

The following program segment shows how to use the MONMEAS command with a controller to verify DC voltage connections on Channels 200 through 219. The CONF command configures the voltmeter accessory for DC voltage measurements. For this example, a FET MUX is installed in slot 2 of the mainframe and a voltmeter accessory is installed in slot 0 of the mainframe.

```
10  OUTPUT 709; "USE 0"
20  OUTPUT 709; "CONF DCV"
30  OUTPUT 709; "MONMEAS DCV,200-219"
40  END
```

The 20 channels will be scanned and measured one at a time starting with Channel 200. Press "SADV KEY" on the HP 3852A front panel to advance the scanning to the next channel. When the scan is advanced past the last channel (Channel 219 in this example), scanning will stop and the last measurement will remain on the display.

Reading Channel State

The CLOSE? command can be used to determine the state of the FET MUX channels. This command returns one of five numbers for each channel queried. The numbers returned indicate if a channel is open or closed and to which bus the channel is connected. Table 7-3 shows the channel state for each value that can be returned by the CLOSE? command when used with the 20-Channel FET MUX.

Table 7-3. Values Returned by the CLOSE? Command

Data Returned	Channel State
0	Channel Open
1	Channel Closed
2	Channel Closed - connected to Sense Bus
3	Channel Closed - connected to Source Bus
4	Channel Closed - connected to Both Buses

NOTE

When the CLOSE? command is used with the FET multiplexer accessories, the state of the isolation relays is ignored.

NOTE

The CLOSE? command will return 2, 3, or 4 only to indicate the state of Channels 0 through 19 (i.e., these values will not be returned for the tree switches).

<u>Example: Reading Channel State</u>

This example shows how to use the CLOSE? command to read the state of Channels 0 through 4 on a FET MUX. The RST command resets the FET MUX to its power-on state where all channels are open and the isolation relays are open. The CLOSE command Channel 3, the BANK A Sense Bus tree switch (Channel 91), and the isolation relays (Channel 90). The OPEN command is used to open the channels and disconnect them from the backplane. For this example, a FET MUX is installed in slot 2 of the mainframe.

```
10  OUTPUT 709; "RST 200"
20  INTEGER State(4)
30  OUTPUT 709; "CLOSE 203,291,290"
40  OUTPUT 709; "CLOSE? 200-204"
50  ENTER 709; State(*)
60  PRINT State(*)
70  OUTPUT 709; "OPEN 203,291,290"
80  END
```

Typical Output (Channel 3 closed - connected to Sense Bus):

```
0    0    0    2    0
```

Programming the 20-Channel FET MUX

As noted in the Introduction section of this chapter, the FET MUX has four primary functions: voltage measurements, current measurements, resistance measurements, and temperature measurements. This section contains examples that show how to program the accessory for each function. It includes a description of each function, applicable commands for the functions, and programming examples. Each example includes a sample program and (where applicable) typical outputs for the assumed conditions.

This section also summarizes the programming commands used with the FET MUX (refer to "Command Summary") and lists the titles of the example programs (refer to "Program Titles").

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

NOTE

The example programs show how to make typical measurements using the FET MUX with the HP 44701A Integrating Voltmeter Accessory or the HP 44702 High-Speed Voltmeter Accessory (when used on the backplane). Refer to the Mainframe Configuration and Programming Manual for instructions on making measurements using an external voltmeter.

Command Summary

Table 7-4 is an alphabetical listing of commands which apply to the FET MUX accessory. Refer to the HP 3852A Command Reference Manual for a complete description of these commands.

Table 7-4. Commands for the 20-Channel FET MUX

CLOSE *ch list*

Closes a single multiplexer channel or a list of channels specified by *ch list*. This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

CLOSE? *ch list* [INTO *name*] or [*fmt*]

Queries the state of channels specified by *ch list*.

CONFMEAS *function* , *ch list* [USE ch] [INTO *name*] or [*fmt*]

Configures the voltmeter accessory and measures a function on the channels specified by *ch list*. This command automatically configures the voltmeter accessory and the tree switches on the multiplexer for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function* , *ch list* [USE *ch*] [INTO *name*] or [*fmt*]

Scans and measures a function on the channels specified by *ch list*. This command does not configure the voltmeter accessory but it does configure the tree switches on the multiplexer for the measurement.

MONMEAS *function* , *ch list* [USE *ch*]

Monitors and measures a function on the channels specified by *ch list*. This command is useful to check wiring connections made on the terminal module.

OPEN *ch list*

Opens a single multiplexer channel or a list of channels specified by *ch list*. This command is used to open channels and place them in a safe state after the measurements have been made.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Program Titles

The discussion for each function includes one or two examples that show how to program the FET MUX for that function. Table 7-5 lists the titles of the example programs in this section.

Table 7-5. Program Titles

Making Voltage Measurements

One of the functions of the FET MUX accessory is to make voltage measurements. This section explains how to program the accessory to make guarded (3-wire) DC and AC voltage measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 7-1 for the specifications.

NOTE

The AC voltage function is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC voltage measurements.

Example: Measuring DC and AC Voltage Sources

Suppose that you want to measure the outputs from 20 voltage sources using the FET MUX and the guarded voltage function. See Figure 7-7 to connect voltage sources to the terminal module.

The following example program uses the CONFMEAS command to measure 20 DC voltage sources connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the 20 channels once.

Table 7-5. Program Titles

TITLE	DESCRIPTION	COMMANDS
	Voltage Measurements	
Measuring DC and AC Voltage Sources	Measures the outputs from 20 voltage sources using the FET MUX.	CONFMEAS
Measuring Voltage Sources using the CLOSE Command	Measures the output from a voltage source using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	Current Measurements	
Making DC and AC Currents Measurements	Makes a current sensing measurement using a shunt resistor installed on the FET MUX.	CONFMEAS
	Resistance Measurements	
Making Resistance Measurements (2-Wire Function)	Measures the 20 resistors using the FET MUX and the 2-wire ohms function.	CONFMEAS
Making 2-Wire Ohms Measurements using the CLOSE Command	Measures a single resistor using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
Making Resistance Measurements (4-Wire Function)	Measures the resistance of a single resistor using the FET MUX and the 4-wire ohms function.	CONFMEAS
	Temperature Measurements	
Measuring Temperature using RTDs (4-Wire Function)	Makes a temperature measurement using the FET MUX and the 4-wire RTD measurement function.	CONFMEAS
Measuring Temperature using Thermistors (4-Wire Function)	Makes a temperature measurement using the FET MUX and the 4-wire thermistor measurement function.	CONFMEAS

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70  OUTPUT 709; "CONFMEAS ACV,200-219,USE 0"
```

```
10  !
20  !Use the CONFMEAS command to measure 20 DC voltages
30  !using a FET MUX in slot 2 of the mainframe.  Install
40  !a voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Volts(19)
70  OUTPUT 709; "CONFMEAS DCV,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Volts(I)
100 PRINT "Ch.";I, Volts(I)
110 NEXT I
120 END
```

Typical DC voltage values for the assumed conditions:

```
Ch. 0   4.30300
Ch. 1   4.33350
        .
        .
        .
Ch. 18  4.58580
Ch. 19  3.49490
```

<u>Example: Measuring Voltage Sources using the CLOSE Command</u>

Suppose that you want to measure the output from a voltage source using the CLOSE command to control the tree switches and bank switches. See Figure 7-7 to connect a voltage source to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the BANK A Sense Bus tree switch (Channel 91), and the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the DC voltage from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 90:

```
90 OUTPUT 709; "FUNC ACV"
```

```
10  !
20  !Use the CLOSE command to make a DC voltage measurement
30  !of the voltage source connected to Channel 0 on a FET
40  !MUX in slot 2 of the mainframe.  Install a voltmeter
50  !accessory in slot 0 of the mainframe.
60  !
70  OUTPUT 709; "USE 0"
80  OUTPUT 709; "CLOSE 200,291,290"
90  OUTPUT 709; "FUNC DCV"
100 OUTPUT 709; "TRIG SGL"
110 OUTPUT 709; "CHREAD 0"
120 ENTER 709; Volts
130 PRINT Volts
140 OUTPUT 709; "OPEN 200,291,290"
150 END
```

Typical DC voltage value for the assumed conditions:

```
3.94940
```

Making Current Measurements

The FET MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across a shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. This section shows how to program the FET MUX to switch signals for DC and AC current measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 7-1 for the specifications.

NOTE

The AC voltage function (used for AC current sensing) is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC current measurements.

Example: Making DC and AC Current Measurements

Suppose that you want to make a current measurement using a 250Ω shunt resistor installed on the terminal module. See Figure 7-9 to install a shunt resistor on the terminal module for a current measurement.

The following example program uses the CONFMEAS command to measure a 250Ω shunt resistor installed on Channel 0. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the channel once. The voltage value is returned to the controller which then calculates the current in DC amps.

NOTE

To use the following program to make AC current measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70  OUTPUT 709; "CONFMEAS ACV,200,USE 0"
```

```
10  !
20  !Use the CONFMEAS command to measure a 250Ω shunt
30  !resistor and calculate the DC current on Channel 0.  Use
40  !a FET MUX in slot 2 of the mainframe.  Install a voltmeter
50  !accessory in slot 0 of the mainframe.
60  !
70  OUTPUT 709; "CONFMEAS DCV,200,USE 0"
80  ENTER 709; Volts
90  !
100 !Current = Voltage Measured/Resistance of Shunt
110 !
120 Current = Volts/250
130 PRINT Current
140 END
```

Typical current value (in DC Amps) for the assumed conditions:

```
.03034
```

Making Resistance Measurements

One of the functions of the FET MUX accessory is to make resistance measurements. This section explains how to program the FET MUX for 2-wire and 4-wire ohms measurements.

2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per FET MUX accessory.

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

When using the FET MUX for 2-wire ohms measurements, the voltmeter accessory is actually configured for a 4-wire ohms measurement. The FET MUX converts the 4-wire function on the voltmeter to a 2-wire function on the component module. It does this by connecting the high voltage sense lead to the high current source lead and the low voltage sense lead to the low current source lead. Therefore, only two leads are used on the FET MUX for the 2-wire ohms measurement.

Example: Making Resistance Measurements (2-Wire Function)

Suppose that you want to measure 20 resistors connected to the FET MUX using the 2-wire ohms function. See Figure 7-10 to connect resistors to the terminal module for 2-wire ohms measurements.

The following example program uses the CONFMEAS command to measure 20 resistors connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for 2-wire ohms measurements and measures the 20 channels once.

```
10  !
20  !Use the CONFMEAS command to measure 20 resistors using a FET
30  !MUX in slot 3 of the mainframe.  Install a voltmeter accessory
40  !in slot 0 of the mainframe.
50  !
60  REAL Ohms(19)
70  OUTPUT 709; "CONFMEAS OHM,300-319,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Ohms(I)
100 PRINT "Ch.";I, Ohms(I)
110 NEXT I
120 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
Ch. 0   4628.340
Ch. 1   5024.900
     .
     .
     .
Ch. 18  4039.400
Ch. 19  6528.380
```

Example: Making 2-Wire Ohms Measurements using the CLOSE Command

Suppose that you want to make a 2-wire ohms measurement of a resistor using the CLOSE command to control the tree switches and bank switches. See Figure 7-10 to connect resistors to the terminal module for a 2-wire ohms measurement.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the BANK A Sense Bus tree switch (Channel 91), the BANK A Source Bus tree switch (Channel 93), and the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for 4-wire ohms measurements (the FET MUX converts the 4-wire function to a 2-wire function on the component module). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance value from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

The following program uses the HP 44701A Integrating Voltmeter Accessory. To use this program with the HP 44702 High-Speed Voltmeter Accessory on the backplane, substitute the following line for the existing line 80:

```
80  OUTPUT 709; "FUNC OHMF100K"
```

```
 10  !
 20  !Use the CLOSE command to make a 2-wire ohms measurement
 30  !of Channel 0 on a FET MUX in slot 3 of the mainframe.
 40  !Install a voltmeter accessory in slot 0 of the mainframe.
 50  !
 60  OUTPUT 709; "USE 0"
 70  OUTPUT 709; "CLOSE 300,391,393,390"
 80  OUTPUT 709; "FUNC OHMF"
 90  OUTPUT 709; "TRIG SGL"
100  OUTPUT 709; "CHREAD 0"
110  ENTER 709; Ohms
120  PRINT Ohms
130  OUTPUT 709; "OPEN 300,391,393,390"
140  END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
11623.570
```

4-Wire Ohms Measurements

The use of the 4-wire ohms measurement virtually eliminates the error caused by the test lead resistances. The current through the unknown resistance is the same regardless of the lead resistance but the voltmeter measures only the voltage across the resistance, not across the combined test lead and the resistance. The 4-wire ohms function is essential when the highest accuracy is required. Since each 4-wire ohms measurement requires two channels, up to 10 resistance measurements can be made per FET MUX accessory.

Example: Making Resistance Measurements (4-Wire Function)

Suppose that you want to measure a resistor using the FET MUX and the 4-wire ohms function. See Figure 7-11 to connect resistors to the terminal module for 4-wire ohms measurements.

The following example program uses the CONFMEAS command to measure a resistor using the 4-wire ohms function. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel. Note that the channel specified in the channel list with the CONFMEAS command (Channel 0) is the sense channel (the HP 3852A automatically configures the channel that is one decade from the sense channel as the source channel). The resistor is scanned once by the voltmeter accessory and the result (in Ohms) is returned to the controller.

```
10  !
20  !Use the CONFMEAS command to make a 4-wire ohms measurement
30  !using a FET MUX in slot 3 of the mainframe.  Install a
40  !voltmeter accessory in slot 0 of the mainframe.
50  !
60  OUTPUT 709; "CONFMEAS OHMF,300,USE 0"
70  ENTER 709; Ohms
80  PRINT Ohms
90  END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
205.955
```

Making Temperature Measurements

One of the functions of the FET MUX accessory is to make temperature measurements. This section shows how to program the FET MUX accessory to make RTD measurements and thermistor measurements.

NOTE

Because of the high "on" resistance of the FET switches and the low resistance values of RTDs and thermistors, the only temperature measurement technique available for the FET MUX is the 4-wire function.

Measuring Temperature using RTDs

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. The HP 3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ and resistance values of 100Ω at 0°C.

Most RTDs have small resistance values (typically less than 300Ω) which makes the test lead resistance a significant factor when making resistance measurements. The only usable RTD measurement method with the FET MUX accessory is the 4-wire ohms measurement function. Since each 4-wire ohms measurement requires two channels, a single FET MUX accessory can be used to make up to 10 RTD measurements.

Example: Measuring Temperature using RTDs (4-Wire Function)

Suppose that you want to make a temperature measurement using an RTD and the 4-wire function. See Figure 7-12 to connect RTDs to the terminal module for 4-wire temperature measurements.

The following example program uses the CONFMEAS command to scan and measure one RTD (with $\alpha = 0.003916\ \Omega/\Omega°C$) using the 4-wire ohms function. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel. Note that the channel specified in the channel list with the CONFMEAS command (Channel 0) is the sense channel (the HP 3852A configures the channel that is one decade from the sense channel as the source channel). The RTD is scanned once by the voltmeter accessory and the result (in °C) is returned to the controller.

```
10 !
20 !Use the CONFMEAS command to measure an RTD using the 4-wire
30 !ohms function.  Use a FET MUX in slot 2 of the mainframe.
40 !Install a voltmeter accessory in slot 0 of the mainframe.
50 !
60 OUTPUT 709; "CONFMEAS RTDF92,200,USE 0"
70 ENTER 709; Temp
80 PRINT Temp
90 END
```

Typical temperature value (in °C) for the assumed conditions:

```
24.54297
```

Measuring Temperature using Thermistors

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too high. They are highly dependent upon variables such as thermistor composition and size. Most thermistors have negative temperature coefficients which means that their resistance values decrease with increasing temperature.

The HP 3852A allows thermistors to be measured using the 4-wire function. Since each 4-wire measurement requires two channels, up to 10 thermistors can be measured per FET MUX accessory. The HP 3852A resistance-to-temperature conversions support thermistors with the following resistance values at 25°C: 2252Ω, 5 kΩ, and 10 kΩ.

Example: Measuring Temperature using Thermistors (4-Wire Function)

Suppose that you want to make a 4-wire temperature measurement using a 2252Ω thermistor. See Figure 7-13 to connect a thermistor to the terminal module for a 4-wire temperature measurement.

The following example program uses the CONFMEAS command to scan and measure a 2252Ω thermistor using the 4-wire ohms function. Channel 0 is used as the voltage sense channel and Channel 10 is used as the current source channel. Note that the channel specified in the channel list with the CONFMEAS command (Channel 0) is the sense channel (the HP 3852A configures the channel that is one decade from the sense channel as the source channel). The thermistor is scanned once by the voltmeter accessory and the result (in °C) is returned to the controller.

```
10  !
20  !Use the CONFMEAS command to measure a thermistor (2252Ω)
30  !using the 4-wire function.  Use a FET MUX in slot 2 of the
40  !mainframe.  Install a voltmeter accessory in slot 0 of the
50  !mainframe.
60  !
70  OUTPUT 709; "CONFMEAS THMF2252,200,USE 0"
80  ENTER 709; Temp
90  PRINT Temp
100 END
```

Typical temperature value (in °C) for the assumed conditions:

```
25.69674
```

Chapter 8
HP 44710A
20-Channel FET Mux/TC

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HP 44710A 20-Channel FET MUX/TC

Chapter 8

20-Channel FET MUX/TC

HP 44710A

Introduction

This chapter shows how to configure and program the HP 44710A 20-Channel FET Multiplexer (MUX) with Thermocouple Compensation Accessory. The chapter has four sections: Introduction, Specifications, Configuring the 20-Channel FET MUX/TC, and Programming the 20-Channel FET MUX/TC.

- **Introduction** contains a chapter overview, a description of the FET MUX, a description of its functions, and shows suggested steps to get started.
- **Specifications** lists the specifications for the accessory.
- **Configuring the 20-Channel FET MUX/TC** contains a block diagram description of the accessory, shows how to hardware configure the terminal module, and shows how to connect field wiring to the terminal module.
- **Programming the 20-Channel FET MUX/TC** shows how to program the accessory for voltage, current, resistance, and thermocouple measurements.

Description

The FET MUX is used to switch (multiplex) signals from up to 20 channels for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory is designed to perform high-speed switching of low signal-level devices with input voltages less than 10.24 VDC or 7.24 VAC RMS (10.24V peak). The 20 channels can be switched at speeds up to 600 channels per second using an HP 3852A voltmeter accessory.

The FET MUX accessory consists of a 20-channel terminal module and a FET MUX component module. This accessory uses the same component module as the HP 44709A 20-Channel FET MUX Accessory but adds a special isothermal connector block on the terminal module. The isothermal connector block is used to eliminate unwanted measurement errors when making thermocouple measurements.

Functions

The FET MUX accessory is used to switch signals for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory can be used to switch signals for four primary functions:

- Voltage Measurements.
- Current Measurements.
- 2-Wire Resistance (or Ohms) Measurements.
- Thermocouple Measurements.

NOTE

Each channel on the FET MUX can be independently configured to allow multiple functions to be measured using the same accessory.

Voltage Measurements

The FET MUX can be used to switch signals for guarded (3-wire) DC voltage and AC voltage measurements. In the guarded voltage measurement function, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection. Use this function to make up to 20 voltage measurements per FET MUX accessory.

Current Measurements

The FET MUX can be used to switch signals for DC and AC current measurements using current sensing. Current sensing is a method of determining current using a shunt resistor that you install on the terminal module. Use this function to make up to 20 current measurements per FET MUX accessory.

NOTE

Current sensing measurements are not recommended when making temperature measurements on the same terminal module. The heat produced by the shunt resistor may affect the accuracy of the temperature measurements.

2-Wire Ohms Measurements

The FET MUX can be used to switch signals for 2-wire ohms measurements. In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per FET MUX accessory.

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

NOTE

Four-wire ohms measurements cannot be made using the 20-Channel FET MUX/TC accessory.

Thermocouple Measurements

The FET MUX can be used to switch signals for making 2-wire temperature measurements using thermocouples. Thermocouples provide simple, durable, inexpensive, and relatively accurate measurements over a wide range of temperatures. The HP 3852A temperature conversions support the following thermocouple types: B, E, J, K, N (awg 14), N (awg 28), R, S, and T.

The HP 3852A uses software compensation to compensate for the effect of the isothermal block reference temperature. With software compensation, up to 20 thermocouples can be measured using a single FET MUX and any mixture of thermocouples can be used.

NOTE

Other transducers can be measured using the FET MUX but only those listed above are supported by the HP 3852A conversions.

Getting Started

To use the FET MUX accessory for your application, you will need to follow three steps:

- Define your application.
- Configure the accessory for your application.
- Program the accessory for your application.

Define your Application

The first step is to define your application and determine if the accessory can meet the requirements of your application. The FET MUX can switch DC or AC inputs up to 10.24 VDC or 7.24 VAC RMS (10.24V peak). Since each of the 20 channels can be independently configured, up to 20 different devices can be connected to the accessory. When selecting devices to be connected, refer to Table 8-1 "20-Channel FET MUX/TC Specifications" to ensure that the voltage and current requirements of your application are within the specifications for this accessory.

Configure the Accessory

The next step is to configure the accessory for your application. Refer to "Configuring the 20-Channel FET MUX/TC" for information on hardware configuration and connecting field wiring to the terminal module for voltage, current, 2-wire ohms, and thermocouple measurements.

Program the Accessory

The third step is to program the FET MUX for your application. Refer to "Programming the 20-Channel FET MUX/TC" to program the accessory for voltage, current, 2-wire ohms, and thermocouple measurements.

Specifications

Table 8-1 lists the specifications for the FET MUX. This table contains five categories: Input Characteristics, Channel Specifications, Operating Characteristics, AC Performance, and Thermocouple Characteristics.

WARNING

The HP 3852A and the HP 3853A internal analog buses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the HP 3852A, HP 3853A, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum Allowable Peak Voltage
HP 3852A Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	350V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexer	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extenders, each instrument is considered as a separate circuit.

Table 8-1. 20-Channel FET MUX/TC Specifications

INPUT CHARACTERISTICS:

Maximum Signal Voltage:

Between any two input terminals or to chassis:
10.24V peak, 10.24 VDC, 7.24 VAC RMS

Input Voltage Protection Limit:

Channel Inputs: ±12V peak maximum
Backplane with isolation relays open: ±42V peak maximum

CHANNEL SPECIFICATIONS:

Bias Currents:

(Channel at 0V with respect to Chassis)
Currents are sourced by the accessory from HIGH or LOW to Chassis.

	Into Transducer or Backplane (0-28°C/0-55°C)	
	Channel Closed	Channel Open
HIGH or LOW	5 nA/45 nA	2 nA/11 nA
GUARD	65 nA/770 nA	6 nA/110 nA

	Into Backplane (0-28°C/0-55°C)	
	Channel Open Isolation Relay Closed[1]	Maximum Differential Offset Voltage[2]
HIGH or LOW	2 nA/11 nA	20 uV/120 uV
GUARD	65 nA/670 nA	–

[1]All channels open, isolation relay closed.

[2]Differential offset voltage between HIGH and LOW with a source resistance < 1 kΩ; RH < 85% @ 28°C or RH < 60% @ 40°C.

Maximum Signal Current: ±1 mA per channel

Isolation:

HIGH to LOW, HIGH to Chassis:
Channel On or Off: $10^8 \Omega$
Power Off: Vin ≤ 10V 1 kΩ
Vin > 10V 200Ω

Low to Chassis: 100Ω

Table 8-1. 20-Channel FET MUX/TC Specifications (cont'd)

Closed Channel "On" Resistance:
HIGH or LOW: 3.0 kΩ
GUARD: 3.2 kΩ

OPERATING CHARACTERISTICS:

Maximum Scan Rate (channels per second):
Using HP 3852A Voltmeter Accessories: 600
Using External Voltmeter: 8,000

Synchronization: Break-Before-Make in scanning operation.

AC PERFORMANCE:

Frequency Response relative to 1 kHz:
(50Ω source, 1 MΩ termination)

50 kHz: -0.6 dB
200 kHz: -3.0 dB

Capacitance with Channel On:
HIGH to LOW: 200 pF
HIGH, LOW to Chassis: 200 pF

Crosstalk, Channel-to-Channel:
(50Ω source, 1 MΩ load); ≤ 5 Vrms

10 kHz: -50 dB
100 kHz: -35 dB

THERMOCOUPLE CHARACTERISTICS:

Sense Accuracy (one year): 18-40° ±0.1°C
0-60° ±0.2°C

Thermocouple Types Supported:
Type B: Platinum/6% Rhodium - Platinum/30% Rhodium
Type E: Chromel - Constantan
Type J: Iron - Constantan
Type K: Chromel - Alumel
Type N: Nicrosil - Nisil (14 awg)
Type N: Nicrosil - Nisil (28 awg)
Type R: Platinum - Platinum/13% Rhodium
Type S: Platinum - Platinum/10% Rhodium
Type T: Copper - Constantan

Configuring the 20-Channel FET MUX/TC

This section shows how to configure the FET MUX accessory. It contains a block diagram description of the accessory, information on hardware configuring the terminal module, and information on connecting field wiring to the terminal module.

Refer to "Programming the 20-Channel FET MUX/TC" to program the accessory for voltage, current, resistance, and thermocouple measurements.

WARNING

⚠ 1 *SHOCK HAZARD. Only qualified, service-trained personnel who are aware of the hazards involved should install, remove, or configure any accessory. Before touching any installed accessory, turn off all power to the mainframe, extenders, and to all external devices connected to the mainframe, extenders, or accessories.*

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers attached.

Block Diagram Description

⚠ 2

The FET MUX accessory consists of a 60-channel terminal module and a FET MUX component module as shown in Figure 8-1. Field wiring from your application sensors, such as thermocouples, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Figure 8-1. 20-Channel FET MUX/TC Block Diagram

A special isothermal connector block on the terminal module eliminates unwanted measurement errors when making thermocouple measurements. A 5 kΩ thermistor is mounted on the isothermal connector block to measure the reference temperature. The HP 3852A uses software compensation to automatically compensate for the reference temperature when making thermocouples measurements.

The component module is made up of 24 switches which are divided into two categories: bank switches and tree switches. Each of the 24 switches consists of three Field Effect Transistors (FETs), one each for HIGH, LOW, and GUARD lines. There are a total of 20 bank switches which are divided into two groups of 10 channels each: BANK A and BANK B. The channels in BANK A are numbered 0 through 9 and the channels in BANK B are numbered 10 through 19.

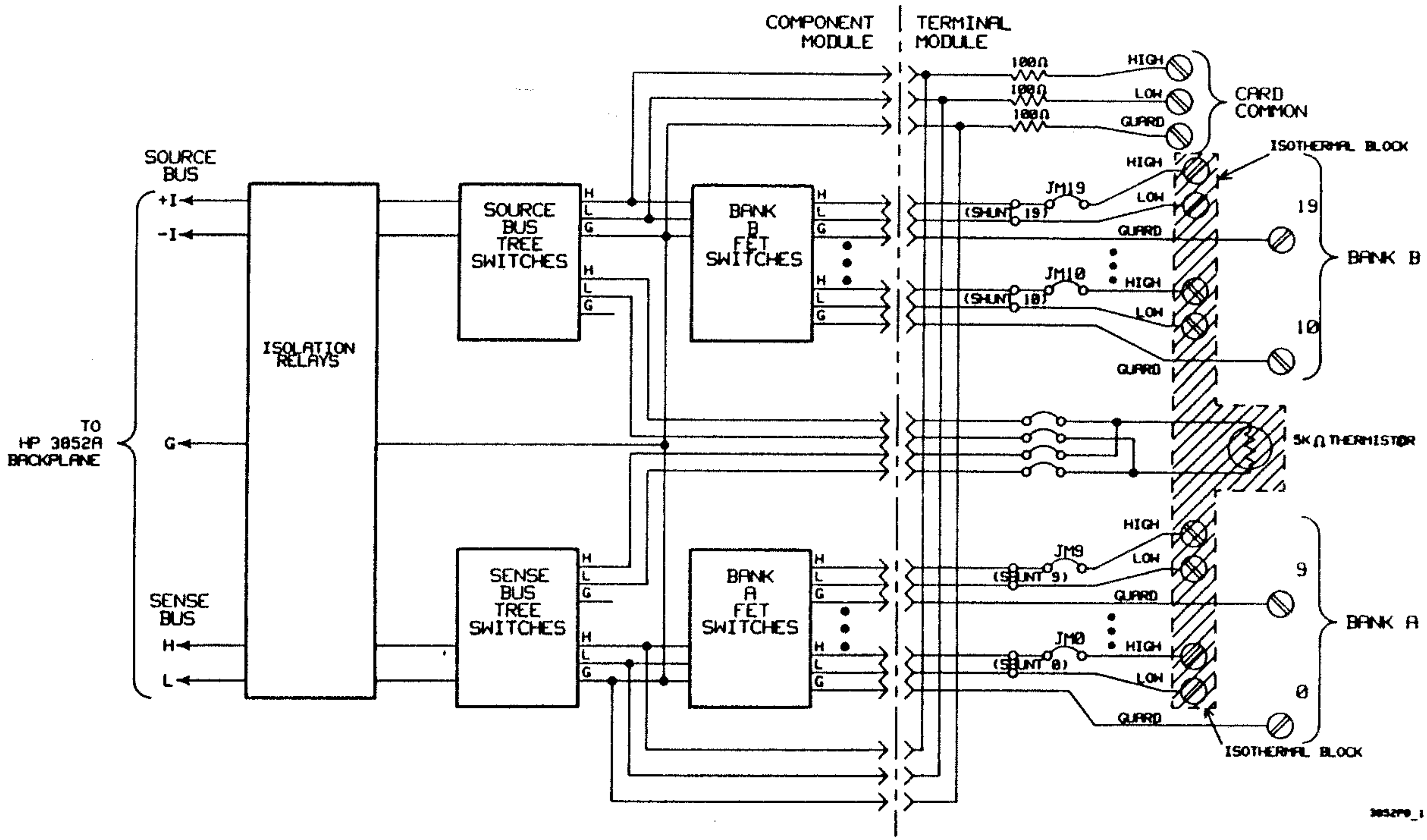

Figure 8-1. 20-Channel FET Mux/TC Block Diagram

NOTE

Only one channel per bank can be closed at a time. Closing a second channel in a bank will open any previously closed channel in that bank.

The component module contains four tree switches which are of two types: Source Bus tree switches and Sense Bus tree switches. The 20 bank switches share a Source Bus tree switch and a Sense Bus tree switch. The other Source Bus and Sense Bus tree switches are used to measure the reference temperature when making thermocouple measurements. The tree switches control signal flow to and from the HP 3852A backplane and also isolate the bank switches from the backplane when they are not in use. The Sense Bus tree switches provide the connections to the backplane for making voltage measurements. The Source Bus tree switches provide the current source connections (+I and -I) to the backplane for making resistance measurements.

The component module also includes isolation relays which allow the accessory to be isolated from the HP 3852A backplane. The isolation relays can be used to reduce the leakage current on the backplane for critical measurements or for using the backplane at voltages greater than the FET MUX voltage specification. The FET MUX has overvoltage protection circuitry which will automatically open the isolation relays when voltages greater than ±15V peak are detected on the HP 3852A backplane.

Table 8-2 shows the channel definitions for the FET MUX accessory. Channels 0 through 19 control the bank switches, Channel 90 controls the isolation relays, and Channels 91 through 94 control the tree switches. Note that Channels 91 and 94 control the tree switches for the measurement channels. Channels 92 and 93 control the tree switches for the thermistor on the isothermal connector block.

Table 8-2. 20-Channel FET MUX/TC Channel Definitions

Channel	Definitions
0 - 19	Bank Switches
90	Isolation relays
91	Sense Bus Tree Switch (bank switches)
92	Sense Bus Tree Switch (thermistor)
93	Source Bus Tree Switch (thermistor)
94	Source Bus Tree Switch (bank switches)

NOTE

Two tree switches of the same type cannot be closed simultaneously (e.g., only one of the two Sense Bus tree switches can be closed at a time). Closing a second tree switch will open any previously closed tree switch of the same type.

The bank switch terminals are connected together on the terminal module to form the CARD COMMON terminal. As factory configured, there are three 100Ω current limiting resistors in series with the CARD COMMON terminal.

⚠ [1] Configuring the Terminal Module

This section explains how to hardware configure the terminal module. It shows how to install low pass filters and attenuators on the terminal module for input signal conditioning.

Installing Low Pass Filters

Space has been provided on the terminal module for you to install one-pole low pass filters for input signal conditioning on each channel. Figure 8-2 shows the normal channel configuration and the low pass filter channel configuration.

Figure 8-2. Low Pass Filter Channel Configuration

Figure 8-3 shows how to install a low pass filter for Channel 10 on the terminal module. To install the low pass filter, remove the jumper (BANK B SERIES JM 0) and install your resistor in its place. Install your capacitor in the BANK B SHUNT 0 position as shown. Precision components should be used to maintain accuracy.

Figure 8-3. Installing Low Pass Filters

Installing Attenuators

The space for low pass filters on the terminal module can also be used to install attenuators to reduce input signals to a usable level for the FET MUX. Figure 8-4 shows the normal channel configuration and how the channels are configured to attenuate input signals.

Figure 8-4. Attenuator Channel Configuration

Figure 8-5 shows how to install an attenuator for Channel 0 on the terminal module. To install the attenuator, remove the jumper (BANK A SERIES JM 0) and install resistor R1 in its place. Install resistor R2 in the BANK A SHUNT 0 position as shown. Precision components should be used to maintain accuracy.

Figure 8-5. Installing Attenuators

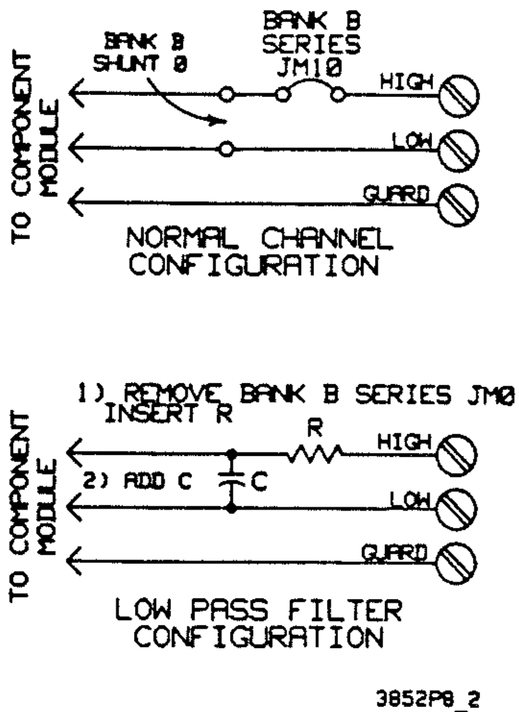

Figure 8-2. Low Pass Filter Channel Configuration

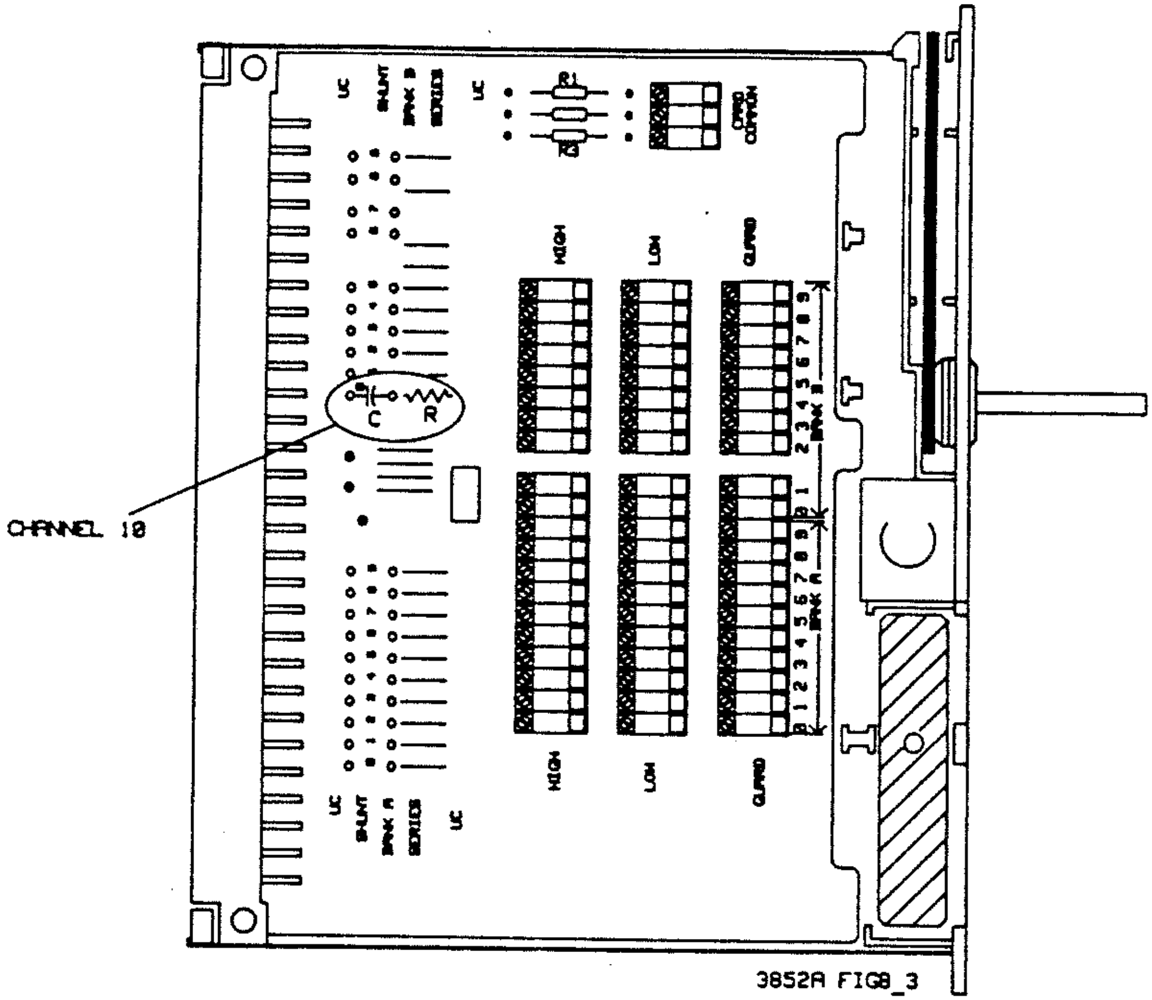

Figure 8-3. Installing Low Pass Filters

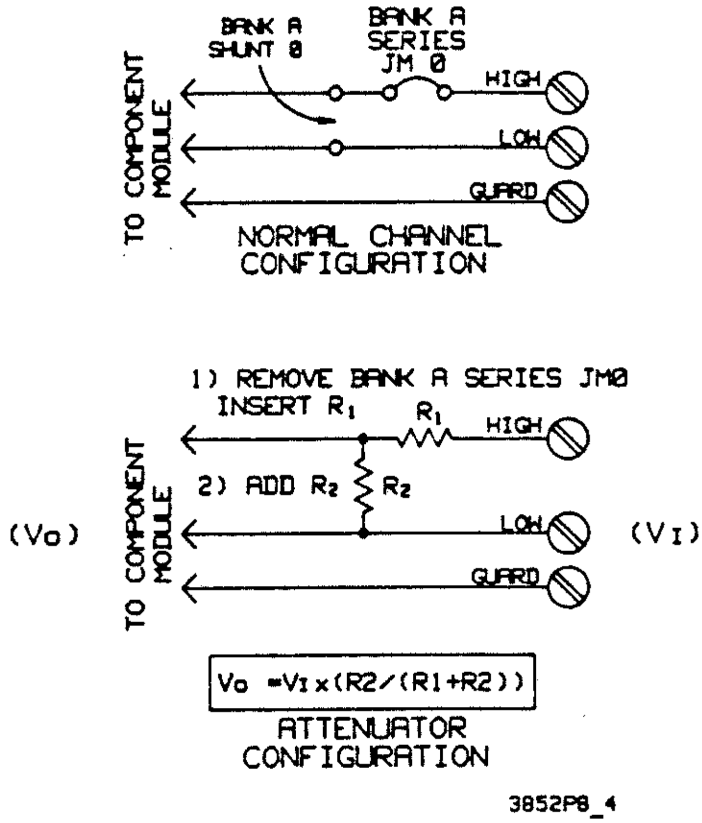

Figure 8-4. Attenuator Channel Configuration

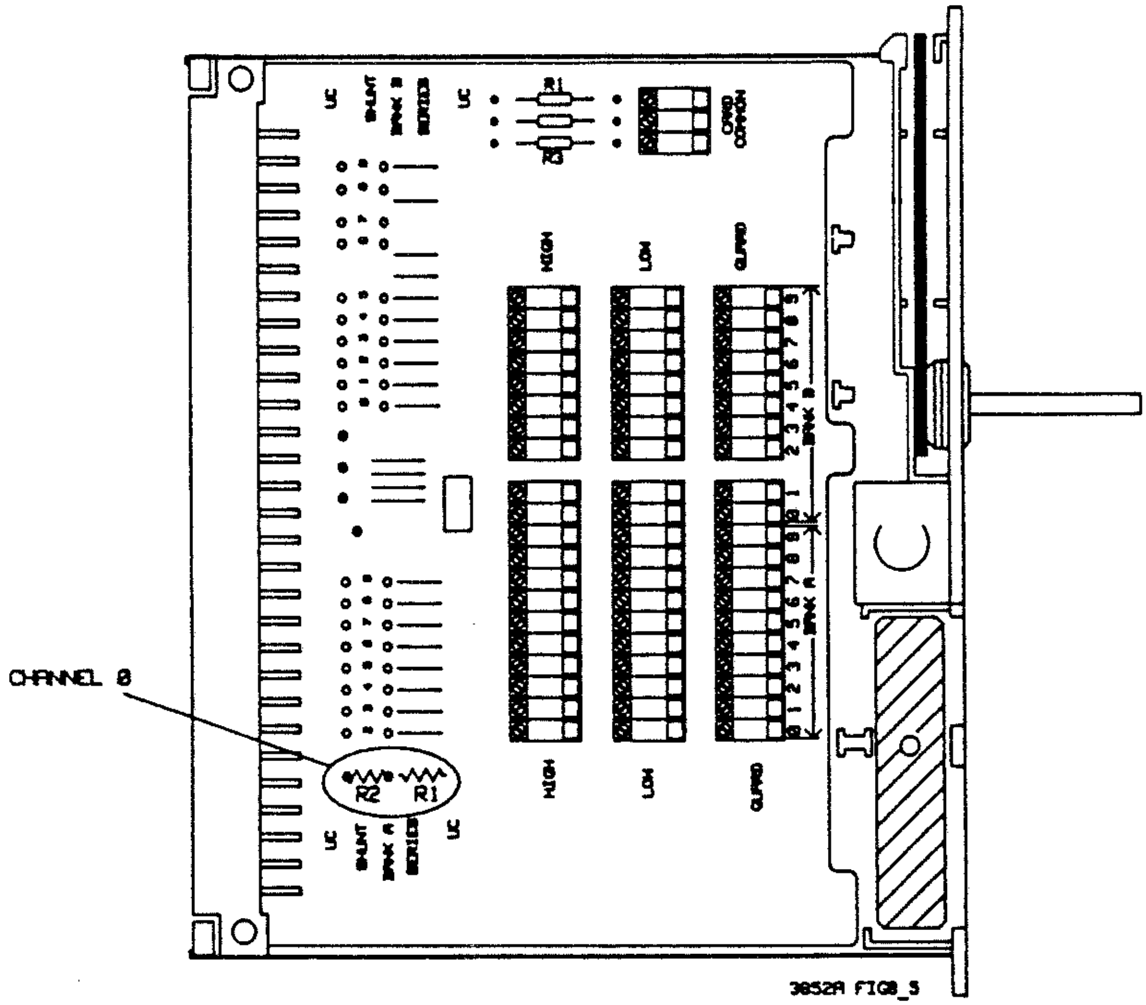

Figure 8-5. Installing Attenuators

Connecting Field Wiring

The next step is to connect field wiring from your application to the appropriate terminals on the terminal module. The following section contains examples that show how to connect field wiring to the terminal module for voltage, current, 2-wire ohms, and thermocouple measurements.

Figure 8-6 shows the terminal module with the cover removed. Each of the 20 channels has a HIGH, LOW, and GUARD terminal. Terminals 0 through 9 in BANK A are for Channels 0 through 9, respectively. Terminals 0 through 9 in BANK B are for Channels 10 through 19, respectively

Figure 8-6. 20-Channel FET MUX/TC Terminal Module

When connecting field wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make it easier to route the wiring.

NOTE

When connecting components such as resistors, the lead length may be too short to route through the strain relief clamp. In this case, the components will have to be stored inside the terminal module. When connecting these components, make sure that no leads are shorted together and bend the leads to allow the terminal module cover to be replaced.

Connections for Voltage Measurements

In the guarded (3-wire) voltage measurement function, the FET MUX accessory can switch signals for up to 20 DC or AC voltage measurements. When making guarded voltage measurements, HIGH, LOW, and GUARD lines are switched on each selected channel for maximum common mode noise rejection.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX/TC is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 8-1 for the specifications.

<u>**Example: Connecting Voltage Sources to the Terminal Module**</u>

A voltage source (V0) is connected to Channel 0 on the terminal module as shown in Figure 8-7. Connect the high (+) lead from the voltage source to the HIGH terminal. Connect the low (-) lead from the voltage source to the LOW terminal. If a guarded (3-wire) voltage measurement is being made, connect the shield from the shielded twisted pair to the GUARD terminal. The shielded twisted pair is used to reduce electrical noise in the measurements.

Figure 8-7. Connecting Voltage Sources to the Terminal Module

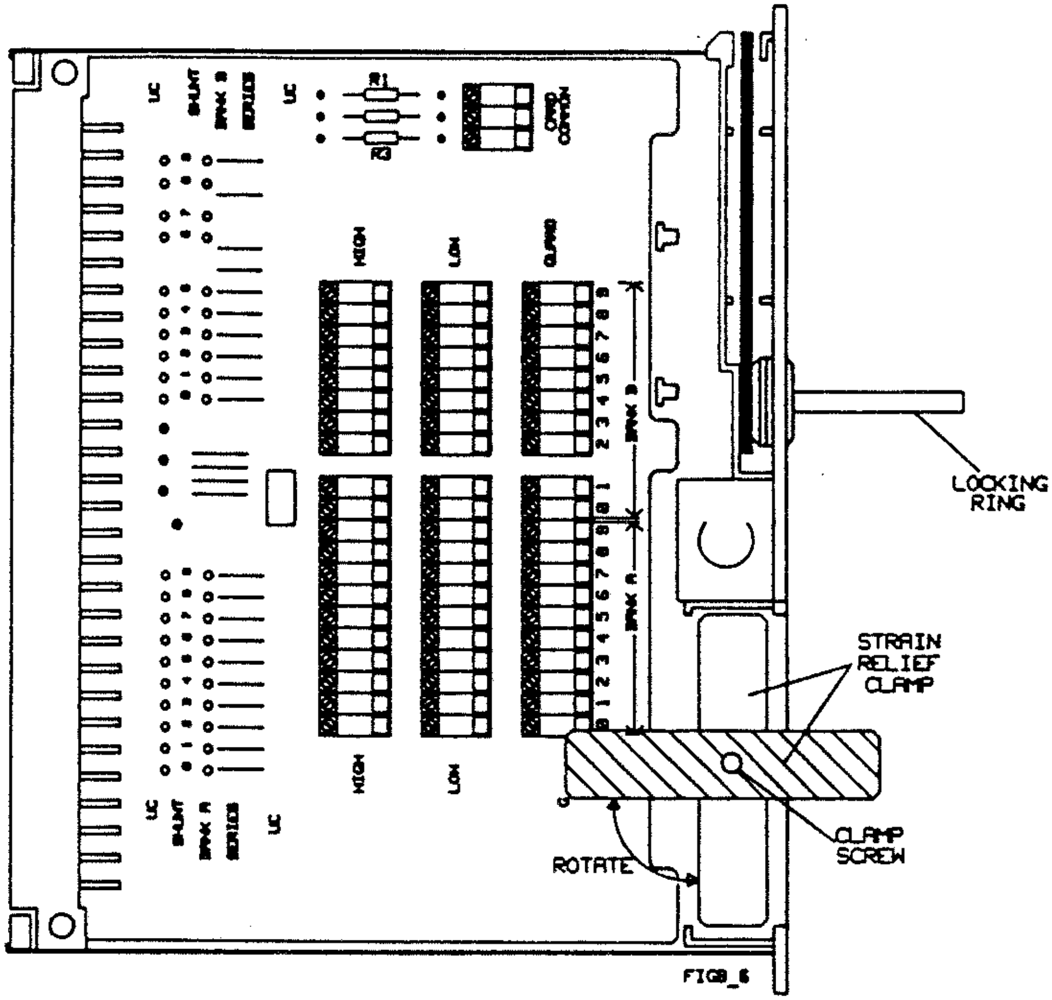

Figure 8-6. 20-Channel FET MUX/TC Terminal Module

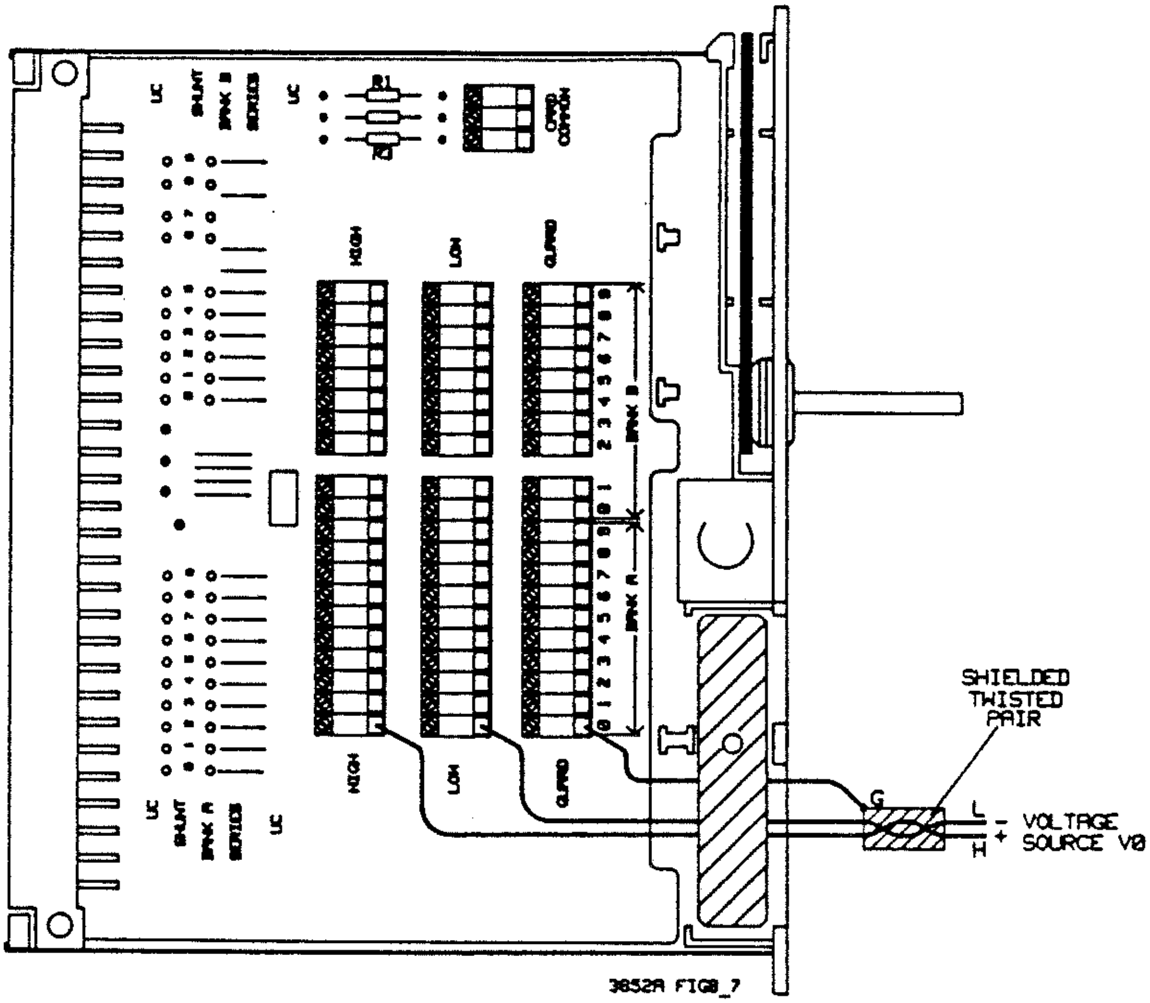

Figure 8-7. Connecting Voltage Sources to the Terminal Module

Connections for Current Measurements

The FET MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across a shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. The FET MUX can be used to switch signals for up to 20 DC or AC current measurements. When making current measurements, HIGH, LOW, and GUARD are switched on each selected channel for maximum common mode noise rejection. Figure 8-8 shows the normal channel configuration and how channels are configured for current sensing measurements.

NOTE

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX/TC is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 8-1 for the specifications.

NOTE

Current sensing measurements are not recommended when making temperature measurements on the same terminal module. The heat produced by the shunt resistor may affect the accuracy of the temperature measurements.

Figure 8-8. Current Sensing Configuration

Example: Installing Shunt Resistors for Current Measurements

A 250Ω shunt resistor (R0) is installed in the shunt position (BANK A SHUNT 0) for Channel 0 on the terminal module as shown in Figure 8-9.

NOTE

The SERIES JM (jumper) must be in place on the terminal module for each channel being used for current measurements (see Figure 8-9).

Figure 8-9. Installing Shunt Resistors for Current Measurements

Connections for Resistance Measurements

One of the functions of the FET MUX accessory is to switch signals for resistance measurements. This section contains a 2-wire ohms configuration example.

Example: Connecting Resistors for 2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to switch signals for up to 20 resistance measurements per FET MUX accessory.

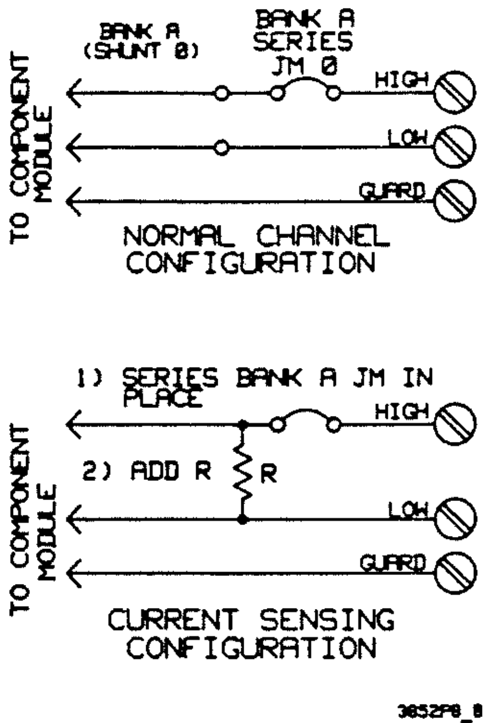

Figure 8-8. Current Sensing Configuration

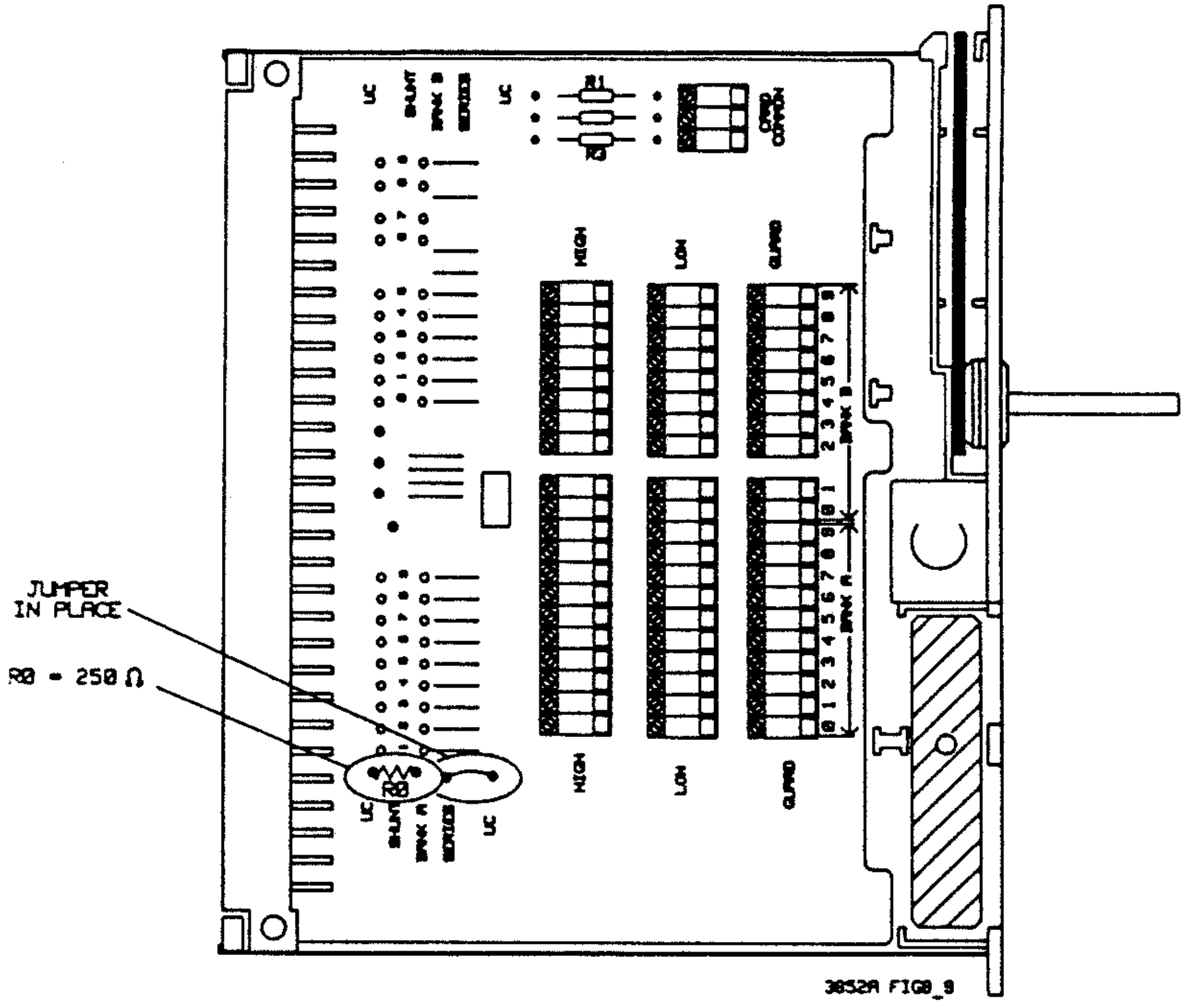

Figure 8-9. Installing Shunt Resistors for Current Measurements

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

A resistor (R0) is connected to Channel 0 on the terminal module as shown in Figure 8-10. Connect one lead of the resistor to the HIGH terminal. Connect the other lead of the resistor to the LOW terminal. Connect the guard lead (if high common mode noise rejection is required) from the resistor low lead to the GUARD terminal.

Figure 8-10. Connecting Resistors for 2-Wire Ohms Measurements

Thermocouple Measurements

One of the functions of the FET MUX accessory is to make temperature measurements using thermocouples. This section contains an example that shows how to connect thermocouples for temperature measurements.

Thermocouples provide a simple, durable, inexpensive, and relatively accurate temperature sensor for a wide variety of applications and environmental conditions. The thermocouple is a junction of two unlike metals that produces a voltage related to the junction temperature. Up to 20 thermocouple measurements can be made per FET MUX accessory. The HP 3852A temperature conversions support B, E, J, K, N14, N28, R, S, and T type thermocouples.

Before connecting thermocouples to the terminal module, refer to Table 8-3 for some connection guidelines.

Table 8-3. Guidelines for Connecting Thermocouples

1. Use the largest wire possible that will not shunt heat away from the thermocouple area.
2. Use thermocouple wire that is well within its rating.
3. Avoid mechanical stress and vibration that could strain the wires.
4. For long runs, use a shielded twisted pair and connect the shield to the GUARD terminal on the terminal module.
5. Avoid steep temperature gradients.
6. In hostile environments, use proper sheathing material to reduce adverse effects on thermocouple wires.

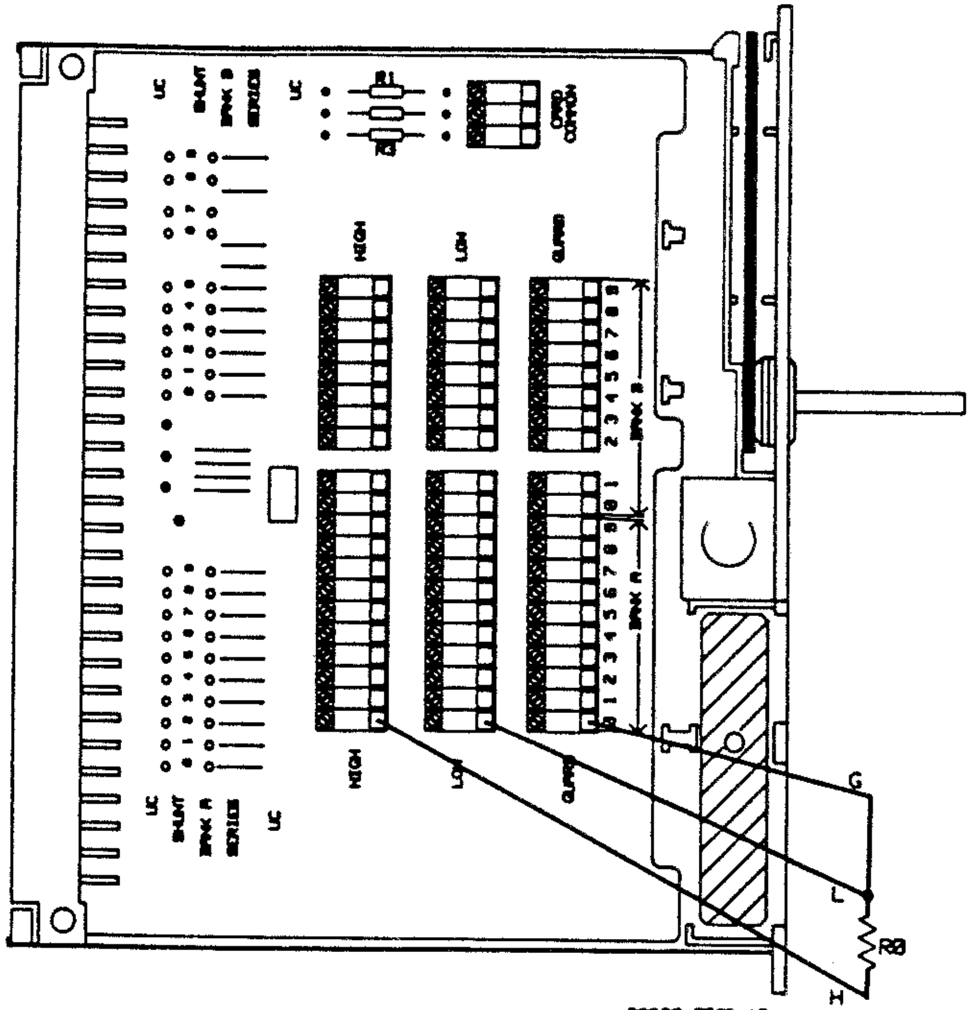

Figure 8-10. Connecting Resistors for 2-Wire Ohms Measurements

NOTE

Since the channels on the FET MUX can be independently configured and software compensation is used, any mixture of thermocouple types can be measured using the FET MUX.

Example: Connecting Thermocouples for Temperature Measurements

A thermocouple (TC0) is connected to Channel 0 on the terminal module as shown in Figure 8-11. Connect the negative metal lead (red lead) to the LOW terminal. Connect the positive metal lead to the HIGH terminal. Connect the guard lead (if high common mode noise rejection is required) from the thermocouple low lead to the GUARD terminal. Figure 8-12 shows three possible thermocouple wiring configurations.

Figure 8-11. Connecting Thermocouples for Temperature Measurements

Figure 8-12. Thermocouple Wiring Configurations

Installation/ Checkout

The following section explains how to check the accessory identity, how to verify the field wiring connections, and how to read the state of the channels.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

Checking the Accessory Identity

After you have connected field wiring from your application to the terminal module, replace the terminal module cover and install the accessory in the desired mainframe or extender slot. Refer to the Mainframe Configuration and Programming Manual to connect the terminal module to the component module and to install the accessory.

To check the accessory identity, you can use the ID? (Identity?) command. The ID? command provides a way to check, from the HP 3852A front panel or from a controller, in what slot an accessory has been installed. The ID? command will return " 44710A" for the 20-Channel FET MUX/TC and " 447XXX" if the terminal module is not connected to the component module. If the ID? command is sent to a slot with no accessory installed, " 000000" will be returned.

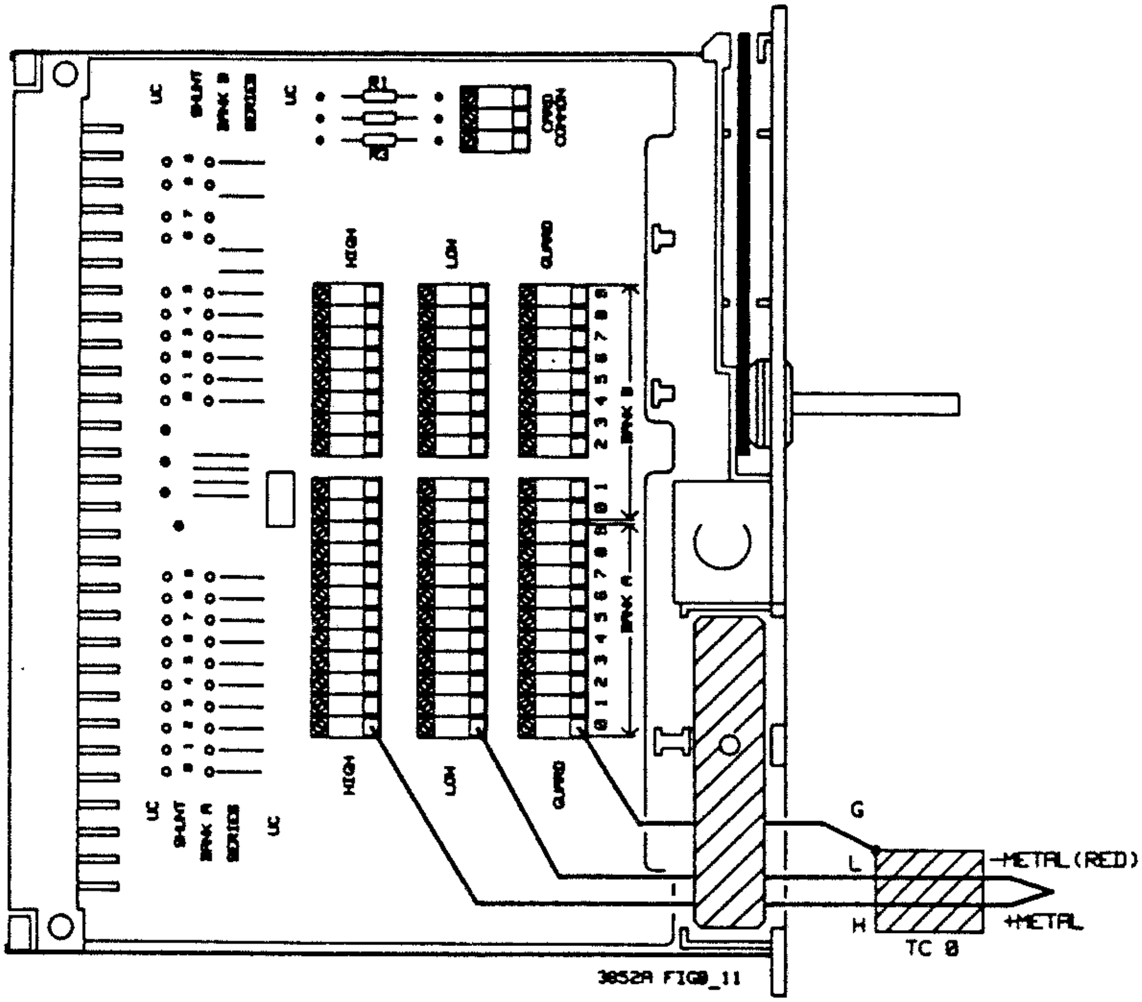

Figure 8-11. Connecting Thermocouples for Temperature Measurements

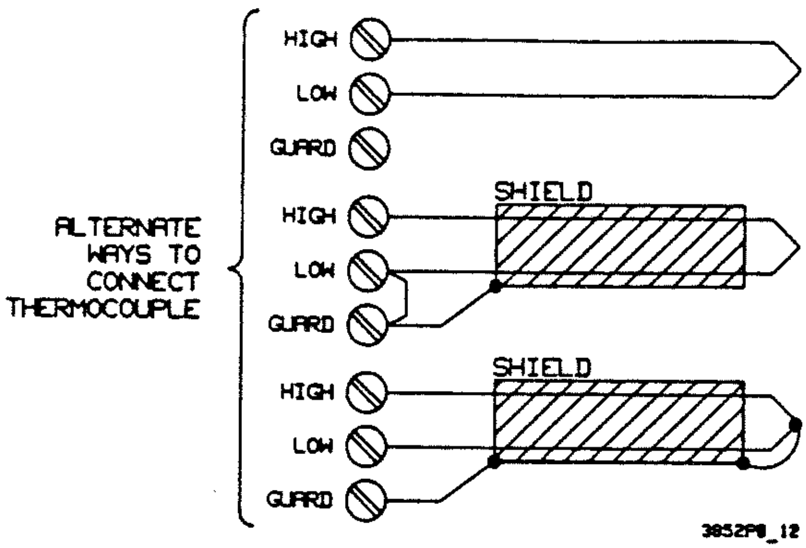

Figure 8-12. Alternate Thermocouple Wiring Configurations

Example: Reading the Accessory Identity

```
10  !
20  !Use the ID? command to read the identity of a FET
30  !MUX installed in slot 2 of the mainframe.
40  !
50  OUTPUT 709; "ID? 200"
60  ENTER 709; Identity$
70  PRINT Identity$
80  END
```

Output with terminal module connected:

```
44710A
```

NOTE

If you have addressed the correct slot and have made sure that the terminal module is connected, but the proper ID number is not returned, refer to the HP 3852A Assembly Level Service Manual for service procedures.

Verifying Wiring Connections

To verify that your field wiring has been properly connected to the terminal module, send the MONMEAS (Monitor/Measure) command from the HP 3852A front panel keyboard or from a controller. This command can be used to check DC voltage, AC voltage, and 2-wire ohms connections.

The following program segment shows how to use the MONMEAS command with a controller to verify DC voltage connections on Channels 200 through 219. The CONF command configures the voltmeter accessory for DC voltage measurements. For this example, a FET MUX is installed in slot 2 of the mainframe and a voltmeter accessory is installed in slot 0 of the mainframe.

```
10  OUTPUT 709; "USE 0"
20  OUTPUT 709; "CONF DCV"
30  OUTPUT 709; "MONMEAS DCV,200-219"
40  END
```

The 20 channels will be scanned and measured one at a time starting with Channel 200. Press "SADV KEY" on the HP 3852A front panel to advance the scanning to the next channel. When the scan is advanced past the last channel (Channel 219 in this example), scanning will stop and the last measurement will remain on the display.

Reading Channel State

The CLOSE? command can be used to determine the state of the FET MUX channels. This command returns one of five numbers for each channel queried. The numbers returned indicate if a channel is open or closed and to which bus the channel is connected. Table 8-4 shows the channel state for each value that can be returned by the CLOSE? command when used with the 20-Channel FET MUX/TC.

Table 8-4. Values Returned by the CLOSE? Command

Data Returned	Channel State
0	Channel Open
1	Channel Closed
2	Channel Closed - connected to Sense Bus
3	Channel Closed - connected to Source Bus
4	Channel Closed - connected to Both Buses

NOTE

When the CLOSE? command is used with the FET multiplexer accessories, the state of the isolation relays is ignored.

NOTE

The CLOSE? command will return 2, 3, or 4 only to indicate the state of Channels 0 through 19 (i.e., these values will not be returned for the tree switches).

Example: Reading Channel State

This program shows how to use the CLOSE? command to read the state of Channels 0 through 4 on a FET MUX. The RST command resets the FET MUX to its power-on state where all channels are open and the isolation relays are open. The CLOSE command closes Channel 3, the Sense Bus tree switch (Channel 91), and the isolation relays (Channel 90). The OPEN command is used to open the channels and disconnect them from the backplane. For this example, a FET MUX is installed in slot 2 of the mainframe.

```
10 OUTPUT 709; "RST 200"
20 INTEGER State(4)
30 OUTPUT 709; "CLOSE 203,291,290"
40 OUTPUT 709; "CLOSE? 200-204"
50 ENTER 709; State(*)
60 PRINT State(*)
70 OUTPUT 709; "OPEN 203,291,290"
80 END
```

Typical Output (Channel 3 closed - connected to Sense Bus):

```
0  0  0  2  0
```

Programming the 20-Channel FET MUX/TC

As noted in the Introduction section of this chapter, the FET MUX has four primary functions: voltage measurements, current measurements, 2-wire ohms measurements, and thermocouple measurements. This section contains examples that show how to program the accessory for each function. It includes a description of each function, applicable commands for the functions, and programming examples. Each example includes a sample program and (where applicable) typical outputs for the assumed conditions.

This section also summarizes the programming commands used with the FET MUX (refer to "Command Summary") and lists the titles of the example programs (refer to "Program Titles").

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

NOTE

The example programs show how to make typical measurements using the FET MUX with the HP 44701A Integrating Voltmeter Accessory or the HP 44702 High-Speed Voltmeter Accessory (when used on the backplane). Refer to the Mainframe Configuration and Programming Manual for instructions on making measurements using an external voltmeter.

Command Summary

Table 8-5 is an alphabetical listing of commands which apply to the FET MUX accessory. Refer to the HP 3852A Command Reference Manual for a complete description of these commands.

Table 8-5. Commands for the 20-Channel FET MUX/TC

CLOSE *ch list*

Closes a single multiplexer channel or a list of channels specified by *ch list*. This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

CLOSE? *ch list* [INTO *name*] or [*fmt*]

Queries the state of channels specified by *ch list*.

CONFMEAS *function* , *ch list* [USE ch] [INTO *name*] or [*fmt*]

Configures the voltmeter accessory and measures a function on the channels specified by *ch list*. This command automatically configures the voltmeter accessory and the tree switches on the multiplexer for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function* , *ch list* [USE *ch*] [INTO *name*] or [*fmt*]

Scans and measures a function on the channels specified by *ch list*. This command does not configure the voltmeter accessory but it does configure the tree switches on the multiplexer for the measurement.

MONMEAS *function* , *ch list* [USE *ch*]

Monitors and measures a function on the channels specified by *ch list*. This command is useful to check wiring connections made on the terminal module.

OPEN *ch list*

Opens a single multiplexer channel or a list of channels specified by *ch list*. This command is used to open channels and place them in a safe state after the measurements have been made.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Program Titles

The discussion for each function includes one or two examples that show how to program the FET MUX for that function. Table 8-6 lists the titles of the example programs in this section.

Table 8-6. Program Titles

Making Voltage Measurements

One of the functions of the FET MUX accessory is to make voltage measurements. This section explains how to program the accessory to make guarded (3-wire) DC and AC voltage measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX/TC is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 8-1 for the specifications.

NOTE

The AC voltage function is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC voltage measurements.

Example: Measuring DC and AC Voltage Sources

Suppose that you want to measure the outputs from 20 voltage sources using the FET MUX and the guarded voltage function. See Figure 8-7 to connect voltage sources to the terminal module.

The following example program uses the CONFMEAS command to measure 20 DC voltage sources connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the 20 channels once.

Table 8-6. Program Titles

TITLE	DESCRIPTION	COMMANDS
	Voltage Measurements	
Measuring DC and AC Voltage Sources	Measures the outputs from 20 voltage sources using the FET MUX.	CONFMEAS
Measuring Voltage Sources using the CLOSE Command	Measures the output from a voltage source using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	Current Measurements	
Making DC and AC Currents Measurements	Makes a current sensing measurement using a shunt resistor installed on the FET MUX.	CONFMEAS
	2-Wire Ohms Measurements	
Measuring Resistors using the 2-Wire Ohms Function	Measures 20 resistors using the FET MUX and the 2-wire ohms function.	CONFMEAS
Making 2-Wire Ohms Measurements using the CLOSE Command	Measures a single resistor using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	Temperature Measurements	
Measuring Temperature using Thermocouples	Makes 20 temperature measurements using the FET MUX and J-type thermocouples.	CONFMEAS
Measuring the Isothermal Reference Temperature	Measures the reference temperature of the isothermal connector block and also the compensated temperature of a B-type thermocouple.	CONFMEAS

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70 OUTPUT 709; "CONFMEAS ACV,200-219,USE 0"
```

```
10  !
20  !Use the CONFMEAS command to measure 20 DC voltages
30  !using a FET MUX in slot 2 of the mainframe.  Install
40  !a voltmeter accessory in slot 0 of the mainframe.
50  !
60  REAL Volts(19)
70  OUTPUT 709; "CONFMEAS DCV,200-219,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Volts(I)
100 PRINT "Ch.";I, Volts(I)
110 NEXT I
120 END
```

Typical DC voltage values for the assumed conditions:

```
Ch. 0   4.30300
Ch. 1   4.33350
      .
      .
      .
Ch. 18  4.58580
Ch. 19  3.49470
```

<u>Example: Measuring Voltage Sources using the CLOSE Command</u>

Suppose that you want to measure the output from a voltage source using the CLOSE command to control the tree switches and bank switches. See Figure 8-7 to connect a voltage source to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the Sense Bus tree switch (Channel 91), and the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the DC voltage from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 90:

```
90  OUTPUT 709; "FUNC ACV"
```

```
 10  !
 20  !Use the CLOSE command to make a DC voltage measurement
 30  !of the voltage source connected to Channel 0 on a FET
 40  !MUX in slot 2 of the mainframe.  Install a voltmeter
 50  !accessory in slot 0 of the mainframe.
 60  !
 70  OUTPUT 709; "USE 0"
 80  OUTPUT 709; "CLOSE 200,291,290"
 90  OUTPUT 709; "FUNC DCV"
100  OUTPUT 709; "TRIG SGL"
110  OUTPUT 709; "CHREAD 0"
120  ENTER 709; Volts
130  PRINT Volts
140  OUTPUT 709; "OPEN 200,291,290"
150  END
```

Typical DC voltage value for the assumed conditions:

```
3.94940
```

Making Current Measurements

The FET MUX uses current sensing to make current measurements. When making a current sensing measurement, the voltage across the shunt resistor is measured and the current is calculated using the measured voltage and the resistance value of the shunt. This section shows how to program the FET MUX to make DC and AC current measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the 20-channel FET MUX/TC is 10.24 VDC or 7.24 VAC RMS (10.24V peak). Refer to Table 8-1 for the specifications.

NOTE

Current sensing measurements are not recommended when making temperature measurements on the same terminal module. The heat produced by the shunt resistor may affect the accuracy of the temperature measurements.

NOTE

The AC voltage function (used for AC current sensing) is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

The HP 44702 High-Speed Voltmeter Accessory cannot be used to make AC current measurements.

Example: Making DC and AC Current Measurements

Suppose that you want to make a current measurement using a 250Ω shunt resistor installed on the terminal module. See Figure 8-9 to install a shunt resistor on the terminal module for current measurements.

The following example program uses the CONFMEAS command to measure a 250Ω shunt resistor installed on Channel 0. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and measures the channel once. The voltage value is returned to the controller which then calculates the current in DC amps.

NOTE

To use the following program to make AC current measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 70:

```
70  OUTPUT 709; "CONFMEAS ACV,200,USE 0"
```

```
 10  !
 20  !Use the CONFMEAS command to measure a 250Ω shunt
 30  !resistor and calculate the DC current on Channel 0.
 40  !Use a FET MUX in slot 2 of the mainframe.  Install a
 50  !voltmeter accessory in slot 0 of the mainframe.
 60  !
 70  OUTPUT 709; "CONFMEAS DCV,200,USE 0"
 80  ENTER 709; Volts
 90  !
100  !Current = Voltage Measured/Resistance of Shunt
110  !
120  Current = Volts/250
130  PRINT Current
140  END
```

Typical current value (in DC Amps) for the assumed conditions:

```
.03034
```

Making 2-Wire Ohms Measurements

One of the functions of the FET MUX accessory is to make resistance measurements. This section explains how to program the FET MUX for 2-wire ohms measurements.

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 20 resistance measurements per FET MUX accessory.

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

When using the FET MUX accessory for 2-wire ohms measurements, the voltmeter accessory is actually configured for a 4-wire ohms measurement. The FET MUX converts the 4-wire function on the voltmeter to a 2-wire function on the component module. It does this by connecting the high voltage sense lead to the high current source lead and the low voltage sense lead to the low current source lead. Therefore, only two leads are used on the FET MUX for the 2-wire ohms measurement.

Example: Measuring Resistors using the 2-Wire Ohms Function

Suppose that you want to measure 20 resistors connected to the FET MUX using the 2-wire ohms function. See Figure 8-10 to connect resistors to the terminal module for a 2-wire ohms measurement.

The following example program uses the CONFMEAS command to measure 20 resistors connected to Channels 0 through 19. The CONFMEAS command configures the voltmeter accessory for 2-wire ohms measurements and measures the 20 channels once.

```
10  !
20  !Use the CONFMEAS command to measure 20 resistors using a
30  !FET MUX in slot 3 of the mainframe.  Install a voltmeter
40  !accessory in slot 0 of the mainframe.
50  !
60  REAL Ohms(19)
70  OUTPUT 709; "CONFMEAS OHM,300-319,USE 0"
80  FOR I = 0 TO 19
90  ENTER 709; Ohms(I)
100 PRINT "Ch.";I, Ohms(I)
110 NEXT I
120 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
Ch. 0   4628.340
Ch. 1   5024.900
      .
      .
      .
Ch. 18  4039.400
Ch. 19  6528.380
```

Example: Making 2-Wire Ohms Measurements using the CLOSE Command

Suppose that you want to make a 2-wire ohms measurement of a resistor using the CLOSE command to control the tree switches and bank switches. See Figure 8-10 to connect a resistor to the terminal module for 2-wire ohms measurements.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the Sense Bus tree switch (Channel 91), the Source Bus tree switch (Channel 94), and the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for 4-wire ohms measurements (the FET MUX converts the 4-wire function to a 2-wire function on the component module). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance value from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the backplane after the measurements have been taken.

NOTE

The following program uses the HP 44701A Integrating Voltmeter Accessory. To use this program with the HP 44702 High-Speed Voltmeter Accessory on the backplane, substitute the following line for the existing line 80:

```
80  OUTPUT 709; "FUNC OHMF100K"
```

```
 10  !
 20  !Use the CLOSE command to make a 2-wire ohms measurement
 30  !of Channel 0 on a FET MUX in slot 3 of the mainframe.
 40  !Install a voltmeter accessory in slot 0 of the mainframe.
 50  !
 60  OUTPUT 709; "USE 0"
 70  OUTPUT 709; "CLOSE 300,391,394,390"
 80  OUTPUT 709; "FUNC OHMF"
 90  OUTPUT 709; "TRIG SGL"
100  OUTPUT 709; "CHREAD 0"
110  ENTER 709; Ohms
120  PRINT Ohms
130  OUTPUT 709; "OPEN 300,391,394,390"
140  END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
11623.57
```

Making Thermocouple Measurements

Thermocouples provide a simple, durable, inexpensive, and relatively accurate temperature sensor for a wide variety of applications and environmental conditions. The thermocouple is a junction of two unlike metals that produces a voltage that is related to the junction temperature. Up to 20 thermocouple measurements can be made per FET MUX accessory. The HP 3852A temperature conversions support B, E, J, K, N14, N28, R, S, and T type thermocouples.

The HP 3852A does not directly measure the temperature of thermocouples but rather, it measures the voltages generated by the thermocouples. The measured voltage is a function of the actual temperature of the thermocouples. The problem with this approach is that the voltage measured by the HP 3852A is different from the actual thermocouple voltage (due to junction voltages on the terminal module) unless some compensating technique is used. The FET MUX uses a technique called software compensation. In performing software compensated thermocouple measurements, the following steps occur:

1. Measure the resistance of the thermistor mounted on the isothermal connector block and compute the isothermal block reference temperature.

2. Measure the voltage produced by the thermocouple.

3. Convert the isothermal block reference temperature to a thermocouple reference voltage. Since the thermocouple voltage depends upon the type of thermocouple being compensated, this allows different types of thermocouples to be used on an accessory.

4. Add the thermocouple voltage measured in step 2 to the voltage computed in step 3.

5. Convert the total voltage in step 4 to a temperature in °C.

NOTE

When used with the scanning commands (CONFMEAS for example), the HP 3852A automatically performs the compensation steps when making thermocouple measurements.

When using low-level commands such as CLOSE and OPEN, the compensation steps are not performed automatically.

NOTE

Since the channels on the FET MUX can be independently configured and software compensation is used, any mixture of thermocouple types can be measured. However, separate commands will have to be executed for each type of thermocouple.

Example: Measuring Temperature using Thermocouples

Suppose that you want to make 20 temperature measurements using thermocouples and the FET MUX. See Figure 8-11 to connect thermocouples to the terminal module for temperature measurements.

The following example program uses the CONFMEAS command to measure 20 J-type thermocouples connected to Channels 0 through 19. The program scans the 20 channels once and returns the results (in °C) to the controller.

```
 10  !
 20  !Use the CONFMEAS command to measure 20 J-type thermocouples
 30  !using a FET MUX in slot 2 of the mainframe.  Install a
 40  !voltmeter accessory in slot 0 of the mainframe.
 50  !
 60  REAL Temp(19)
 70  OUTPUT 709; "CONFMEAS TEMPJ,200-219,USE 0"
 80  FOR I = 0 TO 19
 90  ENTER 709; Temp(I)
100  PRINT "Ch.";I, Temp(I)
110  NEXT I
120  END
```

Typical temperature values (in °C) for the assumed conditions:

```
Ch. 0   24.54297
Ch. 1   24.54200
      .
      .
      .
Ch. 18  25.55800
Ch. 19  25.85600
```

Example: Measuring the Isothermal Reference Temperature

Suppose that you want to measure the temperature (the reference temperature) of the thermistor mounted on the isothermal connector block. The following program uses the CONFMEAS command to measure the reference temperature and also the compensated temperature of a B-type thermocouple connected to Channel 0. See Figure 8-11 to connect thermocouples to the terminal module.

```
10  !
20  !Use the CONFMEAS command to measure the reference temperature
30  !and the compensated temperature of a B-type thermocouple.  Use
40  !a FET MUX in slot 2 of the mainframe.  Install a voltmeter
50  !accessory in slot 0 of the mainframe.
60  !
70  !Measure isothermal reference temperature.
80  !
90  OUTPUT 709; "CONFMEAS REFT,200,USE 0"
100 ENTER 709; Reftemp
110 !
120 !Measure compensated temperature of B-type thermocouple on Channel 0.
130 !
140 OUTPUT 709; "CONFMEAS TEMPB,200,USE 0"
150 ENTER 709; Temp
160 !
170 !Print results.
180 !
190 PRINT "Isothermal Reference Temperature = ";Reftemp
200 PRINT
210 PRINT "Compensated Temperature = ";Temp
220 END
```

Typical Output:

```
Isothermal Reference Temperature = 24.43848

Compensated Temperature = 24.55176
```

Chapter 9

HP 44711A

24-Channel High-Speed FET Mux

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Introduction

Chapter 9 explains how to program and configure the HP 44711A 24-Channel High-Speed General Purpose FET Multiplexer Accessory (24-Channel High Speed FET MUX). This chapter is divided into four sections:

- **Introduction** contains an overview of the chapter, a general description of the 24-Channel High-Speed FET MUX and its functions, and suggested steps to "get started".

- **Specifications** lists the specifications for the 24-Channel High-Speed FET MUX.

- **Configuring the 24-Channel High-Speed FET MUX** contains a block diagram description of the accessory, illustrates how to wire and configure the terminal module, and how to connect external wiring.

- **Programming the 24-Channel High-Speed FET MUX** explains how to program the accessory to make voltage, current, resistance and temperature measurements.

NOTE

Additional information relating to the High-Speed FET MUX can be found in the HP-3852A Mainframe Configuration and Programming Manual.

24-Channel High-Speed FET MUX Description

The 24-Channel High-Speed FET Multiplexer Accessory consists of a 24-channel FET switching assembly and a 24-channel general purpose terminal assembly. The unit is used to multiplex (switch) up to 24 two-wire input signals at a maximum switching rate of 100,000 times per second. Maximum input voltage is limited to ± 10.24 volts peak.

The 24-Channel High-Speed FET MUX is unique to other switching options in that it can be operated under control of the HP-3852A Data Acquisition and Control Unit through the backplane interface or it can be controlled by the HP-44702 13-Bit High-Speed Voltmeter by interconnecting the two with a dedicated interface bus. This interconnection allows the 13-Bit Voltmeter/24-Channel High-Speed FET MUX combination to operate as a scanner system independent of the HP-3852A mainframe.

External connection to the 24-Channel High-Speed FET MUX is made through the general purpose terminal module. The terminal module is also used to configure the assembly to measure voltage, 4-wire or 2-wire ohms, current, and temperature.

24-Channel High-Speed FET MUX Functions

The 24-Channel High-Speed FET Multiplexer accessory is used to switch input signals for measurement by one of the HP-3852 optional voltmeter accessories or by an external voltmeter. The accessory is used to switch signals for the following types of measurements:

- Voltage Measurements.
- Current Measurements.
- 4-Wire and 2-Wire Resistance Measurements.
- Temperature Measurements.

NOTE

2-Wire resistance measurements are not recommended with this accessory because of the high "on" resistance of the FET switches.

Voltage Measurements.

The 24-Channel High-Speed FET Multiplexer is used to make standard DC and AC voltage measurements. Both the HIGH and LOW input lines are switched on all channels. Input voltage is limited to ± 10.24 volts peak. Use this function to measure up to 24 individual voltage inputs per accessory.

Current Measurements.

The 24-Channel FET Multiplexer is used to measure AC and DC current by using current sensing. Current sensing is a method of determining current using a shunt resistor which you install on the terminal module. The value of current which can be measured depends upon the shunt resistance value and the ± 10.24 volt input limitation. Use this function to measure up to 24 individual current inputs per accessory.

Resistance Measurements.

The 24-Channel High-Speed FET Multiplexer is used to make 4-Wire or 2-Wire Ohms measurements. The 2-Wire Ohms function should only be used in applications where test lead resistance and resistance of the analog switches will not affect the accuracy of the measurement. Use the 2-Wire Ohms function to measure up to 24 individual resistance inputs. Use the 4-Wire Ohms function to measure up to 12 individual resistance inputs per accessory.

Temperature Measurements.

The 24-Channel High-Speed FET Multiplexer is used to measure temperature using resistance temperature detectors (RTDs) or thermistors. The RTD is typically more stable and accurate than the thermistor while the thermistor is more sensitive to temperature changes than the RTD. Use the temperature measurement function to measure up to 24 individual temperature sensor inputs.

The HP-3852A firmware supports temperature conversions for the following RTDs and thermistors:

RTDs:

α = 0.00385 Ω/Ω°C (Resistance of 100Ω at 0°C)

α = 0.003916 Ω/Ω°C (Resistance of 100Ω at 0°C)

Thermistors:

2252Ω at 25°C

5 kΩ at 25°C

10 kΩ at 25°C

Getting Started

To use the 24-Channel High-Speed FET Multiplexer for your application, determine what external devices are to be connected to the accessory, configure the accessory for the type of measurement to be made, connect the external devices to the terminal module, and program the 24-Channel High-Speed FET MUX for your application.

Selecting Devices

The first step is to determine what devices you wish to connect to the High-Speed FET MUX. The accessory can switch AC or DC inputs of up to ± 10.24 volts peak. Since each of the 24 inputs can be configured independently, it is possible to connect 24 different devices to the accessory. When selecting a device, refer to Table 9-1 "24-Channel High-Speed FET MUX Specifications" to ensure that the voltage and current requirements of your application are within the rated specifications of this accessory.

Configuring the Accessory

The second step is to configure the 24-Channel FET MUX for the devices selected. Refer to the "Configuring the 24-Channel High-Speed FET MUX" section of this chapter for information concerning hardware configuration and wiring the terminal block for the measurement functions required.

WARNING

For SAFETY when wiring the Terminal Module, consider all channels to be at the highest voltage applied to any channel.

Programming the Accessory

The third step is to program the 24-Channel High-Speed FET MUX for your application. Refer to the "Programming the 24-Channel High-Speed FET MUX" section of this chapter to program the accessory for measuring voltage, current, resistance, or temperature.

Specifications

Table 9-1 lists specifications for the 24-Channel High Speed FET MUX. This table contains six catagories: Input Characteristics, Channel Specifications, Operating Characteristics, AC Performance, RTD Characteristics and Thermistor Characteristics.

Table 9-1. 24-Channel High Speed FET MUX Specifications

INPUT CHARACTERISTICS:

Maximum Signal Voltage, HIGH to LOW:

± 10.24V peak between any two input terminals

Input Voltage Protection Limit:

Channel Inputs: ± 12 volts peak maximum
Backplane (tree switches open): ± 42 peak max

CHANNEL SPECIFICATIONS:

Bias Currents: (channel at 0 volts with respect to chassis) Bias currents are sourced by the accessory from High and Low input terminals to chassis.

Into Transducer or Backplane:

	Channel Closed (0-28°C/0-55°C)	Channel Open (0-28°C/0-55°C)
HIGH or LOW	5 nA / 45 nA	2 nA / 11 nA

Into Backplane:

	Channel Open Tree Switch Closed[1] (0-28°C/0-55°C)	Maximum Differential Offset Voltage[2] (0-28°C/0-55°C)
HIGH or LOW	2 nA / 11 nA	20 uV / 230 uV

[1]All channels open, tree switch closed.
[2]Differential offset voltage between High and Low with a source resistance < 1 kohm.

Maximum Signal Current: ± 1 mA

Closed Channel ON Resistance:

High or Low: ≈ 3.0 kΩ

Table 9-1. 24-Channel High-Speed FET MUX Specifications Cont'd

Isolation (High to Low, High or Low to chassis):

Channel ON or OFF: $10^7 \Omega$
Power OFF: Vin <= 10V 1 kΩ
Vin > 10V 200 Ω

OPERATING CHARACTERISTICS:

Maximum Switching Rate:

Using the HP-44702 Voltmeter Accessory:
100,000 readings/second

Synchronization: Break-Before-Make in scan operation

AC PERFORMANCE:

Frequency Response relative to 1 kHz:
(50Ω source, 1 MΩ termination)

50 kHz: -0.6 dB
200 kHz: -3.0 dB

Capacitance with Channel On:

High to Low: 200 pF
High or Low to Chassis: 200 pF

Crosstalk, channel to channel:
(50Ω source, 1 MΩ termination)

10 kHz: -50 dB
100 kHz: -35 dB

RTD CHARACTERISTICS:

Type: Platinum, $\alpha = 0.00385$ Ω/Ω°C
(Resistance = 100.0 Ω at 0°C)

Type: Platinum, $\alpha = 0.003916$ Ω/Ω°C
(Resistance = 100.0 Ω at 0°C)

Table 9-1. 24-Channel High-Speed FET MUX Specifications Cont'd

THERMISTOR CHARACTERISTICS:
Type: 2252Ω at 25°C
Type: 5 kΩ at 25°C
Type: 10 kΩ at 25°C

Configuring the 24-Channel High-Speed FET MUX

This section explains how to configure the 24-Channel High-Speed FET MUX. The section contains a block diagram description of the accessory, information on configuring the terminal module, and how to connect external wiring to the terminal module.

Refer to "Programming the 24-Channel High-Speed FET MUX" section of this chapter for information concerning programming the accessory to measure voltage, current, resistance, and temperature.

WARNING

SHOCK HAZARD. Only qualified, service-trained personnel, who are aware of the hazards involved, should install, remove, or configure any accessory. If an accessory is to be removed or installed, turn off all power to the mainframe, extenders, all accessories, and all external devices connected to the mainframe, extenders, or accessories.

WARNING

For SAFETY when wiring the Terminal Module, consider all channels to be at the highest voltage applied to any channel.

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers attached.

Block Diagram Description

The 24-Channel High-Speed General Purpose FET Multiplexer accessory consists of a 24 channel FET switching module and a 24 channel terminal module as shown in Figure 9-1. Signals from devices external to the HP-3852A are connected to the terminal module. The terminal module connects to the FET switching module.

Figure 9-1. 24-Channel High-Speed FET MUX Block Diagram

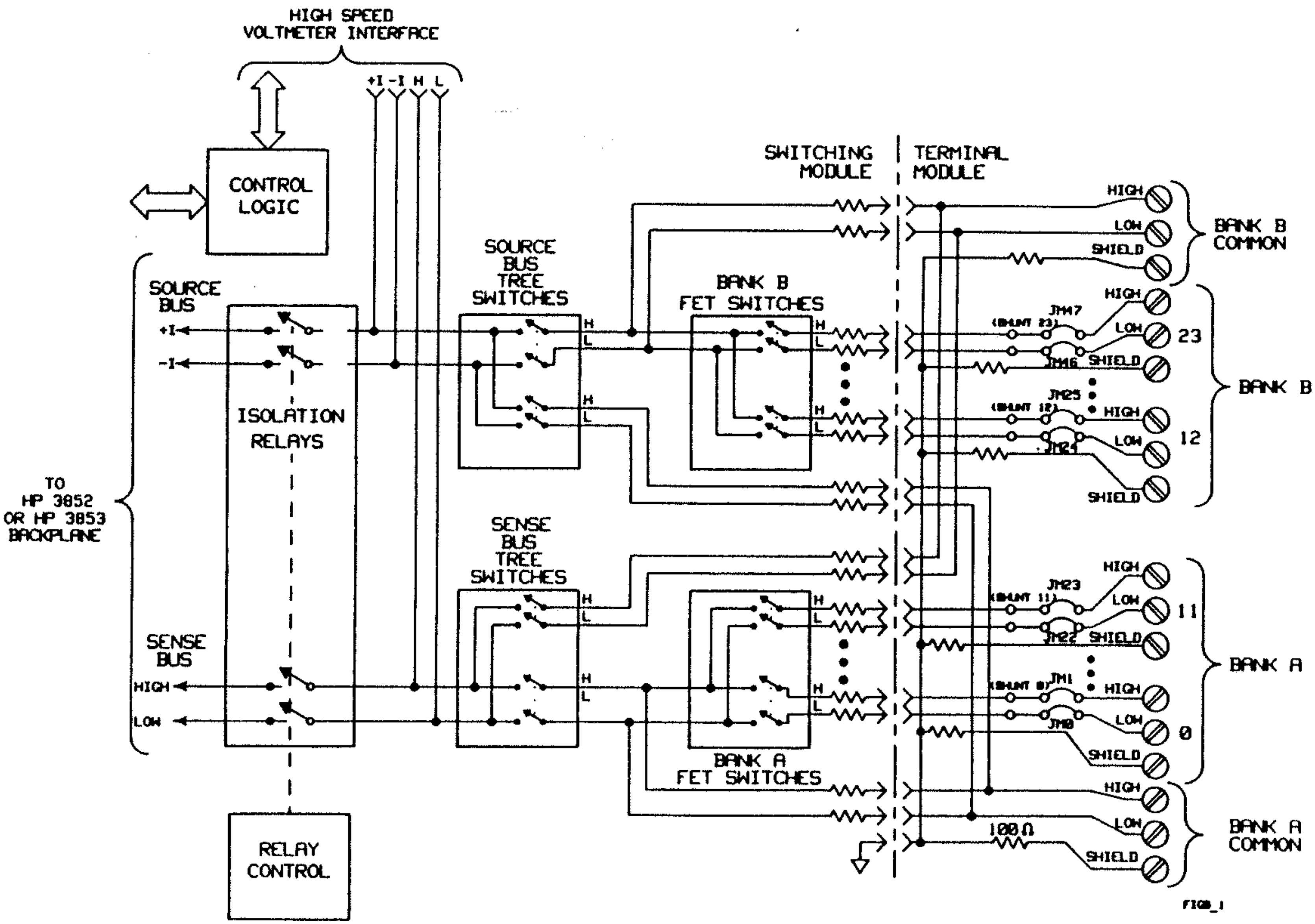

Figure 9-1. 24-Channel General Purpose FET MUX/TC Block Diagram

The FET MUX switch module is made up of 28 switches which are divided into two catagories; tree switches, and bank switches. Each of the 28 switches consists of two Field Effect Transistors (FETs), one each for HIGH and LOW input lines. There are a total of 24 bank switches which are divided into two groups; BANK A and BANK B. Each bank contains 12 input channels. The 12 channels in BANK A are numbered 0 through 11 while the 12 channels in BANK B are numbered 12 through 23.

The switch module has four tree switches divided in two types: Source Bus tree switches and Sense Bus tree switches. Each bank (A & B) has one Source Bus tree switch and one Sense Bus tree switch. The tree switches determine the signal flow to and from the HP-3852A backplane or the high speed voltmeter interface bus. The tree switches also act to isolate the unused bank switches from the backplane and high speed interface bus.

NOTE

The HP-3852A firmware does not allow two tree switches of the same type to be closed simultaneously. For example, only one of the Sense Bus tree switches can be closed at a time. If you attempt to close both Sense Bus tree switches, the result will be that neither switch will close.

The FET MUX switch module has two isolation relays which allow the accessory to be isolated from the HP-3852A backplane. The isolation relays can be used to reduce leakage currents on the backplane during critical measurements or for using the backplane at voltages greater than the ± 10.24 volt peak limitation of the 24-Channel FET MUX. The isolation relays automatically open when voltages greater than 12 volts peak are detected on the backplane. The Isolation relays are also opened when the FET MUX is used with the high speed voltmeter accessory. Table 9-2 shows the channel definitions for the 24-Channel High-Speed FET Multiplexer accessory. Channels 0 through 23 control the bank switches, channel 90 controls the isolation relays, and channels 91 through 94 control the tree switches.

Table 9-2. 24-Channel FET MUX Channel Definitions

Channel	Definitions
0 - 11	BANK A Channel Switches
12 - 23	BANK B Channel Switches
90	Isolation Relays
* 91	Source Bus to BANK A or B
* 92	Sense Bus to BANK A or B
93	2-Wire Ohms Configuration
94	4-Wire Ohms Configuration

** The Source or Sense Bus is connected to Bank A if a channel from 0 through 11 is selected. The Source or Sense Bus is connected to Bank B if a channel from 12 through 23 is selected.*

The BANK A COMMON and BANK B COMMON terminals can be used to connect an external monitoring device to the accessory or be used for diagnostic procedures. As configured at the factory, each of the channel input lines and the BANK A and B COMMON output lines (High, Low, and Shield) has a 100Ω current limiting resistor in series with the line.

Installing Low Pass Filters

Space is provided on the 24-Channel FET MUX terminal module for you to install single-pole, low-pass, filters to condition the input signal. Figure 9-2 shows the normal channel configuration and the channel configuration with the low-pass filter installed on the terminal module.

Figure 9-2. Low-Pass Filter Channel Configuration

Figure 9-3 shows how to install the low-pass filter components on channel 11 of the terminal module. To install the components, remove SERIES JM 22 and install the resistor in its place. Install the capacitor in the SHUNT UC 11 solder pads as shown.

Figure 9-3. Installing Low-Pass Filters

Installing Attenuators

The solder pads provided on the terminal module are also used to install attenuator networks for reducing high level input signals to a usable level. Figure 9-4 shows the normal channel configuration and the channel configuration after installing the attenuator network.

Figure 9-4. Channel Configuration with Attenuator

Figure 9-5 shows how to install attenuator components on Channel 0 of the terminal module. To install the components, remove jumper SERIES JM 0 and install resistor R1 in its place. Install resistor R2 in the SHUNT UC 0 position as shown.

Figure 9-5. Installing Attenuators

Connecting Field Wiring

The next step is to connect wiring from the instrumentation used in your application to the appropriate terminals on the terminal module. The following section contains examples of how to connect the wiring for making voltage, current, resistance and temperature measurements.

WARNING

⚠ 2

For SAFETY when wiring the Terminal Module, consider all channels to be at the highest voltage applied to any channel.

Figure 9-7 shows the terminal module with the cover removed. Each of the 24 channels has a HIGH, LOW, and SHIELD terminal. Terminals 0 through 11 in BANK A are channels 0 through 11. Terminals 0 through 11 in BANK B are channels 12 through 23.

Figure 9-6. 24-Channel High-Speed FET MUX Terminal Module

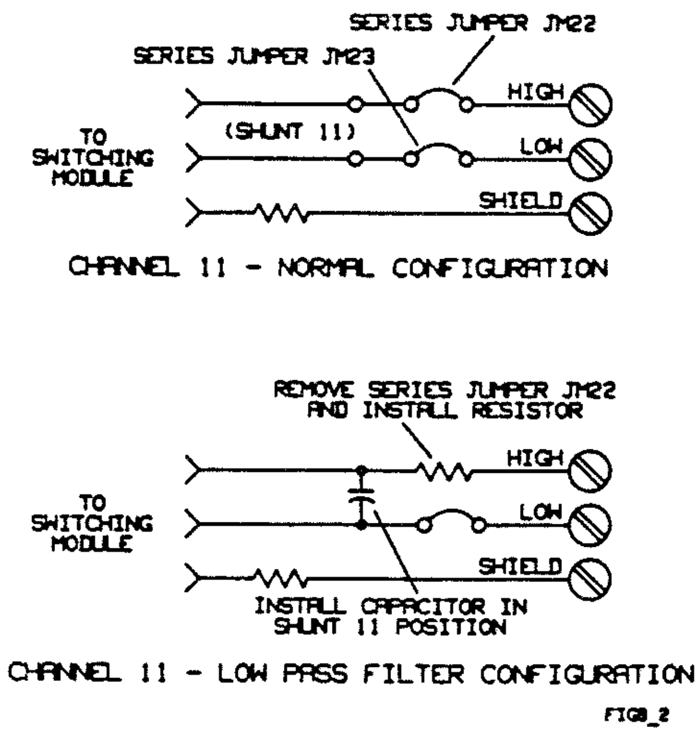

Figure 9-2. Low-Pass Filter Channel Configuration

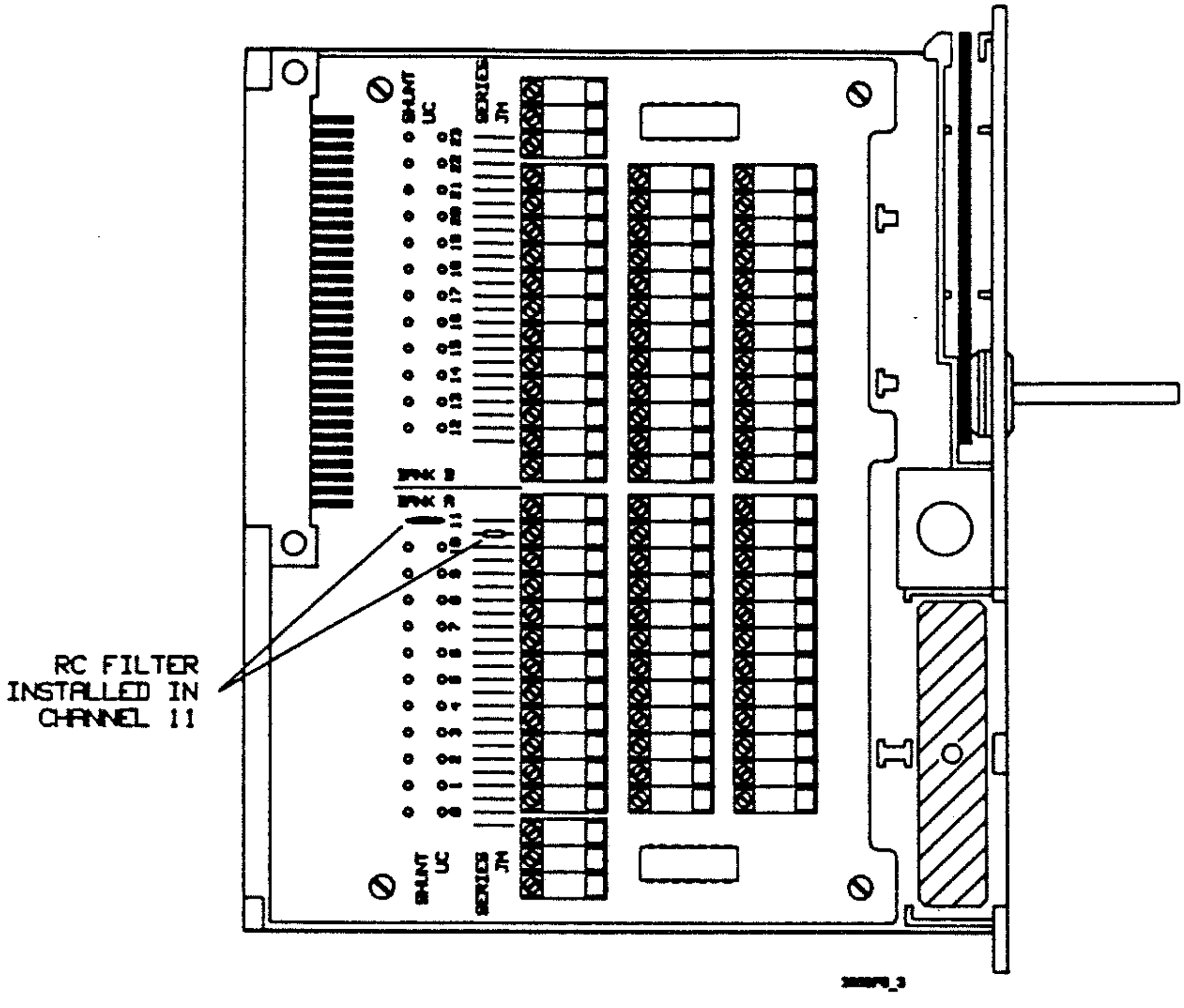

Figure 9-3. Installing Low-Pass Filter

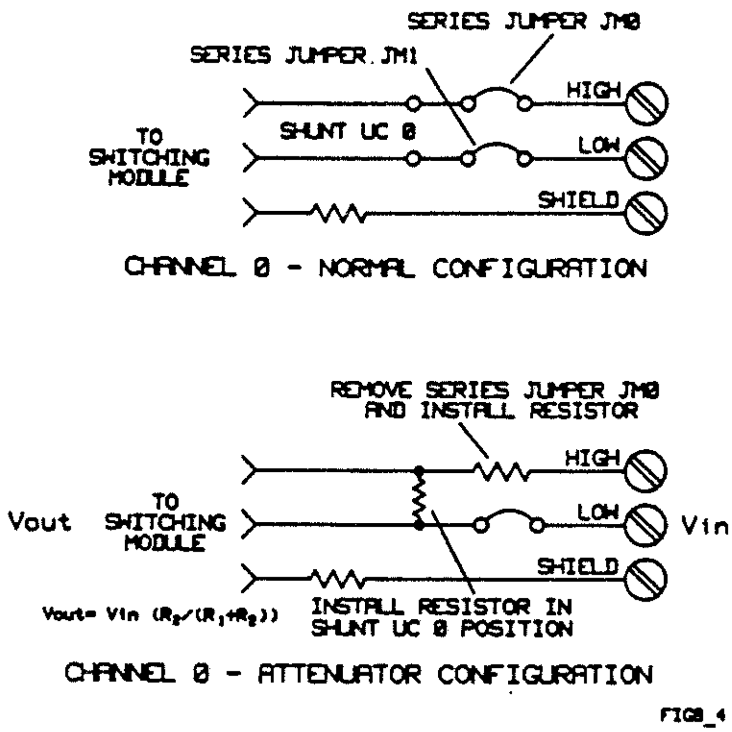

Figure 9-4. Channel Configuration with Attenuator

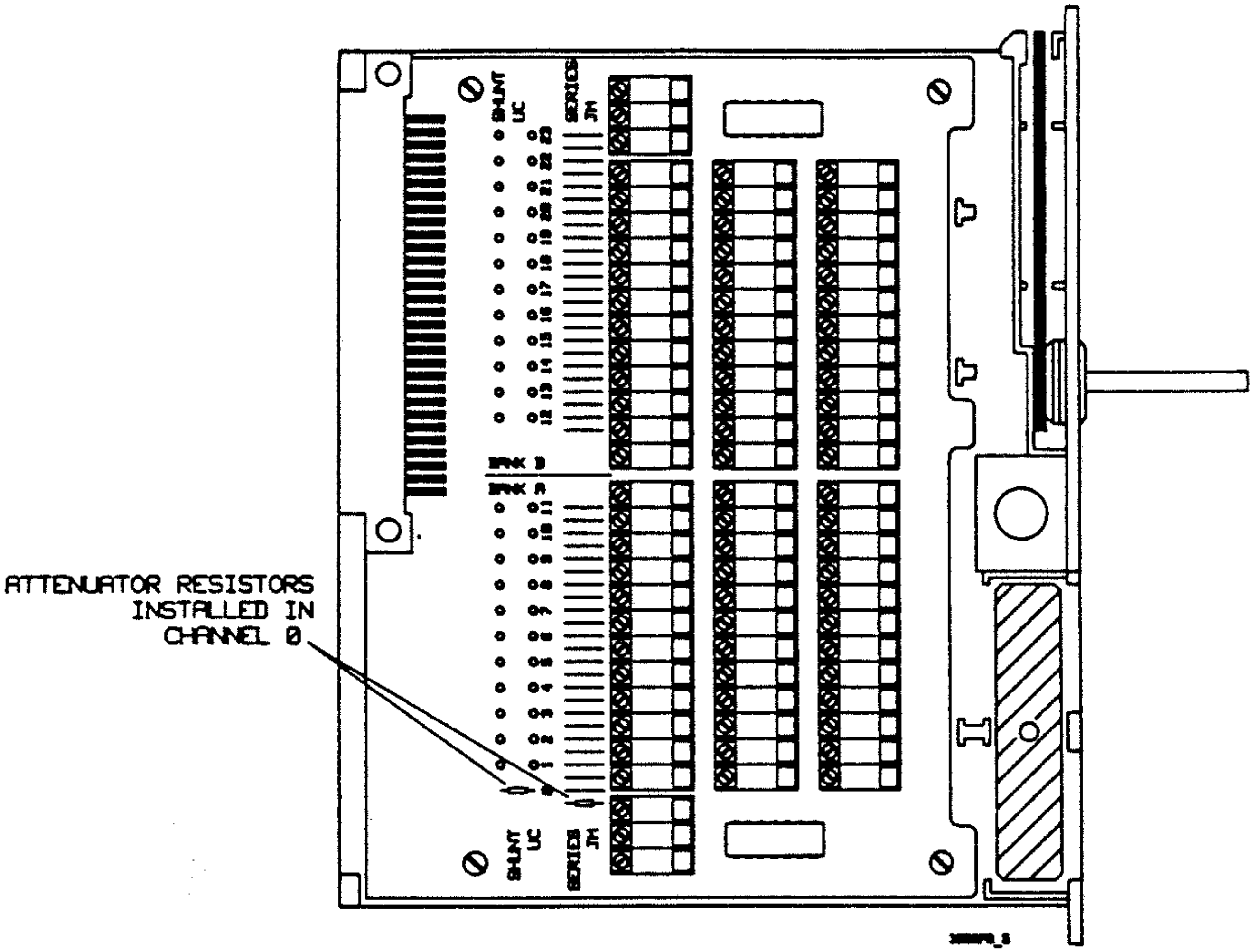

Figure 9-5. Installing Attenuators

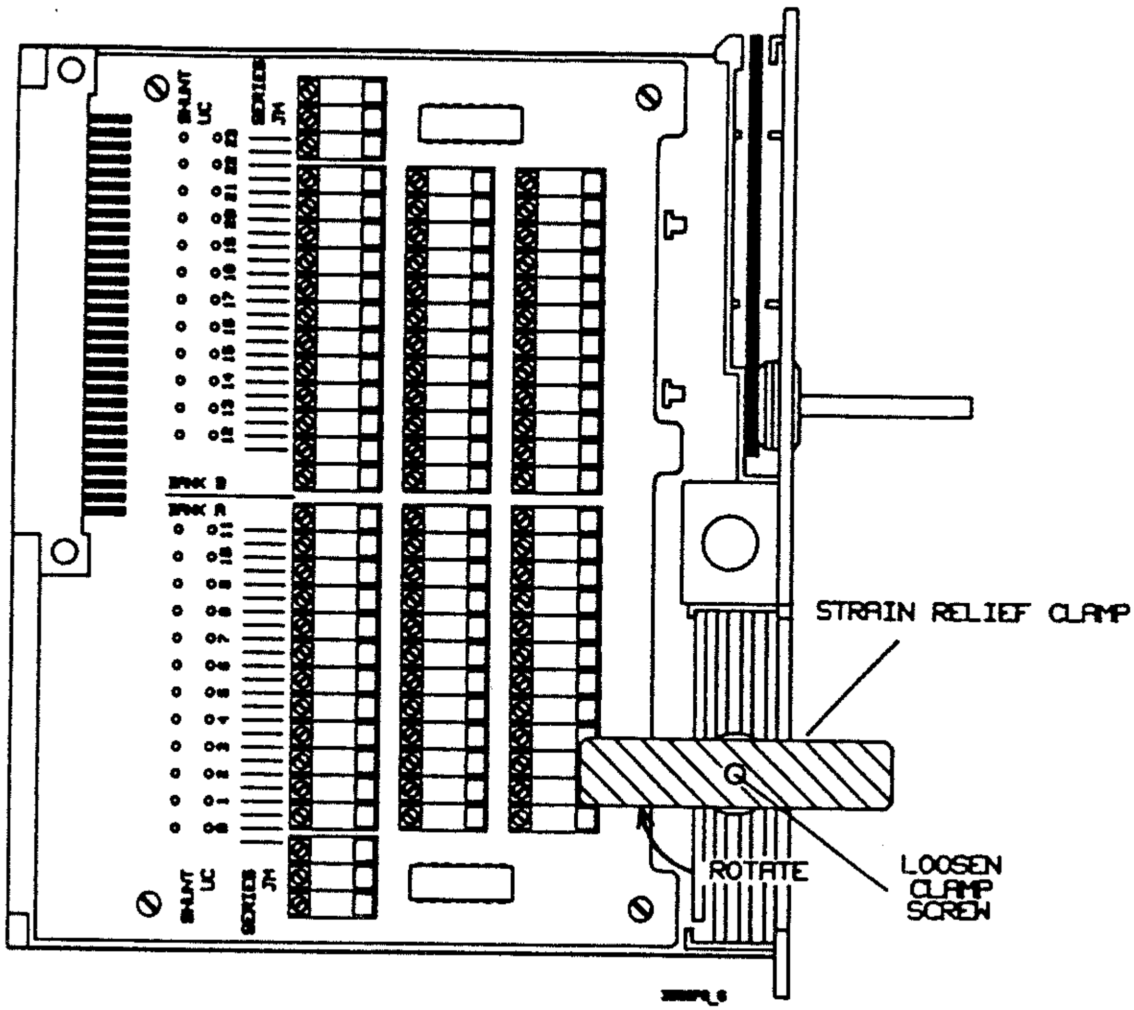

Figure 9-6. 24-Channel High-Speed FET MUX/TC Terminal Module

When connecting wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make it easier to route the wiring. Replace the protective cover after wiring.

Connections For Voltage Measurements

The 24-Channel High-Speed FET MUX can switch up to 24 AC or DC voltage inputs. HIGH and LOW lines are switched on all channels. A SHIELD terminal is provided for connecting shielded cables. Shielded cables are used to reduce electrical noise when making low-level voltage measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the FET switching assembly is ± 10.24 volts peak. Refer to Table 9-1 for the 24-channel High-Speed FET MUX specifications.

Example: Connecting Voltage Sources to the Terminal Module

A voltage source is to be connected to Channel 0 (BANK A terminal 0) on the terminal module as shown in Figure 9-7. Connect the high (+) lead of the voltage source to the HIGH terminal on the terminal module. Connect the low (-) lead of the voltage source to the LOW terminal on the terminal module. If you are using a shielded cable from the voltage source, connect the shield to the SHIELD terminal on the terminal module. A shielded cable is used to reduce electrical noise in the measurement.

Figure 9-7. Connecting Voltage Sources to the Terminal Module

Connections For Current Measurements

The 24-Channel High-Speed FET MUX uses a current sensing technique to measure current. Current sensing is a method of determining current by measuring the voltage drop across a current sensing resistor which you install on the terminal module. The Multiplexer Assembly can be used to switch up to 24 AC or DC current inputs. Figure 9-8 shows the normal channel configuration and the configuration for making current measurements. Figure 9-9 shows the installation of the current sensing resistors on the terminal module.

Figure 9-8. Current Sensing Configuration.

NOTE

The series jumpers (SERIES JM) must be installed on the terminal module for each channel being used to measure current.

Figure 9-9. Installing Current Shunt Resistors

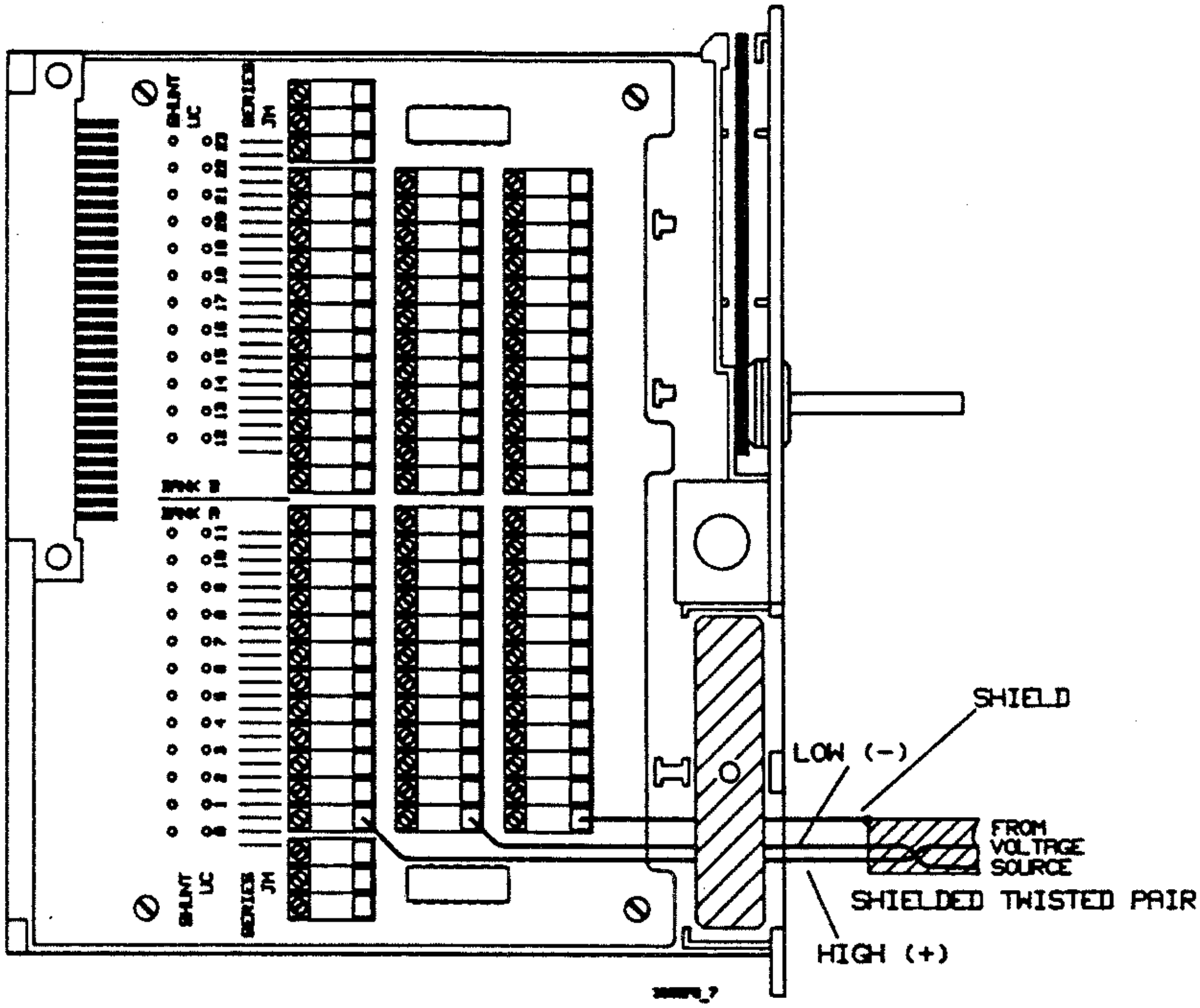

Figure 9-7. Connecting Voltage Sources to the Terminal Module

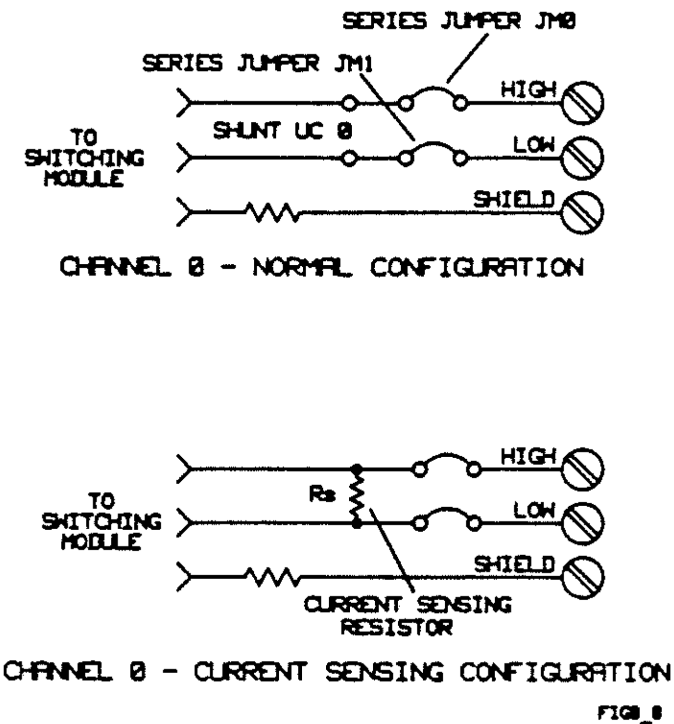

Figure 9-8. Current Sensing Configuration

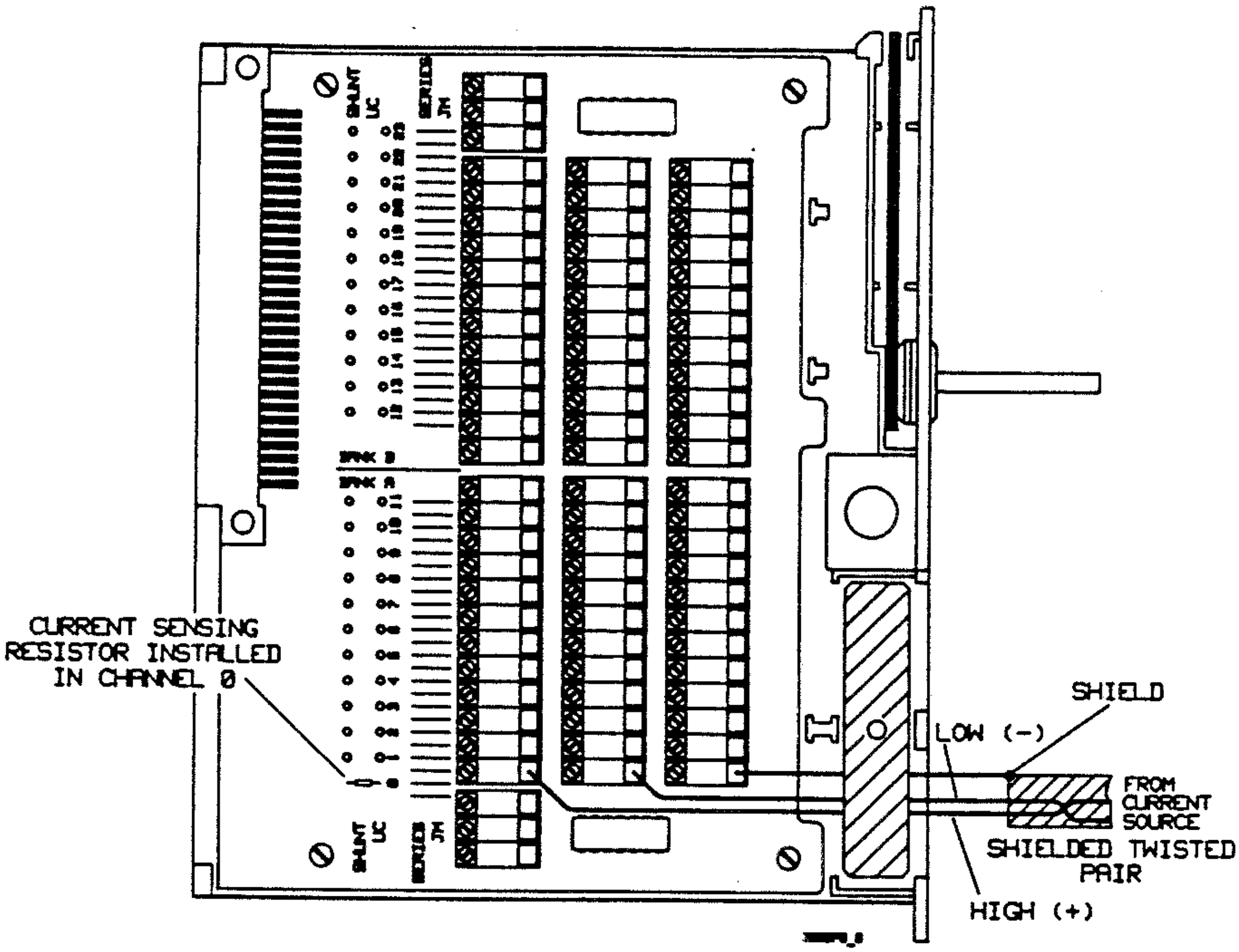

Figure 9-9. Installing Current Shunt Resistors

Example: Installing Shunt Resistors for Current Measurements

A 250Ω shunt resistor is installed in the Channel 0 shunt position on the terminal module as shown in Figure 9-9. Connect the high (+) lead of the current source to the HIGH terminal on the terminal module. Connect the low (-) lead of the current source to the LOW terminal of the terminal module. If a shielded cable is used, connect the shield wire to the SHIELD terminal of the terminal module.

Connections For Resistance Measurements

The 24-Channel High-Speed FET MUX can be configured to make 4-wire or 2-wire resistance measurements. The 2-wire ohms function should only be used in applications where test lead resistance and resistance of the FET switches will not affect the accuracy of the measurement. Up to twenty four 2-wire inputs or twelve 4-wire inputs can be switched by the 24-Channel FET MUX.

Example: Connecting Resistors for 2-Wire Ohms Measurements

The 2-wire ohms function is normally used for measuring high resistances where the resistance of the test leads and FET switches has a minimal effect on the measurement.

NOTE

The high "on" resistance of the FET switches limits the accuracy of 2-Wire Ohms measurements.

Figure 9-10 shows the connection of a resistor (R0) to Channel 0 (BANK A, terminal 0) of the terminal module. Connect one lead of the resistor to the HIGH terminal of the terminal module. Connect the other resistor lead to the LOW terminal. If a shielded cable is being used to connect the resistor, connect the shield to the SHIELD terminal.

Figure 9-10. Connecting Resistors for 2-Wire Ohms Measurements

Example: Connecting Resistors for 4-Wire Ohms Measurements

With 4-Wire Ohms measurements, the current source as well as the sense leads are connected to the resistor to be measured. Since current does not flow through the sense leads, the error due to test lead and FET switch resistance is eliminated. Up to twelve 4-wire inputs can be switched by the 24-Channel FET MUX.

NOTE

Each 4-wire measurement requires two separate channels, one from BANK A and one from BANK B. When connecting resistors to the terminal module for 4-wire ohms measurements, select two channels which are separated by 12 (i.e. Channel 0 and channel 12, channel 1 and channel 13, etc.).

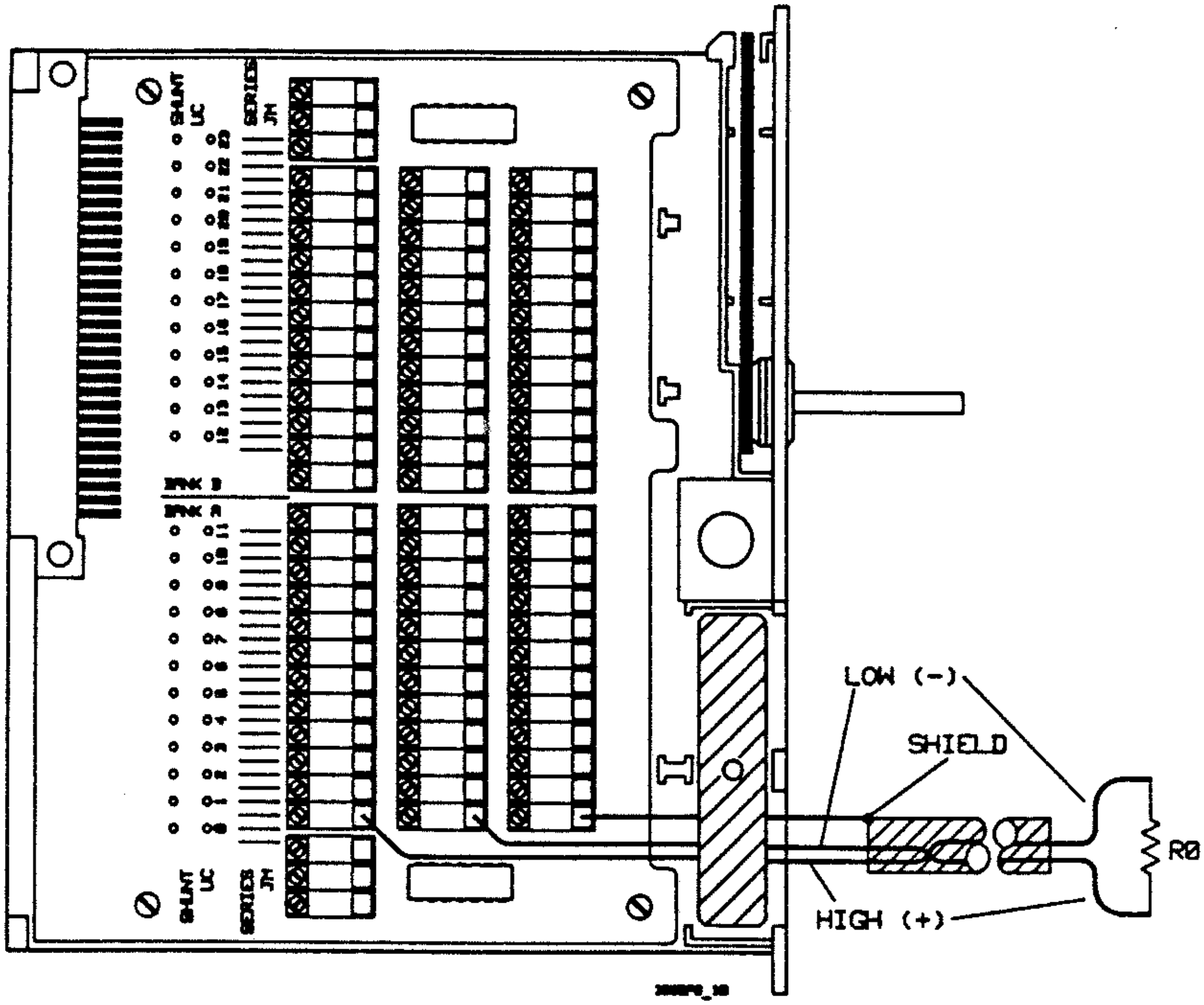

Figure 9-10. Connecting Resistors for 2-Wire Ohms Measurements

Figure 9-11 shows resistor R1 connected to channels 0 and 12 on the terminal module for a 4-wire ohms measurement. Channel 0 is used as the "sense" channel for the measurement while channel 12 is used as the "source" channel. To make the sense connections (channel 0) connect one lead of the resistor to the HIGH terminal connect the other lead to the LOW terminal. If shielded cable is being used, connect the shield to the SHIELD terminal. To make the source connections (channel 12) connect the high lead of the resistor to the channel 12 HIGH terminal. Connect the low lead of the resistor to the channel 12 LOW terminal. If the cable is shielded, connect the shield to the channel 12 SHIELD terminal.

Figure 9-11. Connecting Resistors for 4-Wire Ohms Measurements

Connections For Temperature Measurements

The following paragraphs explain how to connect the 24-Channel High-Speed FET MUX to make temperature measurements using resistance temperature detectors (RTDs) and thermistors. Because of the high "on" resistance of the FET switches, only the 4-Wire function can be used to measure temperature using RTDs and thermistors.

NOTE

Each 4-Wire temperature measurement requires two channels, one from BANK A and one from BANK B. When connecting RTDs or thermistors to the terminal module for 4-Wire temperature measurements, select two channels which are separated by 12 (i.e. Channel 0 and Channel 12, Channel 1 and Channel 13,etc.)

Example: Connecting RTDs for 4-Wire Temperature Measurements

The resistance temperature detector (RTD) is a temperature sensitive resistor which is stable, accurate, and linear. Up to twelve 4-Wire RTD measurements can be made using the 24-channel FET MUX accessory. The HP-3852A resistance to temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$ with resistance values of 100.0Ω at 0°C. Figure 9-12 shows temperature detector RTD1 connected to channels 0 and 12 on the terminal module. Channel 0 is used as the "sense" channel for the measurement while channel 12 is used as the "source" channel. To make the sense connections (channel 0) connect one lead of the RTD to the HIGH terminal connect the other lead to the LOW terminal. If shielded cable is being used, connect the shield to the SHIELD terminal. To make the source connections (channel 12) connect the high lead of the RTD to the channel 12 HIGH terminal. Connect the low lead of the RTD to the channel 12 LOW terminal. If the cable is shielded, connect the shield to the channel 12 SHIELD terminal.

Figure 9-12. Connecting RTDs for 4-Wire Temperature Measurements

Example: Connecting Thermistors for 4-Wire Temperature Measurements

Thermistors detect very small changes in temperature and are used in applications where the temperature extremes are not too great. The thermistor is highly dependent upon variables such as thermistor composition and size. Most thermistors have a negative temperature coefficient, that is, their resistance decreases with an increase in temperature.

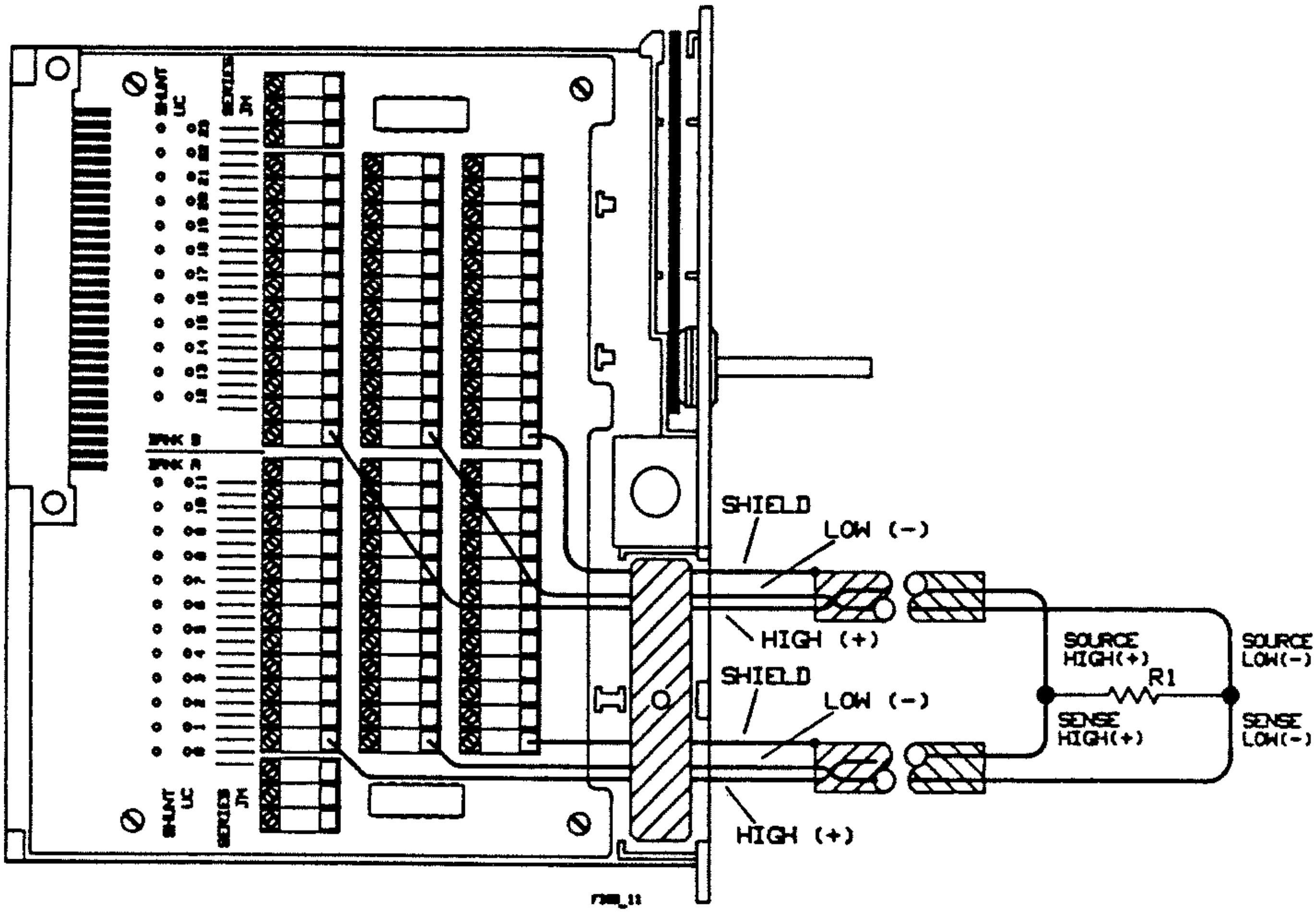

Figure 9-11. Connecting Resistors for 4-Wire Ohms Measurements

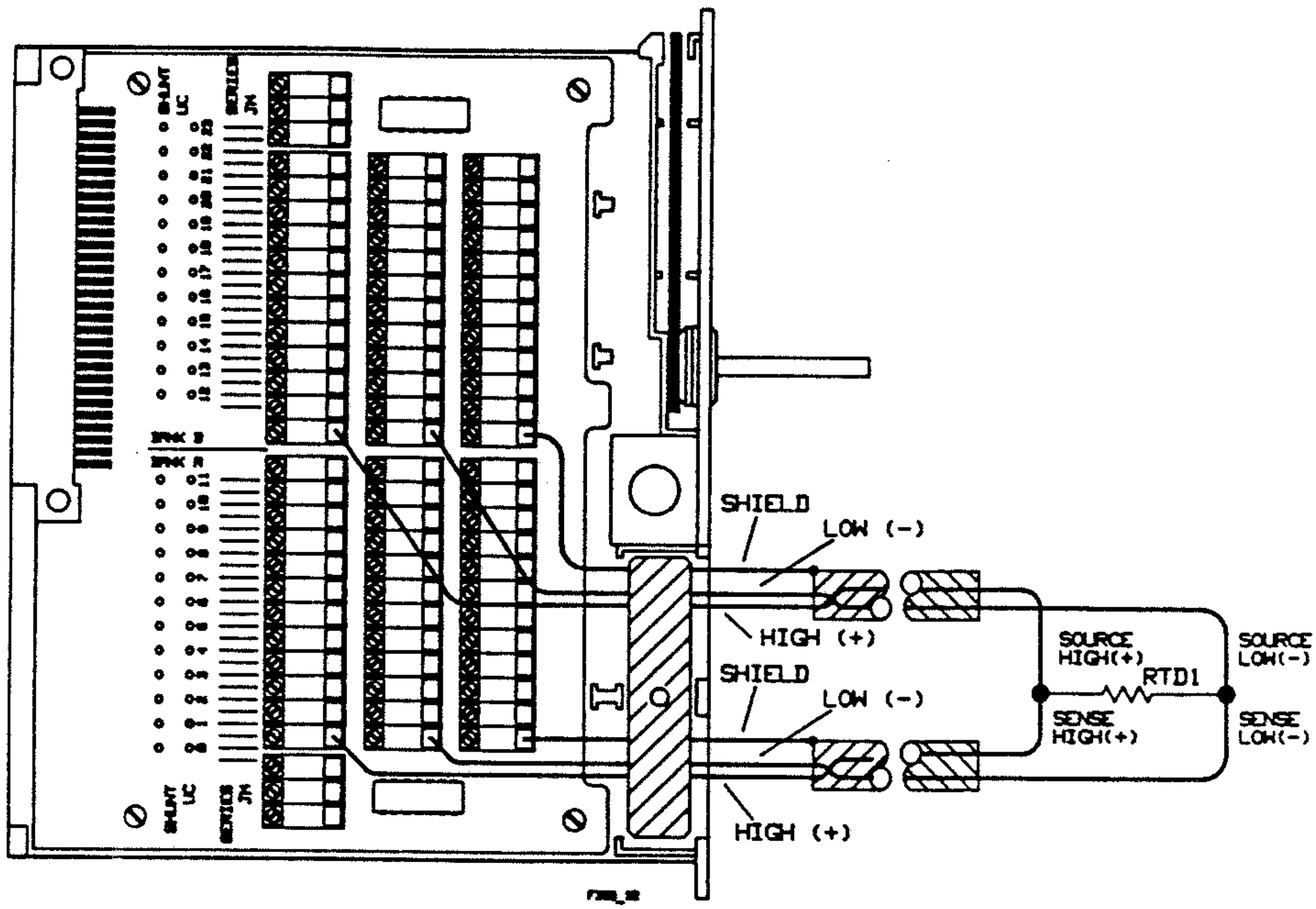

Figure 9-12. Connecting RTDs for 4-Wire Temperature Measurements

Up to twelve 4-wire thermistor inputs can be switched by the 24-channel FET MUX. The HP-3852A resistance to temperature conversions support thermistors with a resistance of 2252 Ω, 5 kΩ, or 10 kΩ at 25°C.

Figure 9-13 shows thermistor THM1 connected to channels 0 and 12 of the terminal module. Channel 0 is used as the "sense" channel for the measurement while channel 12 is used as the "source" channel. To make the sense connections (channel 0) connect one lead of the thermistor to the HIGH terminal of channel 0. Connect the other lead to the LOW terminal of channel 0. If shielded cable is being used to make the connections, connect the shield to the channel 0 SHIELD terminal. To make the source connections (channel 12), connect the high lead of the thermistor to the HIGH terminal of channel 12. Connect the low lead of the thermistor to the LOW terminal of channel 12. If the cable is shielded, connect the shield to the SHIELD terminal of channel 12.

Figure 9-13. Connecting Thermistors for 4-Wire Temperature Measurements

Installation/ Checkout

The following paragraphs explain how to check the identity of the accessory, how to verify wiring connections, and how to read the channel states of the 24-Channel High-Speed FET MUX.

Checking the Accessory Identity

After you have connected the wiring from your application to the terminal module, reconnect the terminal module to the 24-channel switching module and install the assembled unit in the desired slot of the HP-3852A mainframe or HP-3853A extender. Refer to the HP-3852A Mainframe Configuration and Programming Manual for installation instructions.

To check the identity of the 24-Channel High-Speed FET MUX, use the ID? (Identity?) command. The ID? command provides a way to determine, from the 3852A front panel or from a controller, what accessory is installed in a particular slot. The ID? command will return " 44711A" for the 24-Channel High-Speed FET MUX assembly if both the switching module and terminal module were installed when the HP-3852A was "powered-up". If the terminal module is not attached to the switching module at power-on, the ID? command will return " 447XXX". If the ID? command is used to interrogate a slot which does not contain an accessory, the return will be " 000000".

NOTE

If the 24-channel FET MUX does not return the proper ID number, be sure that you have addressed the correct slot and that the terminal module is installed. If you have addressed the correct slot and the terminal module is installed, but the proper ID number is not returned, refer to the HP-3852A Assembly Level Service Manual for service procedures.

The following is an example program which shows how to use the ID? command to check the identity of a 24-Channel FET MUX which is installed in slot 4 of the HP-3852A mainframe.

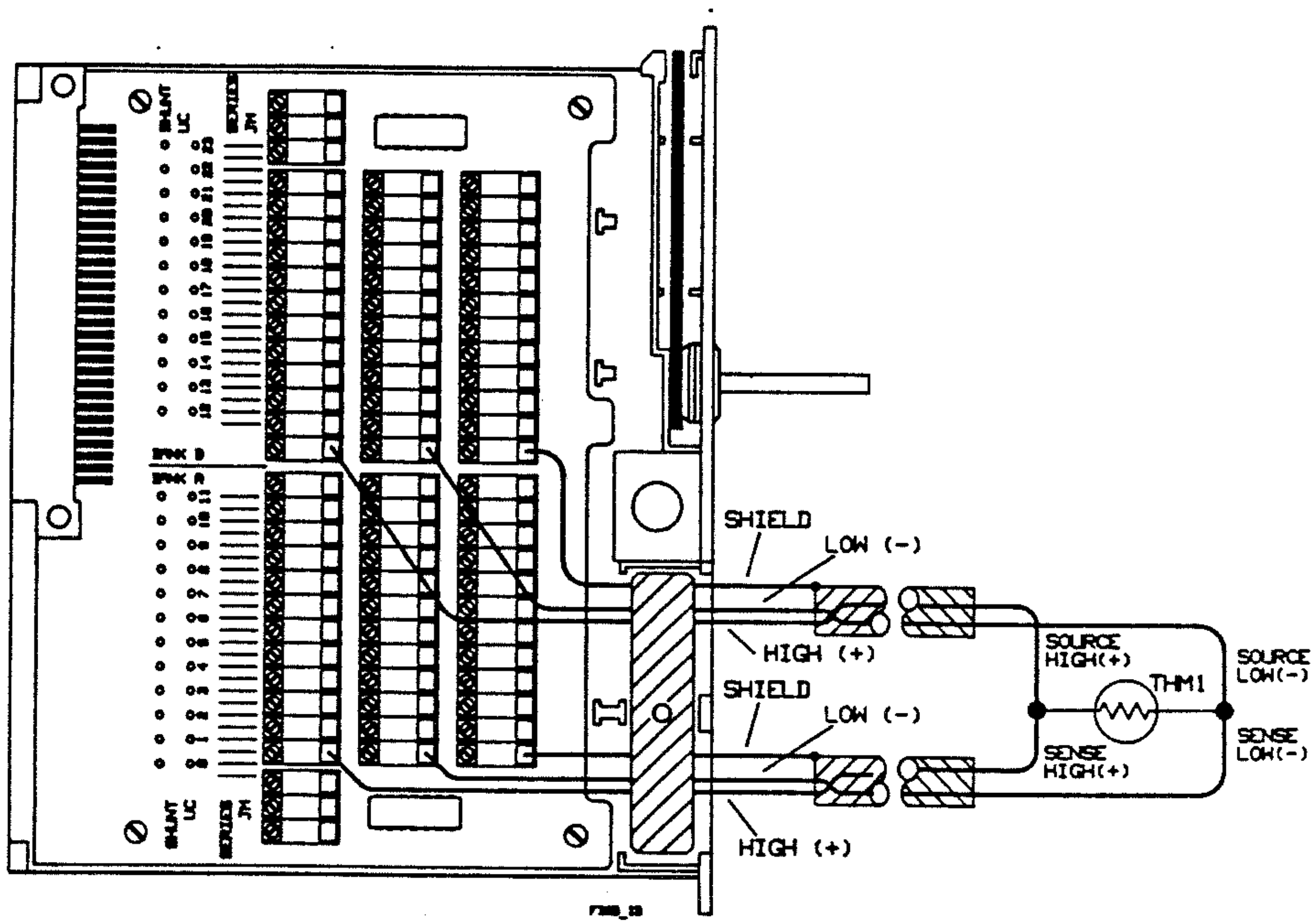

Figure 9-13. Connecting Thermistors for 4-Wire Temperature Measurements

Example: Reading the Accessory Identity

```
10 !
20 !Use the ID? command to read the identity of the
30 !24-channel FET MUX installed in slot 4 of the
40 !3852A mainframe.
50 !
60 OUTPUT 709; "ID? 400"
70 ENTER 709; Identity$
80 PRINT Identity$
90 END
```

Typical output (with the terminal module installed) will be:

```
44711A
```

Verifying Wiring Connections

To verify that your wiring has been properly connected, send the MONMEAS (Monitor/Measure) command from the HP-3852A front panel key board or from a controller. This command verifies DC and AC voltage connections, 2-wire and 4-wire resistance connections, RTD connections, and thermistor connections on the terminal module.

The following program statements show how to use the MONMEAS command to verify DC voltage connections on channels 0 through 23 using a controller. The CONF command configures the voltmeter accessory for DC voltage measurements. In this case, the 24-channel FET MUX is in slot 3 of the mainframe and a voltmeter accessory is installed in slot 0.

```
10 OUTPUT 709; "USE 0"
20 OUTPUT 709; "CONF DCV"
30 OUTPUT 709; "MONMEAS DCV,300-323,USE 0"
40 END
```

The 24 channels will be scanned and measured one at a time. Press the SADV key on the HP-3852A front panel to advance to the next channel. When the scan has advanced beyond the last channel (channel 23), scanning will stop and the last measurement will remain displayed.

Reading Channel State

Use the CLOSE? command to determine the state of each channel on the 24-Channel High-Speed FET MUX accessory. The CLOSE? command returns one of five numbers for each channel interrogated. The number returned indicates whether a channel is open or closed and which bus the channel is connected to. Table 9-3 shows the channel state for each value that can be returned using the CLOSE? command.

Example: Reading Channel State

The following program example shows how to use the CLOSE? command to read the channel state of channels 0 through 4 on the 24-Channel FET MUX. The RST command, used in this program, resets the 24-channel FET MUX to its power-on state (all channels and isolation relays open). The CLOSE command (line 30) closes channel 3, the BANK A Sense Bus Tree Switch (channel 92) and the isolation relays (channel 90). The OPEN command (line 70) is used to open the channels and disconnect them from the HP-3852A backplane after the measurements have been completed. For this example, the 24-channel FET MUX is installed in slot 1 of the mainframe.

```
10  OUTPUT 709; "RST 100"
20  INTEGER State(1:5)
30  OUTPUT 709; "CLOSE 103,192,190"
40  OUTPUT 709; "CLOSE? 100-104"
50  ENTER 709; State(*)
60  PRINT State(*)
70  OUTPUT 709; "OPEN 103,192,190"
80  END
```

Typical Output (channel 3 closed - connected to the Sense Bus):

```
0 0 0 2 0
```

Table 9-3. Values returned by the CLOSE? Command

* Value Returned	Channel State
0	Channel Open
1	Channel Closed - not connected to a Bus
2	Channel Closed - connected to Sense Bus
3	Channel Closed - connected to Source Bus
4	Channel Closed - connected to Both Busses

** Only 2, 3 or 4 will be returned for channels 0 through 23.*

Programming the 24-Channel High-Speed FET MUX

The 24-Channel High-Speed General Purpose FET Multiplexer has four primary functions: voltage measurements, current measurements, resistance measurements, and temperature measurements.

This section contains examples which show how to program the 24-Channel FET MUX to perform each function. Included is a description of each function, applicable commands for the function, and programming examples. Each example includes a sample program and typical outputs for the assumed conditions.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP-3852A. Specific slot and channel numbers are used. Program syntax and data return formats apply to the HP 200 Series controllers. Modify slot and channel addresses as required for your particular configuration.

Command Summary

Table 9-4 is an alphabetical listing of commands which apply to the 24-Channel FET Multiplexer accessory. Refer to the HP-3852A Command Reference Manual for a complete description of these commands.

Table 9-4. Commands for the 24-Channel High-Speed FET MUX

CLOSE *ch list*

Closes a single FET multiplexer channel or a list of channels specified by *ch list* (channel list). This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

CLOSE? *ch list* [,**INTO** *name*] or [,*fmt*]

Queries the state of channels specified by *ch list* (channel list).

CONFMEAS *function, ch list* [,**USE** *ch*] [,**INTO** *name*] or [,*fmt*]

Configures the voltmeter accessory and scans/measures a function on the channels specified by *ch list* (channel list). This command automatically configures the tree switches for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function, ch list* [,**USE** *ch*] [,**INTO** *name*] or [,*fmt*]

Scans and measures a function on the channels specified by *ch list*. Automatically configures the tree switches for the measurement.

MONMEAS *function, ch list* [,**USE** *ch*]

Monitors and measures a function on the channels specified by *ch list*. Automatically configures the tree switches for the measurement. This command is useful in verifying wiring connections made on the terminal module.

OPEN *ch list*

Opens a single channel or a group of channels as specified by *ch list*.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Making Voltage Measurements

One of the functions of the 24-Channel High-Speed FET MUX is to make voltage measurements. The following paragraphs explain how to program the 24-Channel FET MUX to make AC and DC voltage measurements.

DC Voltage Measurements

In the DC voltage measurement function, the High-Speed FET MUX can switch up to 24 DC voltages for measurement by the HP-3852A voltmeter accessories or by external voltmeters.

<u>**Example: Measuring DC Voltage Sources**</u>

Suppose that you wish to measure the outputs from 24 DC voltage sources using the 24-Channel FET MUX. (Refer to Figure 9-7 for wiring DC voltage sources to the 24-Channel terminal module).

The following program example uses the CONFMEAS command to measure 24 DC voltage sources connected to channels 0 through 23 on the 24-Channel FET MUX. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and scans/measures the 24 channels once.

For this example, the 24-Channel High-Speed FET Multiplexer is installed in slot 1 of the mainframe and the voltmeter accessory used for the measurement is installed in slot 0 of the mainframe.

```
 10  !
 20  !Use CONFMEAS command to measure 24 DC voltages
 30  !using the 24-channel FET MUX in slot 1 of the
 40  !mainframe. Use the voltmeter accessory in slot
 50  !0 of the mainframe.
 60  !
 70  REAL Volts(1:24)
 80  OUTPUT 709; "CONFMEAS DCV,100-123,USE 0"
 90  ENTER 709; Volts(*)
100  PRINT USING "K,/";Volts(*)
110  END
```

Typical DC voltage values for the assumed conditions:

```
4.303000  <------  Channel 0
4.333500
1.204400
4.602300
   .
   .
   .
4.595000
2.345600
4.203000
3.897400  <------  Channel 23
```

Example: Measuring a DC Voltage Source using the CLOSE Command

Suppose that you wish to measure a single voltage source using 24-Channel FET MUX. This can be accomplished by using the CLOSE command. (Refer to Figure 9-7 for wiring DC voltage sources to the 24-Channel FET MUX terminal module).

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as with the scanning commands. Channels are not opened and closed in break-before-make fashion with the CLOSE command.

In this program example, CLOSE is used to close Channel 0, close the BANK A Sense tree switch (Channel 92), and close the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the measurement result to the controller. The OPEN command is used to open the channel and tree switches and isolation relays after the measurement has been taken.

For this example, the 24-Channel High-Speed FET MUX is installed in slot 1 of the mainframe and the voltmeter accessory is installed in slot 0.

```
 10  !
 20  !use CLOSE command to make DC voltage measurement
 30  !of the voltage source connected to Channel 0 on
 40  !the 24-channel FET MUX installed in slot 1 of the
 50  !mainframe. Use the voltmeter in slot 0 of the
 60  !mainframe.
 70  !
 80  OUTPUT 709; "USE 0"
 90  OUTPUT 709; "CLOSE 100,192,190"
100  OUTPUT 709; "FUNC DCV"
110  OUTPUT 709; "TRIG SGL"
120  OUTPUT 709; "CHREAD 0"
130  ENTER 709; Volts
140  PRINT Volts
150  OUTPUT 709; "OPEN 100,192,190"
160  END
```

Typical DC voltage value for assumed conditions:

```
4.949400
```

AC Voltage Measurements

In the AC voltage measurement function, the High-Speed FET MUX can switch up to 24 AC voltages for measurement by the HP-3852A voltmeter accessories or by external voltmeters.

Example: Measuring AC Voltage Sources

Suppose that you wish to measure the outputs from 24 AC voltage sources using the 24-Channel FET MUX. (Refer to Figure 9-7 for wiring AC voltage sources to the 24-Channel FET MUX terminal module).

The following program example uses the CONFMEAS command to measure 24 AC voltage sources connected to channels 0 through 23 on the 24-Channel FET MUX. The CONFMEAS command configures the voltmeter accessory for AC voltage measurements and scans/measures the 24 channels once.

For this example, the 24-Channel FET Multiplexer is installed in slot 3 of the mainframe and the HP-44701A Integrating Voltmeter Accessory is installed in slot 0 of the mainframe.

```
10  !
20  !Use CONFMEAS command to measure 24 AC voltages
30  !using the 24-channel FET MUX in slot 3 of the
40  !mainframe. Use the Integrating Voltmeter
50  !Accessory in slot 0 of the mainframe.
60  !
70  REAL Volts(1:24)
80  OUTPUT 709; "CONFMEAS ACV,100-123,USE 0"
90  ENTER 709; Volts(*)
100 PRINT USING "K,/";Volts(*)
110 END
```

Typical AC voltage values for the assumed conditions:

```
4.303000  <------ Channel 0
4.333500
1.204400
4.602300
    .
    .
    .
4.595000
2.345600
4.203000
3.897400  <------ Channel 23
```

Making Current Measurements

The 24-Channel High-Speed FET Multiplexer uses a current sensing technique to make current measurements. Current sensing is a method to determine the current through a shunt resistor which you install on the terminal module. The following paragraphs describe how to program the 24-Channel FET MUX to make DC and AC current measurements.

DC Current Measurements

In the DC Current measurement function, the 24-channel FET MUX accessory can switch up to 24 current inputs for measurement by the HP-3852A voltmeter accessory or external voltmeters.

Example: Making a DC Current Measurement

Suppose that you want to make a DC current measurement using a 250Ω shunt resistor installed on the terminal module. (Refer to Figure 9-9 for information on installing shunt resistors on the terminal module).

The following program example uses the CONFMEAS command to scan and measure the voltage drop across the 250Ω shunt resistor installed in channel 0 of the 24-channel FET MUX. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and scans and measures the channel once. The voltage value is then returned to the controller which is programmed to convert the voltage measurement to a DC current value.

For this example, the High-Speed FET MUX is installed in slot 2 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure the voltage
30  !drop across a 250 Ohm shunt resistor and calculate
40  !the DC current applied to channel 0. Use the
50  !24-channel FET MUX installed in slot 2 and the
60  !voltmeter accessory installed in slot 0.
70  !
80  OUTPUT 709; "CONFMEAS DCV,200,USE 0"
90  ENTER 709; Volts
100 !
110 !Current = Voltage/Shunt Resistance
120 !
130 Current = Volts/250
140 Print Current
150 END
```

Typical DC current value (in DC amps) for the assumed conditions:

```
.030344
```

AC Current Measurements

In the AC Current measurement function, the 24-channel FET MUX accessory can switch up to 24 AC current inputs for measurement by the HP-3852A voltmeter accessories or external voltmeters.

Example: Making an AC Current Measurement

Suppose that you want to make a AC current measurement using a 250Ω shunt resistor installed on the terminal module. (Refer to Figure 9-9 for information on installing shunt resistors on the terminal module).

The following program example uses the CONFMEAS command to scan and measure the voltage drop across the 250Ω shunt resistor installed in channel 0 of the 24-channel FET MUX. The CONFMEAS command configures the voltmeter accessory for AC voltage measurements and scans and measures the channel once. The voltage value is then returned to the controller which is programmed to convert the voltage measurement to an AC current value.

For this example, the 24-Channel FET MUX is installed in slot 1 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure the voltage
30  !drop across a 250 Ohm shunt resistor and calculate
40  !the AC current applied to channel 0. Use the
50  !24-Channel FET MUX installed in slot 1 and the
60  !voltmeter accessory installed in slot 0.
70  !
80  OUTPUT 709; "CONFMEAS ACV,100,USE 0"
90  ENTER 709; Volts
100 !
110 !Current = Voltage/Shunt Resistance
120 !
130 Current = Volts/250
140 Print Current
150 END
```

Typical AC current value (in AC amps) for the assumed conditions:

```
.034210
```

Making Resistance Measurements

The 24-Channel High-Speed FET MUX can be configured to make resistance measurements. The following paragraphs explain how to program the 24-Channel FET MUX to make 2-wire and 4-wire Ohms measurements.

2-Wire Ohms Measurements

The 2-wire ohms function is most commonly used to measure continuity or large resistances where the resistance of the test leads and FET switches will not be a factor in the measurement. In the 2-wire ohms function, the measurement path is through a FET switch and current limiting resistor to the input terminals. This makes the test lead and FET switch resistance appear as part of the unknown resistance. When measuring large resistances the error is less significant. As many as twenty-four 2-Wire resistance inputs can be switched by the 24-Channel FET MUX.

NOTE

The high "on" resistance of the FET switches limits the accuracy of 2-Wire Ohms measurements.

Example: Measuring Resistance using the 2-Wire Ohms Function

Suppose you wish to check the continuity of 24 inputs connected to the High-Speed FET MUX using the 2-Wire Ohms function. (Refer to Figure 9-10 for information on connecting devices for 2-Wire Ohms measurements.)

The following program example uses the CONFMEAS command to measure 24 devices connected to channels 0 through 23 on the 24-Channel High-Speed FET MUX. The CONFMEAS command configures the voltmeter accessory for 2-wire resistance measurements and scans and measures each of the 24 channels once.

For this example, the 24-Channel High-Speed FET MUX is installed in slot 4 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure 24 devices
30  !using the 24-Channel High-Speed FET MUX in slot 4
40  !of the mainframe. Use the voltmeter accessory
50  !installed in slot 0 of the mainframe.
60  !
70  REAL Ohms(1:24)
80  OUTPUT '0); "CONFMEAS OHM,400-423,USE 0"
90  ENTER 709; OHMS(*)
100 PRINT USING "K,/";Ohms(*)
110 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
3628.340  <------ Channel 0
4024.900
4030.400
3460.230
    .
    .
    .
3459.500
3234.560
4203.000
3389.740  <------ Channel 23
```

4-Wire Ohms Measurements

The 4-Wire Ohms function is most commonly used in applications where the test-lead resistance would affect measurement accuracy. With the 4-Wire Ohms function, the ohms current source is connected to the unknown resistance through separate leads. Since current does not flow through the measurement circuit, lead resistance is no longer a problem. Each 4-Wire Ohms input requires two input channels, therefore, a maximum of twelve 4-Wire measurements can be made using a single 24-Channel FET Multiplexer.

Example: Measuring Resistance using the 4-Wire Ohms Function

Suppose you wish to measure a group of resistors using the 24-Channel FET MUX configured for 4-wire measurements. (Refer to Figure 9-11 for information on wiring the terminal module for 4-wire ohms measurements).

The following program example uses the CONFMEAS command to measure resistors using the 4-Wire Ohms function. Channels 0 through 11 are used as the "Sense" channels and channels 12 through 23 are used as the "Source" channels. Note that the channels specified with the CONFMEAS command (channels 0 through 11) are the Sense channels. The HP-3852A determines the proper Source channels. The channels are scanned and measured once by the voltmeter accessory and the results (in Ohms) are returned to the controller.

For this example, the 24-Channel FET MUX is installed in slot 4 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to make 4-wire Ohms
30  !measurements using the 24-channel FET MUX in
40  !slot 4 of the mainframe and the voltmeter
50  !accessory in slot 0.
60  !
70  REAL Ohms (1:24)
80  OUTPUT 709; "CONFMEAS OHMF,400-411,USE 0"
90  ENTER 709; Ohms(*)
100 PRINT USING "K,/";Ohms(*)
110 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
628.340    <------  Channel 0
1024.900
460.230
   .
   .
   .
459.500
1203.000
389.740    <------  Channel 11
```

Making Temperature Measurements

The 24-Channel High-Speed FET Multiplexer can be configured to make temperature measurements. The HP-3852A firmware is designed to support temperature conversions for RTDs and thermistors. This section shows how to program the 24-Channel FET MUX accessory to measure RTDs and thermistors

Measuring Temperature using RTDs

The resistance temperature detector (RTD) is a temperature-sensitive resistor that is typically stable, accurate, and linear. The HP-3852A resistance-to-temperature conversions support RTDs with temperature coefficients (α) of 0.00385 $\Omega/\Omega°C$ and 0.003916 $\Omega/\Omega°C$.

Example: Measuring RTDs using the 4-Wire Function

Suppose you want to measure the temperature of 24 solar collectors using the 4-Wire temperature function. (Refer to Figure 9-12 for information on connecting the RTDs to the terminal module.)

The following program example uses the CONFMEAS command to scan and measure twelve RTDs (with $\alpha = 0.00385$) using the 4-Wire function. Channels 0 through 11 are used as the "Sense" channels and channels 12 through 23 are used as the "Source" channels. Note that the channels specified with the CONFMEAS command are the Sense channels (the HP-3852A determines the Source channels). The channels are scanned and measured once and the results (in degrees C) are returned to the controller.

For this example, the High-Speed FET MUX is installed in slot 2 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure RTDs using the
30  !4-Wire Ohms function. Use the 24-Channel FET MUX in
40  !slot 2 of the mainframe. Use the voltmeter accessory
50  !in slot 0.
60  !
70  REAL Temp(1:12)
80  OUTPUT 709; "CONFMEAS RTD85,200-211,USE 0"
90  ENTER 709; Temp(*)
100 PRINT USING "K,/";Temp(*)
110 END
```

Typical temperature values (in degrees C) for the assumed conditions:

```
24.542970  <------ Channel 0
24.542990
24.549390
    .
    .
    .
24.959990
25.558050
25.856450  <------ Channel 11
```

Measuring Temperature Using Thermistors

Thermistors are capable of detecting small changes in temperature and are used in applications where the temperature extremes are not too great. The thermistor is highly dependent upon variables such as composition and size. Most thermistors have negative temperature coefficients, that is, their resistance decreases as temperature increases.

The HP-3852A measures thermistors using the 4-Wire function. Each 24-Channel FET MUX can switch up to 12 thermistor inputs using the 4-Wire function. The HP-3852A resistance-to-temperature conversions support thermistors with the following values at 25°C: 2252 Ω, 5 kΩ, and 10 kΩ.

Example: Measuring Thermistors using the 4-Wire Function

Suppose you wish to measure two temperatures using 5 kΩ thermistors and the 4-Wire function. (Refer to Figure 9-13 for information on connecting thermistors to the terminal module.)

For this program example, the 24-Channel FET MUX is installed in slot 2 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure two thermistors
30  !using the 4-Wire Ohms function. Use the 24-Channel
40  !FET MUX in slot 2 of the mainframe. Use the voltmeter
50  !accessory in slot 0.
60  !
70  REAL Temp(1:2)
80  OUTPUT 709; "CONFMEAS THMF5K,200,209,USE 0"
90  ENTER 709; Temp(*)
100 PRINT USING "K,/";Temp(*)
110 END
```

Typical temperature values (in degrees C) for the assumed conditions:

```
24.542970
24.542990
```

Chapter 10
HP 44712A
48-Channel High-Speed FET Mux

Contents

Chapter 10
HP 44712A 48-Channel High-Speed FET MUX

Chapter 10

48-Channel High-Speed FET MUX

HP 44712A

Introduction

This chapter shows how to configure and program the HP 44712A 48-Channel High-Speed Single-Ended FET Multiplexer (MUX) Accessory. The chapter has four sections: Introduction, Specifications, Configuring the 48-Channel FET MUX, and Programming the 48-Channel FET MUX.

- **Introduction** contains a chapter overview, a description of the FET MUX, a description of its functions, and shows suggested steps to get started.
- **Specifications** lists the specifications for the accessory.
- **Configuring the 48-Channel FET MUX** contains a block diagram description of the accessory and shows how to connect field wiring to the terminal module.
- **Programming the 48-Channel FET MUX** shows how to program the accessory for single-ended voltage and resistance measurements.

Description

The FET MUX is used to switch (multiplex) signals from up to 48 single-ended channels for measurement by the HP 3852A voltmeter accessories or by external voltmeters. This accessory is designed to perform high-speed switching of low signal-level devices with input voltages less than 10.24 VDC or 7.24 VAC rms (10.24V peak).

The FET MUX can be controlled by the HP 3852A on the analog backplane or it can be independently controlled by the HP 44702 High-Speed Voltmeter Accessory using a dedicated ribbon cable. The ribbon cable allows the HP 44702 High-Speed Voltmeter to perform high-speed scanning operations with the FET MUX while leaving the HP 3852A free to perform other operations. The 48 channels can be switched at speeds up to 600 channels per second on the HP 3852A backplane or up to 100,000 channels per second using the ribbon cable and the HP 44702 High-Speed Voltmeter Accessory.

The FET MUX accessory consists of a 48-channel terminal module and a FET MUX component module. This accessory uses the same component module as the HP 44711A 24-Channel High-Speed FET MUX and the HP 44713A 24-Channel High-Speed FET MUX/TC. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

Functions

The FET MUX accessory is used to switch signals in applications that don't require the accuracy of a guarded (3-wire) measurement but high channel count is required. This accessory can be used to switch signals for two primary functions:

- Voltage Measurements.
- 2-Wire Resistance (or Ohms) Measurements.

NOTE

Each channel on the FET MUX can be independently configured to allow multiple functions to be measured using the same accessory.

Voltage Measurements

The FET MUX can be used to switch signals for single-ended DC voltage and AC voltage measurements. In the single-ended voltage measurement function, only the HIGH line is switched to allow for more channels per accessory at low cost per channel (LOW is common to all channels but is not switched). Use this function to make up to 48 single-ended voltage measurements per FET MUX accessory.

2-Wire Ohms Measurements

The FET MUX can be used to switch signals for 2-wire ohms measurements. In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 48 resistance measurements per FET MUX accessory.

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

NOTE

Four-wire ohms measurements cannot be made using the 48-Channel FET MUX accessory.

Getting Started

To use the FET MUX accessory for your application, you will need to follow three steps:

- Define your application.
- Configure the accessory for your application.
- Program the accessory for your application.

Define your Application

The first step is to define your application and determine if the accessory can meet the requirements of your application. The FET MUX can switch DC or AC inputs up to 10.24 VDC or 7.24 VAC rms (10.24V peak). Scanning can take place at speeds up to 600 channels per second on the HP 3852A backplane or up to 100,000 channels per second using the HP 44702 High-Speed Voltmeter Accessory and the ribbon cable. Since each of the 48 channels can be independently configured, up to 48 different devices can be connected to the FET MUX. When selecting devices to be connected, refer to Table 10-1 "48-Channel FET MUX Specifications" to ensure that the voltage and current requirements of your application are within the specifications for this accessory.

Configure the Accessory

The next step is to configure the accessory for your application. Refer to "Configuring the 48-Channel FET MUX" for information on hardware configuration and connecting field wiring to the terminal module for voltage measurements and 2-wire ohms measurements.

Program the Accessory

The third step is to program the FET MUX for your application. Refer to "Programming the 48-Channel FET MUX" to program the accessory for voltage measurements and 2-wire ohms measurements.

Specifications

Table 10-1 lists the specifications for the FET MUX. This table contains four categories: Input Characteristics, Channel Specifications, Operating Characteristics, and AC Performance.

WARNING

The HP 3852A and the HP 3853A internal analog buses interconnect the multiplexer and voltmeter accessories to form one circuit. To protect against personal injury due to equipment failure or programming error, limitations are placed on the potentials that can appear between any two points on the circuit (or between the circuit and chassis). These limitations are listed below for the HP 3852A, HP 3853A, and all plug-in accessories. For any given set of accessories installed in the mainframe or extender, the maximum potential between any two points is determined by the accessory with the LOWEST peak voltage limitation, as follows:

Instrument/Accessory	Maximum Allowable Peak Voltage
HP 3852A Mainframe	350V
HP 3853A Extender	350V
HP 44701A Integrating Voltmeter	350V
HP 44702A/B High-Speed Voltmeter	42V
20-Channel Relay Multiplexers	170V
60-Channel Relay Multiplexer	42V
All FET Multiplexers	42V

If the analog extender cable is NOT connected between the mainframe and the extenders, each instrument is considered as a separate circuit.

Table 10-1. 48-Channel FET MUX Specifications

INPUT CHARACTERISTICS:

Maximum Signal Voltage:

Between any input terminal and chassis:
10.24V peak, 10.24 VDC, 7.24 VAC rms

Input Voltage Protection Limit:

Channel Inputs: ±12V peak maximum
Backplane with isolation relays open: ±42V peak maximum

CHANNEL SPECIFICATIONS:

Bias Currents:

(Channel at 0V with respect to Chassis)
Currents are sourced by the accessory from HIGH or LOW to Chassis.

	Into Transducer or Backplane (0-28°C/0-55°C)	
	Channel Closed	Channel Open
HIGH or LOW	5 nA/45 nA	2 nA/11 nA

	Into Backplane (0-28°C/0-55°C)	
	Channel Open Isolation Relay Closed[1]	Maximum Differential Offset Voltage[2]
HIGH or LOW	2 nA/11 nA	20 uV/120 uV

[1]All channels open, isolation relay closed.

[2]Differential offset voltage between HIGH and LOW with a source resistance < 1 kΩ; RH < 85% @ 28°C or RH < 60% @ 40°C.

Maximum Signal Current: ±1 mA per channel

Isolation:

HIGH to LOW, HIGH to Chassis:
Channel On or Off: $10^8\Omega$
Power Off: Vin ≤ 10V 1 kΩ
Vin > 10V 200Ω

Low to Chassis: 100Ω

Table 10-1. 48-Channel FET MUX Specifications (cont'd)

Closed Channel "On" Resistance:
HIGH: 3.0 kΩ
LOW: 1.5 kΩ

OPERATING CHARACTERISTICS:

Maximum Scan Rate (channels per second):
Using HP 3852A Voltmeter Accessories on backplane: 600
Using HP 44702 High-Speed Voltmeter and ribbon cable: 100,000
Using External Voltmeter: 8,000

Synchronization: Break-Before-Make in scanning operation.

AC PERFORMANCE:

Frequency Response relative to 1 kHz:
(50Ω source, 1 MΩ termination)

50 kHz: -0.6 dB
200 kHz: -3.0 dB

Capacitance with Channel On:
HIGH to LOW: 200 pF
HIGH, LOW to Chassis: 200 pF

Crosstalk, Channel-to-Channel:
(50Ω source, 1 MΩ load); $\leq$ 5 Vrms

10 kHz: -50 dB
100 kHz: -35 dB

Configuring the 48-Channel FET MUX

This section shows how to configure the FET MUX accessory. It contains a block diagram of the accessory, information on connecting field wiring to the terminal module, and information on the measurement modes.

Refer to "Programming the 48-Channel FET MUX" to program the FET MUX for voltage measurements and 2-wire ohms measurements.

WARNING

1 *SHOCK HAZARD. Only qualified, service-trained personnel who are aware of the hazards involved should install, remove, or configure any accessory. Before touching any installed accessory, turn off all power to the mainframe, extenders, and to all external devices connected to the mainframe, extenders, or accessories.*

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers attached.

Block Diagram Description

The FET MUX accessory consists of a 48-channel terminal module and a FET MUX component module as shown in Figure 10-1. Field wiring from your application sensors, such as voltage sources, will be connected to the terminal module and the signals will be sent to the switches located on the component module.

2 **Figure 10-1. 48-Channel FET MUX Block Diagram**

The component module is made up of two types of switches: bank switches and tree switches. There are a total of 48 bank switches which are divided into two groups of 24 channels each: BANK A and BANK B. Unlike the guarded multiplexer accessories, the FET MUX switches only the HIGH line (LOW is common to all channels and to chassis but is not switched).

The component module has four tree switches which are of two types: Source Bus tree switches and Sense Bus tree switches. There are two Source Bus tree switches and two Sense Bus tree switches. The tree switches control signal flow to and from the HP 3852A backplane and also isolate the bank switches from the backplane when they are not in use. The Sense Bus tree switches provide the connections to the backplane for making voltage measurements. The Source Bus tree switches provide the current source connections (+I and -I) to the backplane for resistance measurements.

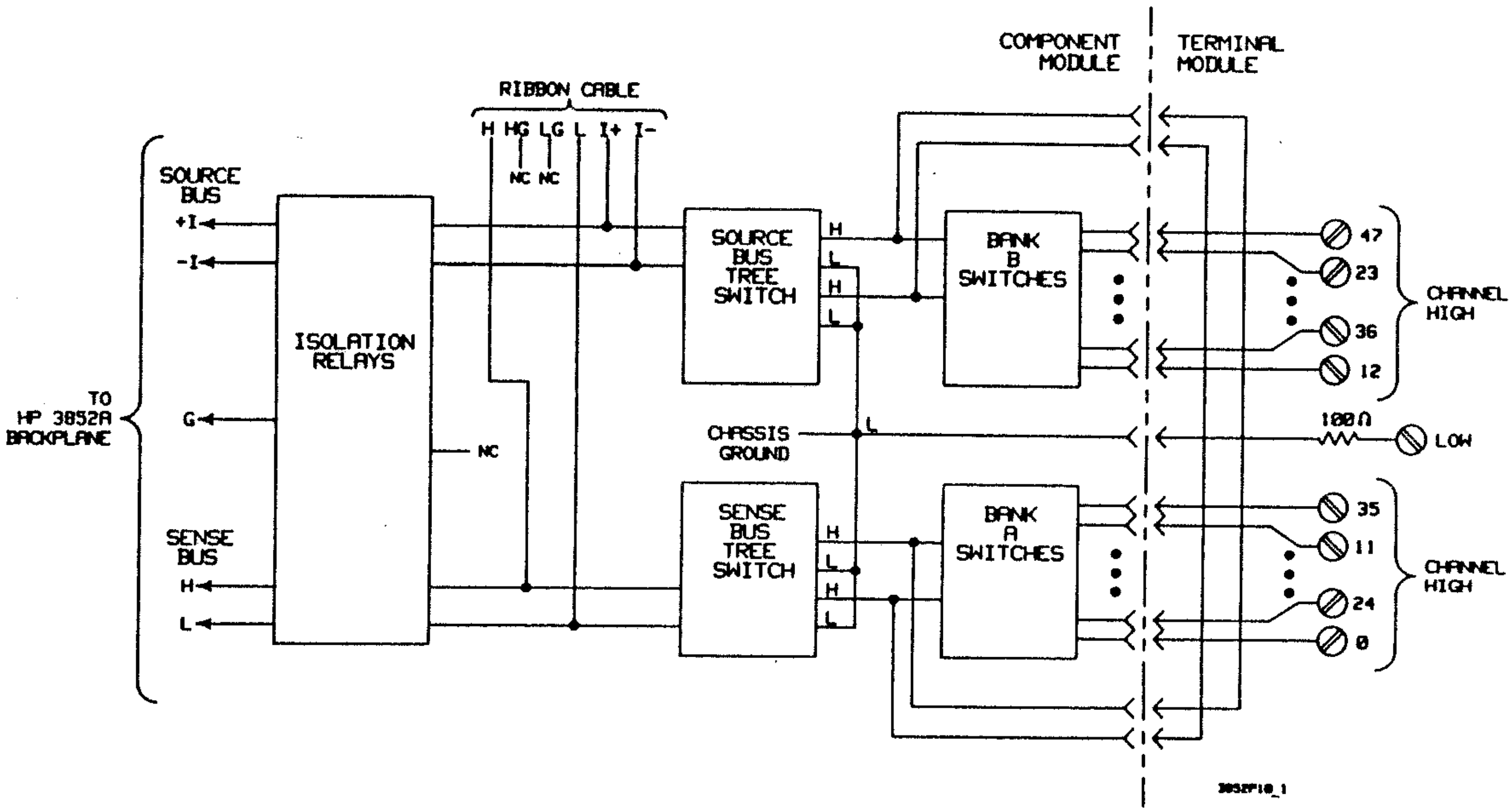

Figure 10-1. 48-Channel FET MUX Block Diagram

The component module also includes isolation relays which allow the accessory to be isolated from the HP 3852A backplane. The isolation relays can be used to reduce the leakage current on the backplane for critical measurements or for using the backplane at voltages greater than the FET MUX voltage specification. The accessory has overvoltage protection circuitry which will automatically open the isolation relays when voltages greater than ±15V peak are detected on the backplane.

Table 10-2 shows the channel definitions for the FET MUX accessory. Channels 0 through 47 control the bank switches, Channel 90 controls the isolation relays, and Channels 91 through 93 control the tree switches.

Table 10-2. 48-Channel FET MUX Channel Definitions

Channel	Definitions
0 - 47	Bank Switches
90	Isolation Relays
91	Source Bus Tree Switch
92	Sense Bus Tree Switch
93	Sense Bus Tree Switch and Source Bus Tree Switch

Connecting Field Wiring

The next step is to connect field wiring from your application to the appropriate terminals on the terminal module. The following section contains examples that show how to connect field wiring to the terminal module for making voltage measurements and 2-wire ohms measurements.

Figure 10-2 shows the terminal module with the terminal module cover removed. There are 48 CHANNEL HIGH terminals (numbered 0 through 47) and 24 LOW terminals on the terminal module. All 24 LOW terminals are common to one another and to chassis ground.

Figure 10-2. 48-Channel FET MUX Terminal Module

When connecting field wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make it easier to route the wiring.

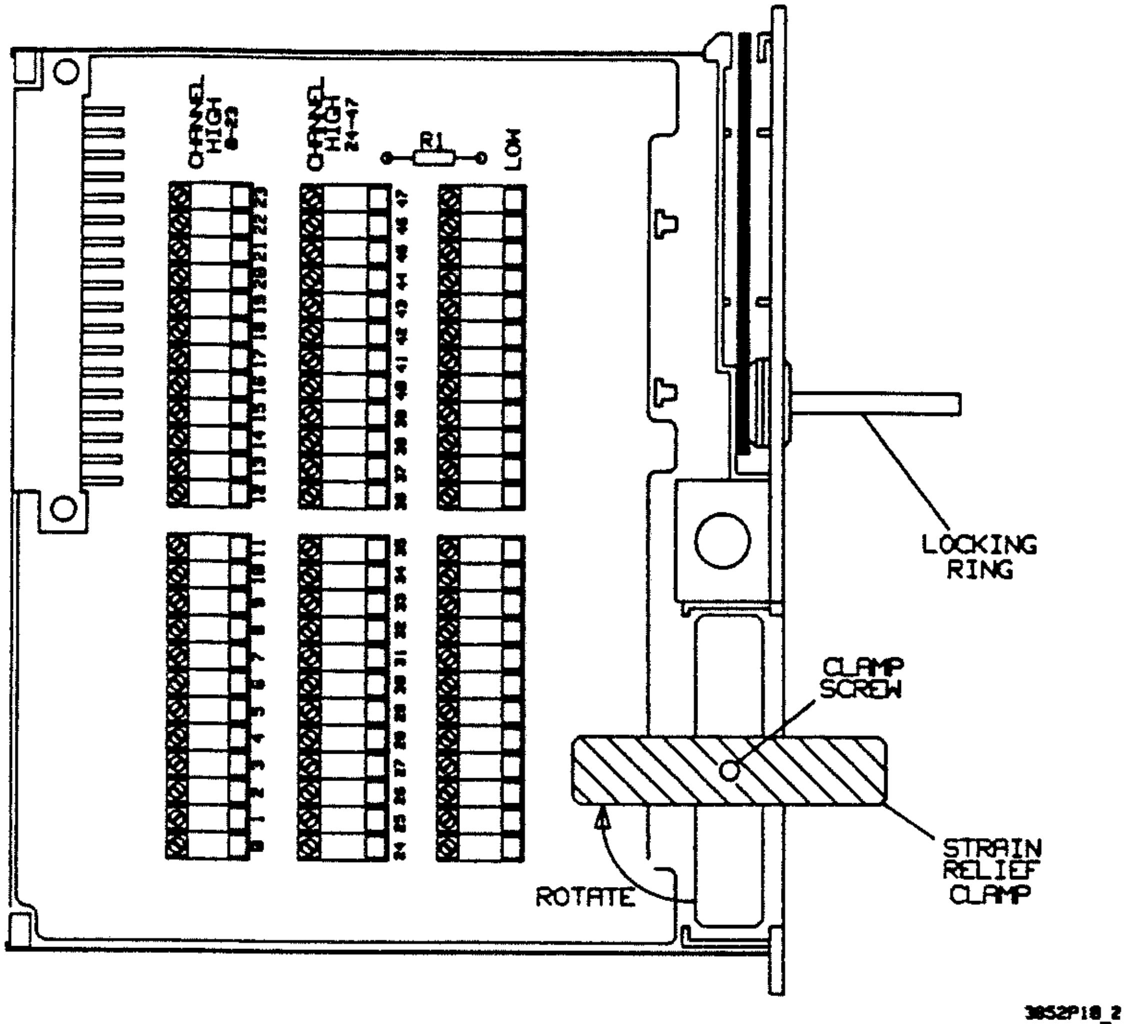

Figure 10-2. 48-Channel FET MUX Terminal Module

NOTE

When connecting components such as resistors, the lead length may be too short to route through the strain relief clamp. In this case, the components will have to be stored inside the terminal module. When connecting these components, make sure that no leads are shorted together and bend the leads to allow the terminal module cover to be attached.

Voltage Measurements

In the voltage measurement function, the FET MUX accessory can switch signals for up to 48 single-ended DC or AC voltage measurements. When making single-ended voltage measurements, only the HIGH line is switched (LOW is common to all channels and to chassis but is not switched).

CAUTION

The maximum non-destructive voltage which can be applied to the FET MUX is 10.24 VDC or 7.24 VAC rms (10.24V peak). Refer to Table 10-1 for the specifications.

Example: Connecting Voltage Sources to the Terminal Module

A voltage source (V0) is connected to Channel 0 on the terminal module as shown in Figure 10-3. Connect the high (+) lead from the voltage source to the CHANNEL HIGH terminal for Channel 0. Connect the low lead (-) from the voltage source to one of the LOW terminals.

Figure 10-3. Connecting Voltage Sources to the Terminal Module

2-Wire Ohms Measurements

One of the functions of the FET MUX accessory is to switch signals for resistance measurements. This section contains a 2-wire ohms configuration example.

Example: Connecting Resistors for 2-Wire Ohms Measurements

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 48 resistance measurements per FET MUX accessory.

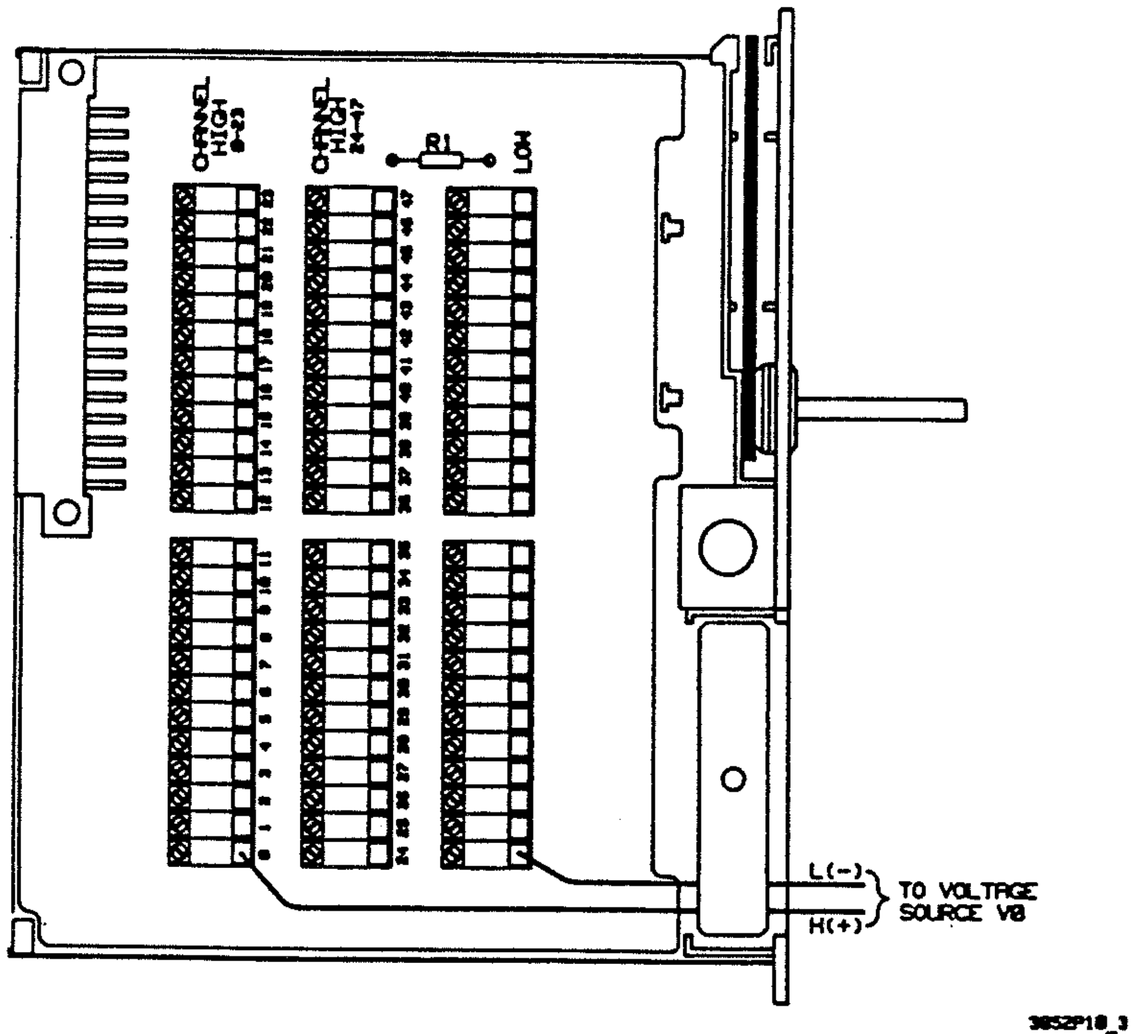

Figure 10-3. Connecting Voltage Sources to the Terminal Module

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

A resistor (R0) is connected to Channel 0 on the terminal module as shown in Figure 10-4. Connect one lead of the resistor to the CHANNEL HIGH terminal for Channel 0. Connect the other lead of the resistor to one of the LOW terminals.

Figure 10-4. Connecting Resistors for 2-Wire Ohms Measurements

Installation/ Checkout

⚠ 4

The following section explains how to check the accessory identity, how to verify the field wiring connections, and how to read the state of the channels.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

Measurement Modes

The FET MUX can be used in two modes: the System Mode and the Scanner Mode. In the System Mode, the accessory can be used either with the HP 44701A Integrating Voltmeter or the HP 44702 High-Speed Voltmeter (on the backplane). This mode can be used for low-speed scanning on the backplane and the ribbon cable must be disconnected.

For high-speed scanning, the FET MUX can be used in the Scanner Mode. In the Scanner Mode, the ribbon cable from the FET MUX must be connected to the HP 44702 High-Speed Voltmeter Accessory. Up to six high-speed FET MUX accessories can be connected together (up to eight in an extender) using the ribbon cable. Refer to the Mainframe Configuration and Programming Manual for information on installing and removing the ribbon cable and connecting multiple FET multiplexer accessories.

Checking the Accessory Identity

After you have connected field wiring from your application to the terminal module, replace the terminal module cover and install the accessory in the desired mainframe or extender slot. Refer to the Mainframe Configuration and Programming Manual to connect the terminal module to the component module and to install the accessory.

To check the accessory identity, you can use the ID? (Identity?) command. The ID? command provides a way to check, from the HP 3852A front panel or from a controller, in what slot an accessory has been installed. The ID? command will

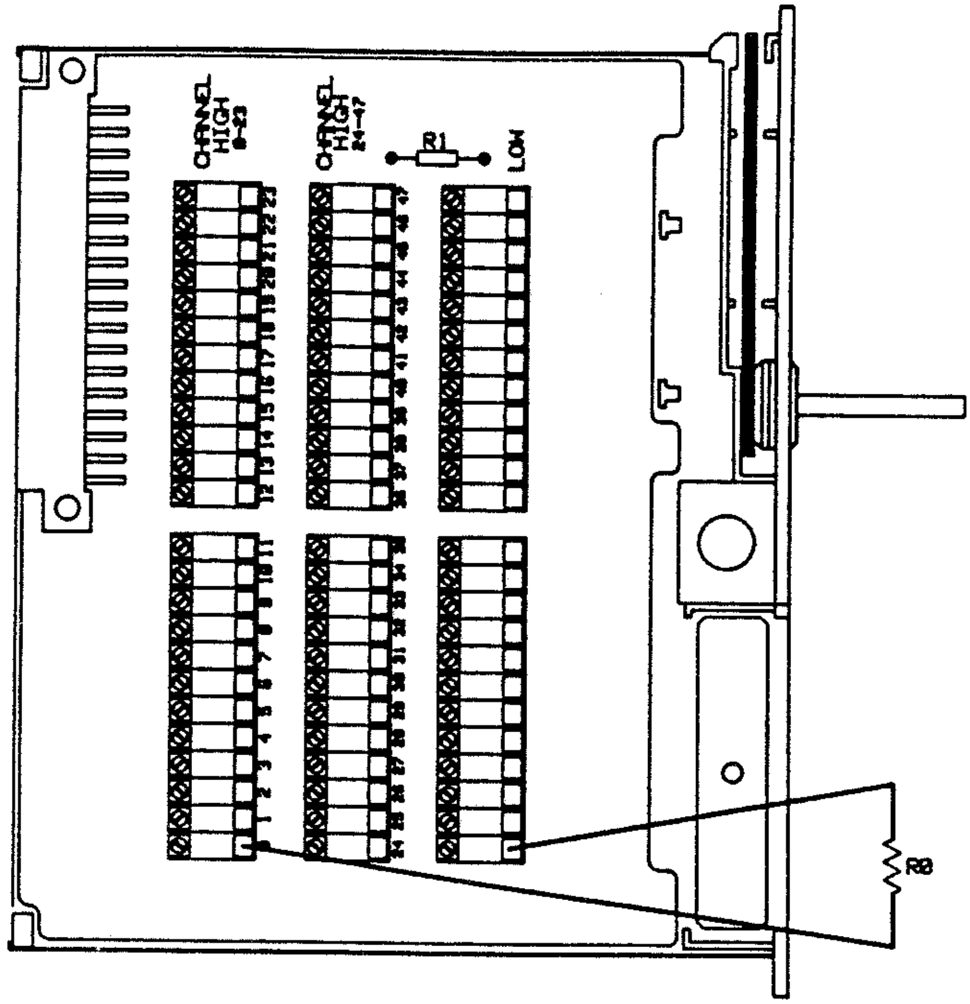

Figure 10-4. Connecting Resistors for 2-Wire Ohms Measurements

return " 44712A" for the 48-Channel FET MUX and " 447XXX" if the terminal module is not connected to the component module. If the ID? command is sent to a slot with no accessory installed, " 000000" will be returned.

Example: Reading the Accessory Identity

```
10  !
20  !Use the ID? command to read the identity of a
30  !FET MUX installed in slot 2 of the mainframe.
40  !
50  OUTPUT 709; "ID? 200"
60  ENTER 709; Identity$
70  PRINT Identity$
80  END
```

Output with terminal module connected:

```
44712A
```

NOTE

If you have addressed the correct slot and have made sure that the terminal module is connected, but the proper ID number is not returned, refer to the HP 3852A Assembly Level Service Manual for service procedures.

Verifying Wiring Connections

To verify that your field wiring has been properly connected to the terminal module, send the MONMEAS (Monitor/Measure) command from the HP 3852A front panel keyboard or from a controller. This command can be used to check DC voltage, AC voltage, and 2-wire ohms connections.

The following program segment shows how to use the MONMEAS command with a controller to verify DC voltage connections on Channels 200 through 204. The CONF command configures the voltmeter accessory for DC voltage measurements in the System Mode (no ribbon cable connected). For this example, a FET MUX in slot 2 of the mainframe and an HP 44702 High-Speed Voltmeter in slots 0 and 1 (or just slot 0 for the Integrating Voltmeter) of the mainframe are used.

```
10  OUTPUT 709; "USE 0"
20  OUTPUT 709; "CONF DCV"
30  OUTPUT 709; "MONMEAS DCV,200-204"
40  END
```

The five channels will be scanned and measured one at a time starting with Channel 200. Press "SADV KEY" on the HP 3852A front panel to advance the scanning to the next channel. When the scan is advanced past the last channel (Channel 204 in this example), scanning will stop and the last

Reading Channel State

The CLOSE? command can be used to determine the state of the FET MUX channels. This command returns one of five numbers for for each channel queried. The numbers returned indicate if a channel is open or closed and to which bus the channel is connected. Table 10-3 shows the channel state for each value that can be returned by the CLOSE? command when used with the FET MUX.

Table 10-3. Values Returned by the CLOSE? Command

Data Returned	Channel State
0	Channel Open
1	Channel Closed
2	Channel Closed - connected to Sense Bus
3	Channel Closed - connected to Source Bus
4	Channel Closed - connected to Both Buses

NOTE

When the CLOSE? command is used with the FET multiplexer accessories, the state of the isolation relays is ignored.

NOTE

The CLOSE? command will return 2, 3, or 4 only to indicate the state of Channels 0 through 47 (i.e., these values will not be returned for the tree switches).

<u>Example: Reading Channel State</u>

This example program shows how to use the CLOSE? command to read the state of Channels 0 through 4 on a FET MUX when used in the System Mode. The RST command resets the FET MUX to its power-on state where all channels are open and the isolation relays are open. The CLOSE command closes Channel 3, the Sense Bus tree switch (Channel 92), and the isolation relays (Channel 90). The OPEN command is used to open the channels and disconnect them from the HP 3852A backplane. For this example, a FET MUX is installed in slot 2 of the mainframe.

```
10  OUTPUT 709; "RST 200"
20  INTEGER State(4)
30  OUTPUT 709; "CLOSE 203,292,290"
40  OUTPUT 709; "CLOSE? 200-204"
50  ENTER 709; State(*)
60  PRINT State(*)
70  OUTPUT 709; "OPEN 203,292,290"
80  END
```

Typical Output (Channel 3 closed - connected to Sense Bus):

```
0   0   0   2   0
```

Programming the 48-Channel FET MUX

As noted in the Introduction section of this chapter, the FET MUX has two primary functions: voltage measurements and 2-wire ohms measurements. This section contains examples that show how to program the FET MUX for each function. It includes a description of each function, applicable commands for the functions, and programming examples. Each example includes a sample program and (where applicable) typical outputs for the assumed conditions.

This section also summarizes the programming commands used with the FET MUX (refer to "Command Summary") and lists the titles of the example programs (refer to "Program Titles").

NOTE

The example programs in this section use "709" as the HP-IB address for the HP 3852A. Specific slot and channel numbers are also used. Program syntax and data return formats apply to HP Series 200/300 Controllers. Modify slot and channel numbers as required.

NOTE

The example programs show how to make typical measurements using the FET MUX and the HP 3852A Voltmeter Accessories. Refer to the Mainframe Configuration and Programming Manual for instructions on making measurements using external voltmeters.

Command Summary

Table 10-4 is an alphabetical listing of commands which apply to the FET MUX accessory. Refer to the HP 3852A Command Reference Manual for a complete description of these commands.

Table 10-4. Commands for the 48-Channel FET MUX

CLOSE *ch list*

Closes a single multiplexer channel or a list of channels specified by *ch list*. This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

CLOSE? *ch list* [INTO *name*] or [*fmt*]

Queries the state of channels specified by *ch list*.

CONFMEAS *function* , *ch list* [USE ch] [INTO *name*] or [*fmt*]

Configures the voltmeter accessory and measures a function on the channels specified by *ch list*. This command automatically configures the voltmeter accessory and the tree switches on the multiplexer for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function* , *ch list* [USE *ch*] [INTO *name*] or [*fmt*]

Scans and measures a function on the channels specified by *ch list*. This command does not configure the voltmeter accessory but it does configure the tree switches on the multiplexer for the measurement.

MONMEAS *function* , *ch list* [USE *ch*]

Monitors and measures a function on the channels specified by *ch list*. This command is useful to check wiring connections made on the terminal module.

OPEN *ch list*

Opens a single multiplexer channel or a list of channels specified by *ch list*. This command is used to open channels and place them in a safe state after the measurements have been made.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Program Titles

The discussion for each function includes one or two examples that show how to program the FET MUX for that function. Table 10-5 lists the titles of the example programs in this section.

Table 10-5. Program Titles

Measurement Modes

The FET MUX can be used in two modes: the System Mode and the Scanner Mode. In the System Mode, the accessory can be used either with the HP 44701A Integrating Voltmeter Accessory or the HP 44702 High-Speed Voltmeter (on the backplane). This mode can be used for low-speed scanning on the backplane with the ribbon cable disconnected.

For high-speed scanning, the FET MUX can be used in the Scanner Mode. In the Scanner Mode, the ribbon cable from the FET MUX must be connected to the HP 44702 High-Speed Voltmeter Accessory. Up to six high-speed FET MUX accessories can be connected together (up to eight in an extender) using the ribbon cable. Refer to the Mainframe Configuration and Programming Manual for information on installing and removing the ribbon cable and connecting multiple FET multiplexer accessories.

Making Voltage Measurements

One of the functions of the FET MUX accessory is to make single-ended voltage measurements. This section explains how to program the accessory to make single-ended DC and AC voltage measurements.

NOTE

The maximum non-destructive voltage which can be applied to the FET MUX is 10.24 VDC or 7.24 VAC rms (10.24V peak). Refer to Table 10-1 for the specifications.

NOTE

The AC voltage function is considerably slower than the DC voltage function. It takes approximately two seconds for the HP 44701A Integrating Voltmeter to configure for AC voltage measurements and approximately 1.5 seconds per reading.

AC voltage measurements cannot be made using the HP 44702 High-Speed Voltmeter Accessory.

Example: Making High-Speed DC Voltage Measurements (Scanner Mode)

Suppose that you want to measure the outputs from 48 DC voltage sources using the FET MUX in the high-speed Scanner Mode. See Figure 10-3 to connect voltage sources to the terminal module.

Table 10-5. Program Titles

TITLE	DESCRIPTION	COMMANDS
	<u>Voltage Measurements</u>	
Making High-Speed DC Voltage Measurements (Scanner Mode)	Measures the outputs from 48 voltage sources using the FET MUX with a High-Speed Voltmeter Accessory in the high-speed scanner mode. For this example, the FET MUX is completely controlled by the High-Speed Voltmeter commands.	SCANMODE, CONF, CLWRITE, SCTRIG, XRDGS
Measuring DC and AC Voltage Sources (System Mode)	Measures the outputs from 48 voltage sources using the FET MUX with a voltmeter accessory on the backplane.	CONFMEAS
Measuring Voltage Sources using CLOSE Command (System Mode)	Measures the output from a voltage source using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN
	<u>2-Wire Ohms Measurements</u>	
Making High-Speed 2-Wire Ohms Measurements (Scanner Mode)	Measures 48 resistors using the FET MUX with a High-Speed Voltmeter Accessory in the high-speed scanner mode. For this example, the FET MUX is completely controlled by the High-Speed Voltmeter commands.	SCANMODE, CONF, CLWRITE, SCTRIG, XRDGS
Measuring Resistors using 2-Wire Ohms Function (System Mode)	Measures 48 resistors using the FET MUX and the 2-wire ohms measurement function in the system mode.	CONFMEAS
Measuring Resistors using the CLOSE Command (System Mode)	Measures a single resistor using the CLOSE and OPEN commands to control the tree switches and the bank switches for the measurement.	CLOSE, OPEN

NOTE

This example shows how to make simple, high-speed DC voltage measurements using the FET MUX and the HP 44702 High-Speed Voltmeter Accessory. Refer to Chapter 3 "High-Speed Voltmeter" for more detailed information on high-speed scanning.

NOTE

Since this example uses the Scanner Mode, the ribbon cable from the FET MUX must be connected to the HP 44702 High-Speed Voltmeter. Refer to the Mainframe Configuration and Programming Manual for information on connecting the ribbon cable and installing the accessories.

```
10  !
20  !Use the HP 44702 High-Speed Voltmeter installed in slots 6
30  !and 7 of the mainframe to make 48 high-speed DC voltage
40  !measurements.  Install a FET MUX in slot 5 of the mainframe.
50  !
60  REAL Volts(47)
70  OUTPUT 709; "USE 600"
80  !
90  !Enable Scanner Mode; Select voltmeter function.
100 !
110 OUTPUT 709; "SCANMODE ON;CONF DCV"
120 !
130 !Select channel list for the voltage measurements.
140 !
150 OUTPUT 709; "CLWRITE SENSE 500-547"
160 !
170 !Trigger voltmeter accessory; Transfer readings from channel.
180 !
190 OUTPUT 709; "SCTRIG SGL; XRDGS 600"
200 FOR I = 0 TO 47
210 ENTER 709; Volts(I)
220 PRINT "Ch.";I, Volts(I)
230 NEXT I
240 END
```

Typical DC voltage values for the assumed conditions:

```
Ch. 0   4.30300
Ch. 1   4.33350
      .
      .
      .
Ch. 46  4.58580
Ch. 47  3.49490
```

Example: Measuring DC and AC Voltage Sources (System Mode)

Suppose that you want to measure the outputs from 48 voltage sources using the FET MUX and the System Mode. See Figure 10-3 to connect voltage sources to the terminal module.

The following example program uses the CONFMEAS command to measure 48 DC voltage sources connected to Channels 0 through 47. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements (in the System Mode) and measures the 48 channels once.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 80:

```
80  OUTPUT 709; "CONFMEAS ACV,500-547,USE 600"
```

```
10  !
20  !Use the CONFMEAS command to measure 48 DC voltages using
30  !a FET MUX installed in slot 5 of the mainframe.  Install
40  !a voltmeter accessory in slots 6 and 7 (or just slot 6
50  !for the Integrating Voltmeter) of the mainframe.
60  !
70  REAL Volts(47)
80  OUTPUT 709; "CONFMEAS DCV,500-547,USE 600"
90  FOR I = 0 TO 47
100 ENTER 709; Volts(I)
110 PRINT "Ch.";I, Volts(I)
120 NEXT I
130 END
```

Typical DC voltage values for the assumed conditions:

```
Ch. 0   4.30300
Ch. 1   4.33350
      .
      .
      .
Ch. 46  4.58580
Ch. 47  3.49490
```

Example: Measuring Voltage Sources using CLOSE Command (System Mode)

Suppose that you want to measure the output from a voltage source using the CLOSE command in the System Mode. See Figure 10-3 to connect a voltage source to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the Sense Bus tree switch (Channel 92), and the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for DC voltage measurements (in the System Mode). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the DC voltage from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the HP 3852A backplane after the measurements have been taken.

NOTE

To use the following program to make AC voltage measurements with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 100:

```
100 OUTPUT 709; "FUNC ACV"
```

```
10  !
20  !Use the CLOSE command to make a DC voltage measurement of
30  !the voltage source connected to Channel 0 on a FET MUX in slot
40  !slot 5 of mainframe.  Install a voltmeter accessory in slots
50  !6 and 7 (or just slot 6 for the Integrating Voltmeter)
60  !of the mainframe.
70  !
80  OUTPUT 709; "USE 600"
90  OUTPUT 709; "CLOSE 500,592,590"
100 OUTPUT 709; "FUNC DCV"
110 OUTPUT 709; "TRIG SGL"
120 OUTPUT 709; "CHREAD 600"
130 ENTER 709; Volts
140 PRINT Volts
150 OUTPUT 709; "OPEN 500,592,590"
160 END
```

Typical DC voltage value for the assumed conditions:

```
3.94940
```

Making 2-Wire Ohms Measurements

One of the functions of the FET MUX is to make 2-wire ohms measurements. The section explains how to program the FET MUX for 2-wire ohms measurements.

In applications where the resistance of the test leads is not critical, the 2-wire ohms function can be used. Generally, the larger the resistance being measured, the less you have to be concerned about test lead resistances. Use the 2-wire ohms function to make up to 48 resistance measurements per FET MUX.

NOTE

The high "on" resistance of the FET switches (approximately 3 kΩ) limits the accuracy of 2-wire ohms measurements.

When using the FET MUX accessory for 2-wire ohms measurements, the voltmeter accessory is actually configured for a 4-wire ohms measurement. The FET MUX converts the 4-wire ohms function on the voltmeter to a 2-wire ohms function on the component module. It does this by connecting the high voltage sense lead to the high current source lead and the low voltage sense lead to the low current sense lead. Therefore, only two leads are used on the FET MUX for the 2-wire ohms measurement.

Example: Making High-Speed 2-Wire Ohms Measurements (Scanner Mode)

Suppose that you want to make 48 2-wire resistance measurements using the FET MUX in the high-speed Scanner Mode. See Figure 10-4 to connect voltage sources to the terminal module.

NOTE

This example shows how to make simple, high-speed 2-wire ohms measurements using the FET MUX and the HP 44702 High-Speed Voltmeter Accessory. Refer to Chapter 3 "High-Speed Voltmeter" for more detailed information on high-speed scanning.

NOTE

Since this example uses the Scanner Mode, the ribbon cable from the FET MUX must be connected to the HP 44702 High-Speed Voltmeter. Refer to the Mainframe Configuration and Programming Manual for information on connecting the ribbon cable and installing the accessories.

```
10  !
20  !Use a HP 44702 High-Speed Voltmeter in slots 6 and 7 of
30  !the mainframe to make 48 high-speed 2-wire ohms measurements.
40  !Install a FET MUX in slot 5 of the mainframe.
50  !
60  REAL Ohms(47)
70  OUTPUT 709; "USE 600"
80  !
90  !Enable Scanner Mode; Select voltmeter function.
100 !
110 OUTPUT 709; "SCANMODE ON; CONF OHMF10K"
120 !
130 !Select the channel list.
140 !
150 OUTPUT 709; "CLWRITE COM 500-547"
160 !
170 !Trigger the voltmeter accessory; Transfer readings from voltmeter.
180 !
190 OUTPUT 709; "SCTRIG SGL; XRDGS 600"
200 FOR I = 0 TO 47
210 ENTER 709; Ohms(I)
220 PRINT "Ch.";I, Ohms(I)
230 NEXT I
240 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
Ch. 0   6628.340
Ch. 1   5024.960
     .
     .
     .
Ch. 46  8039.460
Ch. 47  6528.380
```

Example: Measuring Resistors using 2-Wire Ohms Function (System Mode)

Suppose that you want to measure 48 resistors connected to the FET MUX using the 2-wire ohms function and the System Mode. See Figure 10-4 to connect resistors to the terminal module for 2-wire ohms measurements.

The following example program uses the CONFMEAS command to measure 48 resistors connected to Channels 0 through 47. The CONFMEAS command configures the voltmeter accessory for 2-wire ohms measurements and measures the 48 channels once.

```
10  !
20  !Use the CONFMEAS command to measure 48 resistors using a FET
30  !MUX installed in slot 5 of the mainframe.  Install a voltmeter
40  !accessory in slots 6 and 7 (or just slot 6 for the Integrating
50  !Voltmeter) of the mainframe.
60  !
70  REAL Ohms(47)
80  OUTPUT 709; "CONFMEAS OHM,500-547,USE 600"
90  FOR I = 0 TO 47
100 ENTER 709; Ohms(I)
110 PRINT "Ch.";I, Ohms(I)
120 NEXT I
130 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
Ch. 0   6628.340
Ch. 1   5024.960
       .
       .
       .
Ch. 46  8039.460
Ch. 47  6528.380
```

<u>Example: Measuring Resistors using the CLOSE Command (System Mode)</u>

Suppose that you want to make a 2-wire ohms measurement of a resistor using the CLOSE command and the System Mode. See Figure 10-4 to connect a resistor to the terminal module for a 2-wire ohms measurement.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches and the isolation relays are not automatically configured as in the scanning commands.

In this example program, CLOSE is used to close Channel 0, the Sense Bus and Source Bus tree switches (Channel 93), and the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for 4-wire ohms measurements (the FET MUX converts the 4-wire function to a 2-wire function on the component module). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance value from the voltmeter channel to the controller. The OPEN command is used to open the channels and disconnect them from the HP 3852A backplane after the measurements have been taken.

NOTE

The following program uses the HP 44702 High-Speed Voltmeter Accessory in the System Mode. To use the program with the HP 44701A Integrating Voltmeter Accessory, substitute the following line for the existing line 90:

```
90  OUTPUT 709; "FUNC OHMF"
```

```
 10  !
 20  !Use the CLOSE command to make a 2-wire ohms measurement of a
 30  !resistor connected to Channel 0.  Install a FET MUX in slot 5 of
 40  !the mainframe.  Install a voltmeter accessory in slots 6 and 7
 50  !(or just slot 6 for the Integrating Voltmeter) of the mainframe.
 60  !
 70  OUTPUT 709; "USE 600"
 80  OUTPUT 709; "CLOSE 500,593,590"
 90  OUTPUT 709; "FUNC OHMF10K"
100  OUTPUT 709; "TRIG SGL"
110  OUTPUT 709; "CHREAD 600"
120  ENTER 709; Ohms
130  PRINT Ohms
140  OUTPUT 709; "OPEN 500,593,590"
150  END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
6623.570
```

Chapter 11
HP 44713A
24-Channel High-Speed FET Mux/TC

Contents

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HP 44713A 24-Channel High-Speed FET MUX/TC

Chapter 11

24-Channel High Speed FET MUX/TC

HP-44713A

Introduction

Chapter 11 explains how to program and configure the HP-44713A 24-Channel High-Speed Thermocouple Compensated FET Multiplexer Accessory (24-Channel High-Speed FET MUX/TC). This chapter is divided into four sections:

- **Introduction** contains an overview of this chapter, a general description of the 24-Channel FET MUX/TC and its functions, and suggested steps to "get started".

- **Specifications** lists the specifications for the 24-Channel FET MUX/TC.

- **Configuring the 24-Channel High-Speed FET MUX/TC** contains a block diagram description of the accessory, illustrates how to wire and configure the terminal module, and how to connect external wiring.

- **Programming the 24-Channel High-Speed FET MUX/TC** explains how to program the accessory to make voltage, current, resistance and temperature measurements.

NOTE

Additional information relating to the 24-Channel FET MUX/TC can be found in the HP-3852 Configuration and Programming Manual.

24-Channel High-Speed FET MUX/TC Description

The 24-Channel FET MUX/TC Accessory consists of a 24-channel FET switching assembly and a 24-channel terminal assembly. The unit is used to multiplex (switch) up to twenty-four 2-wire input signals at a maximum switching rate of 100,000 times per second. Maximum input voltage is limited to ± 10.24 volts peak.

External connection to the assembly is made through the terminal module. The terminal module is also used to configure the assembly to measure voltage, 2-wire ohms, current and temperature.

A thermistor, mounted on the isothermal terminal block, is used to measure the temperature of the connection terminals. The HP-3852 then uses a "software compensation" technique to compensate for the error generated by the ambient temperature of the connection terminals.

The High-Speed FET MUX/TC is unique to other switching options in that it can be operated under control of the HP-3852 Data Acquisition and Control Unit through the backplane interface or it can be controlled by the HP-44702 13-Bit High-Speed Voltmeter Accessory by connecting the two with a dedicated interface bus. This connection allows the 13-Bit Voltmeter/24-Channel High-Speed FET MUX/TC combination to operate as a scanner system independent of the HP-3852 mainframe.

24-Channel High-Speed FET MUX/TC Functions

The 24-Channel Thermocouple Compensated FET Multiplexer is used to switch input signals for measurement by one of the HP-3852 optional voltmeters or by an external voltmeter. The accessory is used to switch signals for the following types of measurements:

- Voltage Measurements.
- Current Measurements.
- 2-Wire Resistance Measurements.
- Thermocouple Temperature Measurements.

Voltage Measurements.

The 24-Channel FET MUX/TC is used to make standard two-terminal DC and AC voltage measurements. Both the HIGH and LOW input lines are switched on all channels. Input voltage is limited to ± 10.24 volts peak. Use this function to measure up to 24 individual voltage inputs per accessory.

Current Measurements.

The High-Speed Multiplexer is used to measure AC and DC current by using current sensing. Current sensing is a method of determining current using a shunt resistance which you install on the terminal module. The value of current which can be measured depends upon the shunt resistance value and the ± 10.24 volt input limitation. Use this function to measure up to 24 individual current inputs per accessory.

Resistance Measurements.

The 24-Channel FET MUX/TC is used to make 2-Wire Ohms measurements. This function should only be used in applications where test lead resistance and resistance of the FET switches will not affect the accuracy of the measurement. Use the 2-Wire Ohms function to measure up to 24 individual inputs per accessory.

Temperature Measurements.

The High-Speed FET MUX/TC assembly is specifically designed to measure temperature using thermocouples. Thermocouples provide simple, durable, inexpensive, and relatively accurate temperature measurements over a wide range of temperatures. Use the temperature measurement function to measure up to 24 individual thermocouple inputs per accessory.

The HP-3852 firmware supports temperature conversions for the following thermocouples:

Types Supported: B, E, J, K, N14, N28, R, S, and T

Getting Started

To use the 24-Channel High-Speed Thermocouple Compensated FET Multiplexer for your application, determine what external devices are to be connected to the accessory, configure the accessory for the type of measurement to be made, connect the external devices to the terminal module, and program the unit for your application.

Selecting Devices

The first step is to determine what devices you wish to connect to the 24-Channel FET MUX/TC. The accessory can switch AC or DC inputs of up to ± 10.24 volts peak. Since each of the 24 inputs can be configured independently, it is possible to connect 24 different devices to the accessory. When selecting a device, refer to Table 11-1 "24-Channel High-Speed FET MUX/TC Specifications" to ensure that the voltage and current requirements of your application are within the rated specifications of this accessory.

Configuring the Accessory

The second step is to configure the accessory for the devices selected. Refer to the "Configuring the 24-Channel High-Speed FET MUX/TC" section of this chapter for information concerning hardware configuration and wiring the terminal block for the measurement functions required.

WARNING

For SAFETY when wiring the Terminal Module, consider all channels to be at the highest voltage applied to any channel.

Programming the Accessory

The third step is to program the High-Speed Multiplexer for your application. Refer to the "Programming the 24-Channel High-Speed FET MUX/TC" section of this chapter to program the accessory for measuring voltage, current, resistance, or temperature.

Specifications

Table 11-1 lists specifications for the 24-Channel High Speed FET MUX/TC. This table contains five catagories: Input Characteristics, Channel Specifications, Operating Characteristics, AC Performance, and Thermocouple Characteristics.

Table 11-1. 24-Channel High-Speed FET MUX/TC Specifications

INPUT CHARACTERISTICS:

Maximum Signal Voltage, HIGH to LOW:

± 10.24V peak between any two input terminals

Input Voltage Protection Limit:

Channel Inputs: ± 12 volts peak maximum
Backplane (tree switches open): ± 42 peak max

CHANNEL SPECIFICATIONS:

Bias Currents: (channel at 0 volts with respect to chassis) Bias currents are sourced by the accessory from High and Low input terminals to chassis.

Into Transducer or Backplane:

	Channel Closed (0-28°C/0-55°C)	Channel Open (0-28°C/0-55°C)
HIGH or LOW	5 nA / 45 nA	2 nA / 11 nA

Into Backplane:

	Channel Open Tree Switch Closed[1] (0-28°C/0-55°C)	Maximum Differential Offset Voltage[2] (0-28°C/0-55°C)
HIGH or LOW	2 nA / 11 nA	20 uV / 230 uV

[1]All channels open, tree switch closed.
[2]Differential offset voltage between High and Low with a source resistance < 1 kohm.

Maximum Signal Current: ± 1 mA per channel

Closed Channel ON Resistance:

High or Low: ≈ 3.0 kΩ

Table 11-1. 24-Channel High-Speed FET MUX/TC Specifications Cont'd

Isolation (High to Low, High or Low to chassis):

Channel ON or OFF: $10^{7}\Omega$
Power OFF: Vin <= 10V 1 kΩ
Vin > 10V 200 Ω

OPERATING CHARACTERISTICS:

Maximum Switching Rate:

Using HP-44702 Voltmeter Accessory:
100,000 readings/second

Synchronization: Break-Before-Make in scan operation

AC PERFORMANCE:

Frequency Response relative to 1 kHz:
(50Ω source, 1 MΩ termination)

50 kHz: -0.6 dB
200 kHz: -3.0 dB

Capacitance with Channel On:

High to Low: 200 pF
High or Low to Chassis: 200 pF

Crosstalk, channel to channel:
(50Ω source, 1 MΩ termination)

10 kHz: -50 dB
100 kHz: -35 dB

Table 11-1. 24-Channel High-Speed FET MUX/TC Specifications Cont'd

THERMOCOUPLE CHARACTERISTICS:
Type B: Platinum/6% Rhodium - Platinum/30% Rhodium
Type E: Chromel - Constantan
Type J: Iron - Constantan
Type K: Chromel - Alumel
Type N14: Nicrosil - Nisil (14 awg)
Type N28: Nicrosil - Nisil (28 awg)
Type R: Platinum - Platinum/13% Rhodium
Type S: Platinum - Platinum/10% Rhodium
Type T: Copper - Constantan

Configuring the 24-Channel High-Speed FET MUX/TC

This section explains how to configure the High-Speed Mutiplexer. The section contains a block diagram description of the accessory, information on configuring the terminal module, and how to connect external wiring to the terminal module.

Refer to "Programming the 24-Channel High-Speed FET MUX/TC" section of this chapter for information concerning programming the accessory to measure voltage, current, resistance, and temperature.

WARNING

SHOCK HAZARD. Only qualified, service-trained personnel, who are aware of the hazards involved, should install, remove, or configure any accessory. If an accessory is to be removed or installed, turn off all power to the mainframe, extenders, accessories, and all external devices which are connected to the mainframe, extenders, or accessories.

WARNING

For SAFETY when wiring the Terminal Module, consider all channels to be at the highest voltage applied to any channel.

CAUTION

STATIC SENSITIVE. Use clean-handling techniques when handling the accessory. Do not install an accessory without the metal covers in place.

Block Diagram Description

The 24-Channel High-Speed FET MUX/TC assembly consists of the 24 channel FET switching module and a 24-Channel terminal module as shown in Figure 11-1. Inputs from external devices are connected to the terminal module which is connected to the switching module.

An isothermal connector block, in conjunction with a thermistor, is used to eliminate thermocouple measurement errors. The 5 kΩ thermistor is used to measure the temperature of the isothermal connector. The HP-3852 then uses a "software compensation" technique to compensate for the error generated by the terminal connections.

Figure 11-1. 24-Channel High-Speed FET MUX/TC Block Diagram

The FET MUX switching module is made up of 28 switches which are divided into two catagories; tree switches, and channel switches. Each of the 28 switches consists of Field Effect Transistor (FET) pairs, one each for HIGH and LOW input lines. The switch module has four tree switches divided in two types: Source Bus tree switches and Sense Bus tree switches. The tree switches determine the signal flow to and from the HP-3852 backplane or the high speed voltmeter interface bus. The tree switches also act to isolate the unused bank switches from the backplane and high speed interface bus.

NOTE

Only one measurement channel can be closed at a time on the 24-Channel FET MUX/TC. Closing a measurement channel will open any previously closed channel.

The FET MUX switch module has two isolation relays which allow the accessory to be isolated from the HP-3852 backplane. The isolation relays can be used to reduce leakage currents on the backplane during critical measurements or for using the backplane at voltages greater than the ± 10.24 volt peak limitation of the 24-Channel FET MUX/TC. The isolation relays automatically open when voltages greater than ± 12 volts peak are detected on the backplane or when the FET Multiplexer is connected to the HP-44702 High Speed Voltmeter Accessory. Table 11-2 shows the channel definitions for the 24-Channel FET MUX/TC accessory. Channels 0 through 23 control the channel switches, channel 90 controls the isolation relays, and channels 91 through 94 control the tree switches.

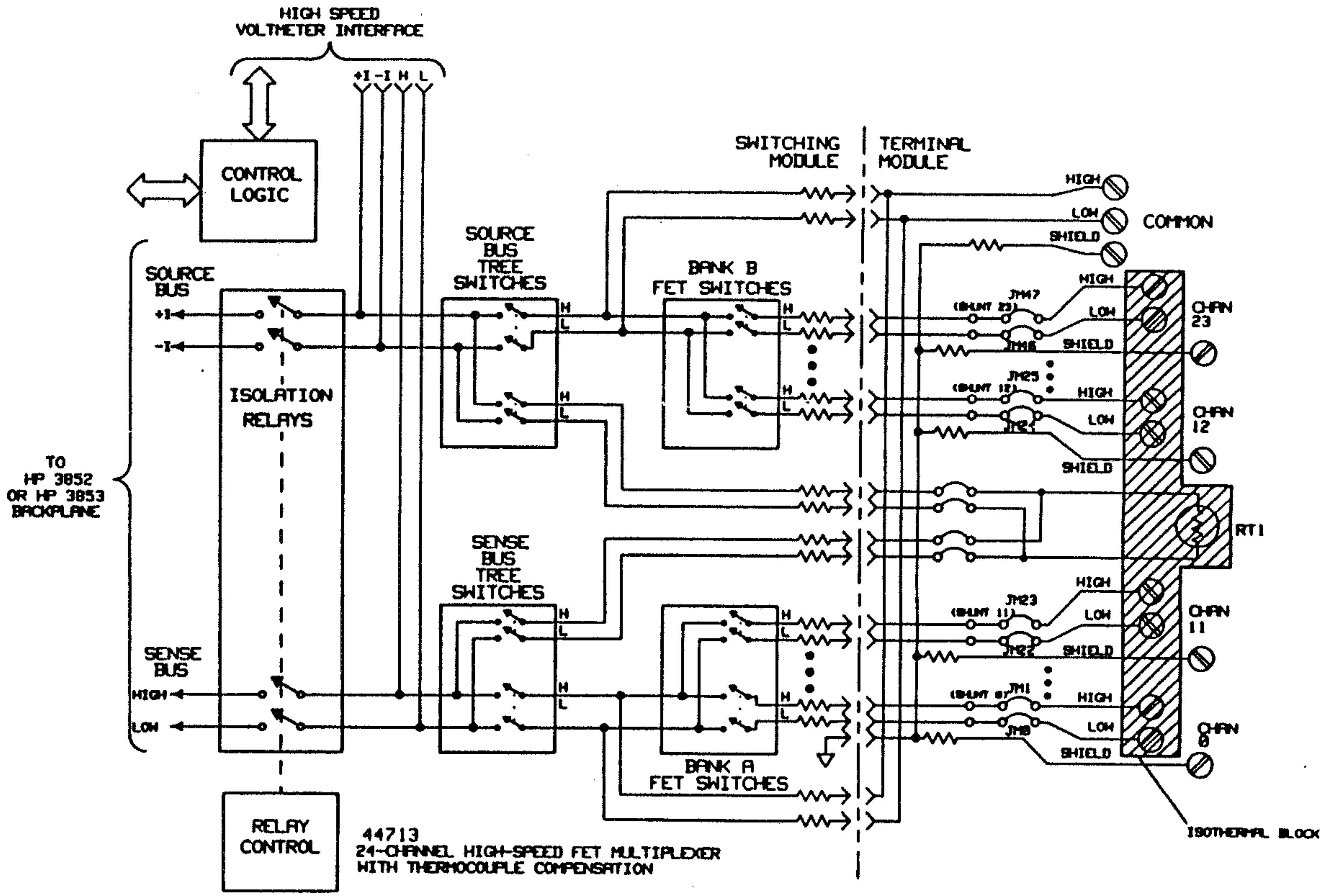


Figure 11-1. 24-Channel High-Speed FET MUX/TC Block Diagram

Table 11-2. 24-Channel FET MUX/TC Channel Definitions

Channel	Definitions
0 - 23	Channel Switches
90	Isolation Relays
91	Source Bus Tree Switch to all Channels
92	Sense Bus Tree Switch to all Channels
93	Source & Sense Bus Tree Switches to Channels
94	Source & Sense Bus Tree Switches to Thermistor

The COMMON terminals can be used to connect an external monitoring device to the accessory or be used for diagnostic procedures. As configured at the factory, each of the channel input lines and the COMMON output lines (High, Low, Shield) has a 100Ω series current limiting resistor.

Installing Low Pass Filters

Space is provided on the High-Speed FET MUX/TC terminal module for you to install a single-pole, low-pass, filter on each channel to condition the input signal. Figure 11-2 shows the normal channel configuration and the channel configuration with the low-pass filter installed on the terminal module.

Figure 11-2. Low-Pass Filter Channel Configuration

Figure 11-3 shows how to install the low-pass filter components on channel 11 of the terminal module. To install the components, remove series jumper SERIES JM 22 and install the resistor in its place. Install the capacitor in the SHUNT UC 11 solder pads as shown.

Figure 11-3. Installing Low-Pass Filters

Installing Attenuators

The solder pads provided on the terminal module are also used to install attenuator networks to reduce high level input signals to a usable level. Figure 11-4 shows the normal channel configuration and the channel configuration after installing the attenuator network.

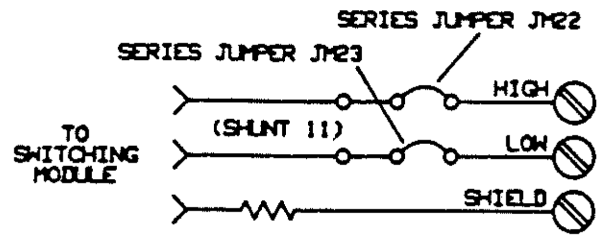
Figure 11-4. Channel Configuration with Attenuator

Figure 11-5 shows how to install attenuator components to Channel 0 on the terminal module. To install the components, remove jumper SERIES JM 0 and install resistor R1 in its place. Install resistor R2 in the SHUNT UC 0 position as shown.

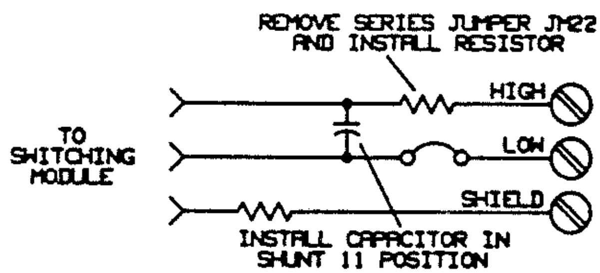
Figure 11-5. Installing Attenuators

Connecting Field Wiring

The next step is to connect wiring from the instrumentation used in your application to the appropriate terminals on the terminal module. The following section contains examples of how to connect the wiring for making voltage, current, resistance and temperature measurements.



CHANNEL 11 - NORMAL CONFIGURATION



CHANNEL 11 - LOW PASS FILTER CONFIGURATION

3852P11_2

Figure 11-2. Low-Pass Filter Channel Configuration

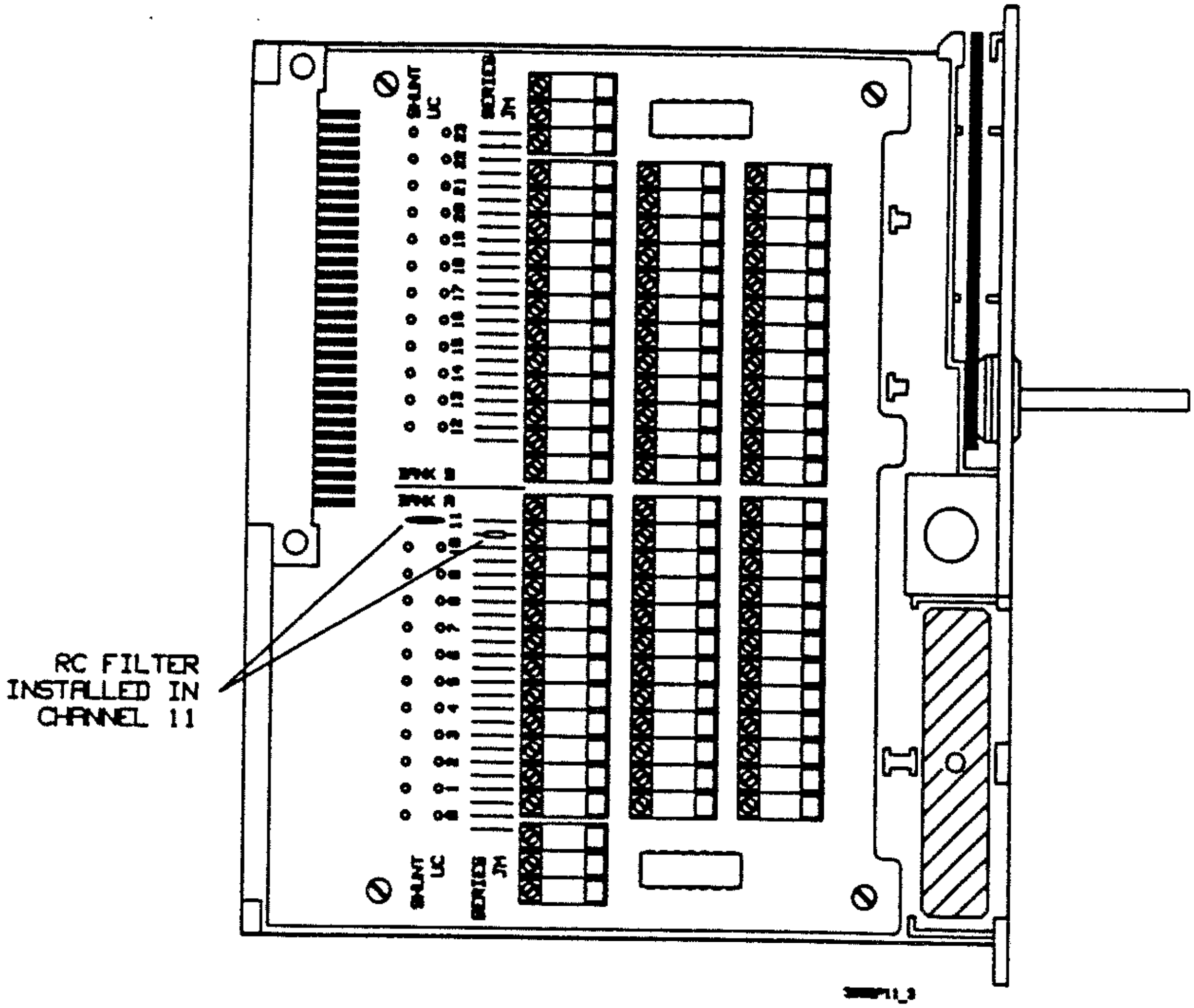


Figure 11-3. Installing Low-Pass Filter

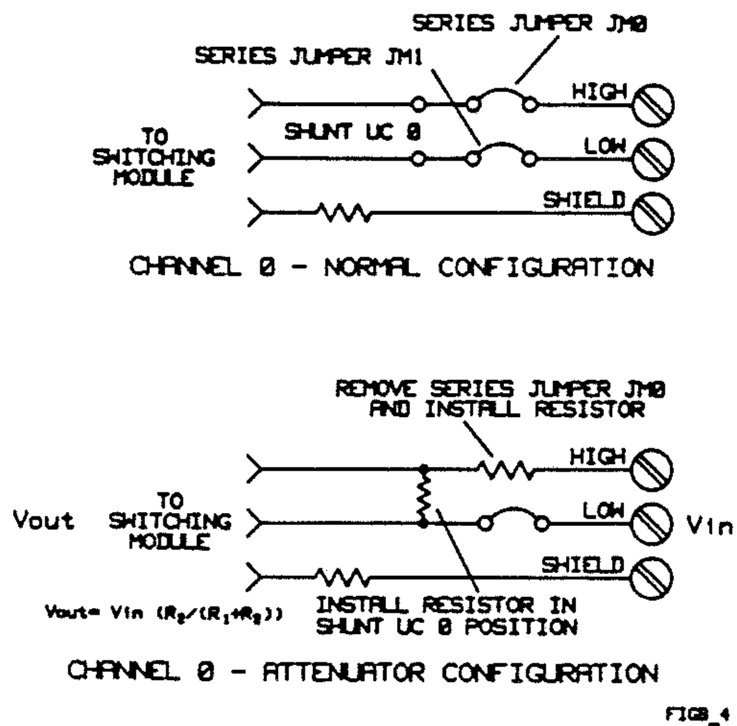


Figure 11-4. Channel Configuration with Attenuator

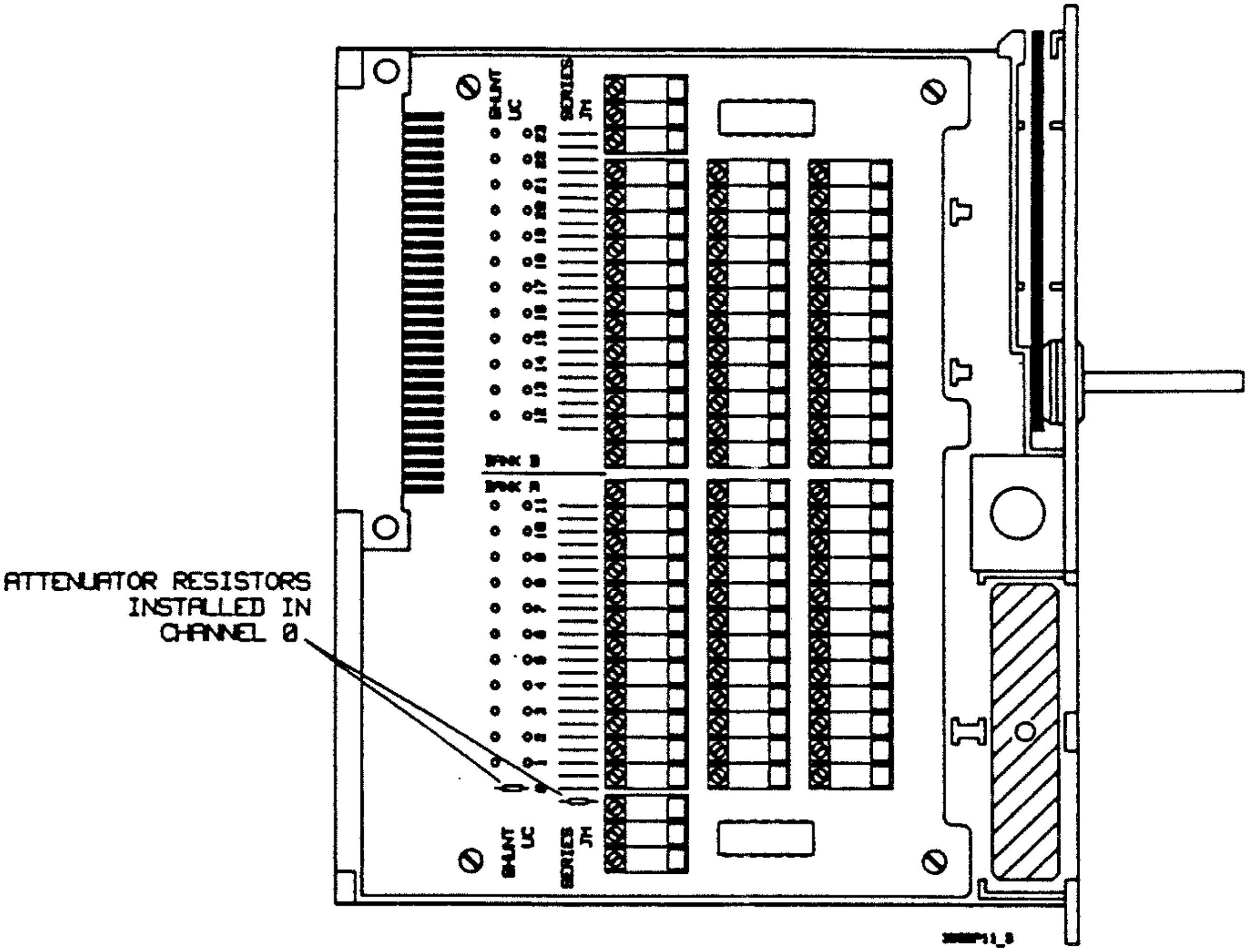


Figure 11-5. Installing Attenuators

WARNING

2 *For SAFETY, consider all channels to be at the highest voltage applied to any channel.*

Figure 11-6 shows the terminal module with the cover removed. Each of the 24 channels has a HIGH, LOW, and SHIELD terminal. Terminals 0 through 11 in BANK A are channels 0 through 11. Terminals 0 through 11 in BANK B are channels 12 through 23.

Figure 11-6. 24-Channel High-Speed FET MUX/TC Terminal Module

When connecting wiring to the terminal module, route the wires through the strain relief clamp and tighten the clamp screw to reduce the chance of wires being pulled out of the terminal connectors. If the clamp screw is loosened far enough, the strain relief clamp can be rotated to make wire routing easier. When you have completed wiring the terminal module, replace the protective cover.

Connections For Voltage Measurements

The 24-Channel FET MUX/TC can switch up to 24 AC or DC voltage inputs. Both HIGH and LOW input lines are switched on all channels. A SHIELD terminal is provided for connecting shielded cables. Shielded cables reduce electrical noise when making low-level voltage measurements.

CAUTION

The maximum non-destructive voltage which can be applied to the FET switching assembly is ± 10.24 volts peak. Refer to Table 11-1 for the 24-channel High-Speed FET MUX/TC specifications.

Example: Connecting Voltage Sources to the Terminal Module

A voltage source is to be connected to Channel 0 (BANK A, terminal 0) on the terminal module as shown in Figure 11-7. Connect the high (+) lead of the voltage source to the HIGH terminal on the terminal module. Connect the low (-) lead of the voltage source to the LOW terminal on the terminal module. If you are using a shielded cable from the voltage source, connect the shield to the SHIELD terminal on the terminal module. A shielded cable is used to reduce electrical noise in the measurement.

Figure 11-7. Connecting Voltage Sources to the Terminal Module

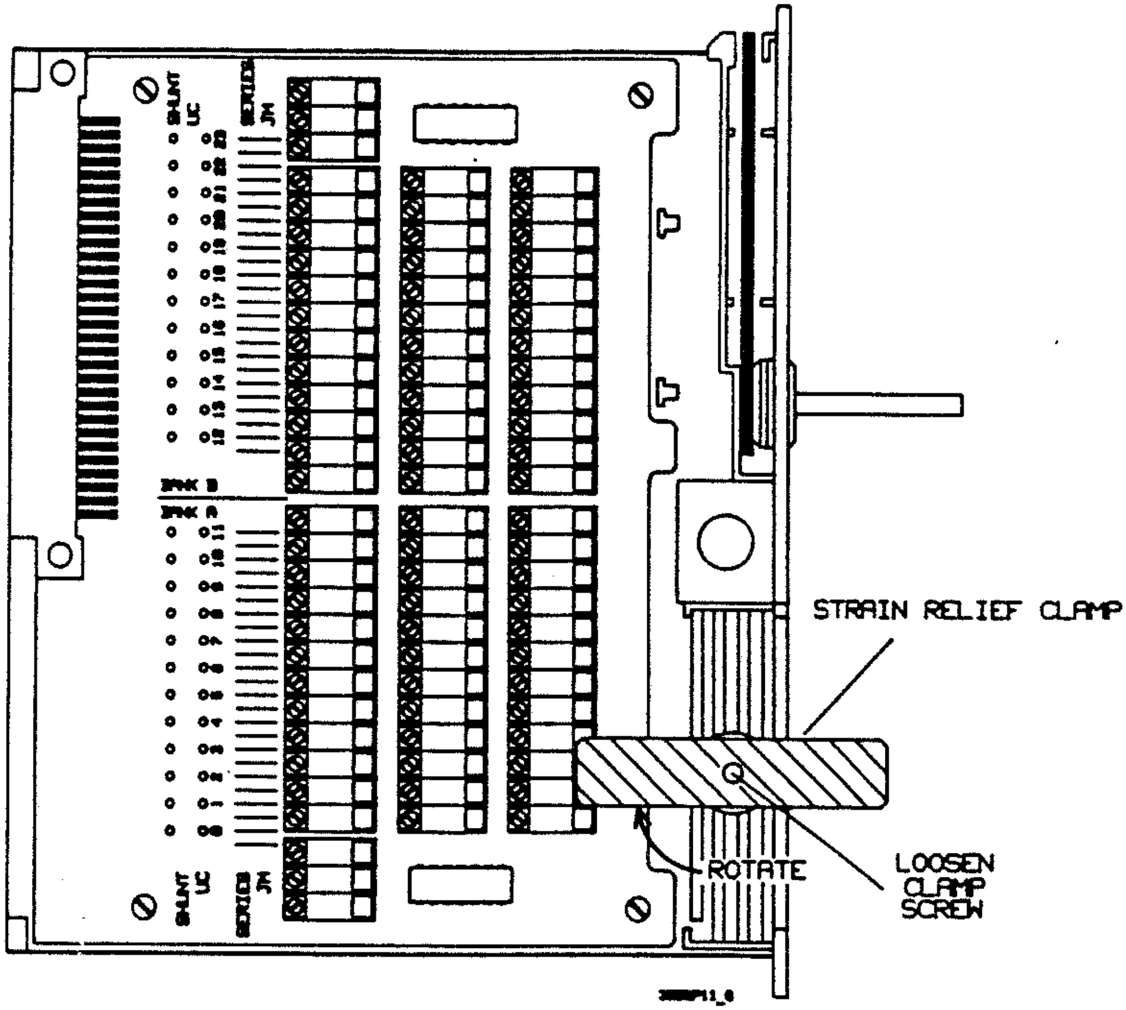


Figure 11-6. 24-Channel High-Speed FET MUX/TC Terminal Module

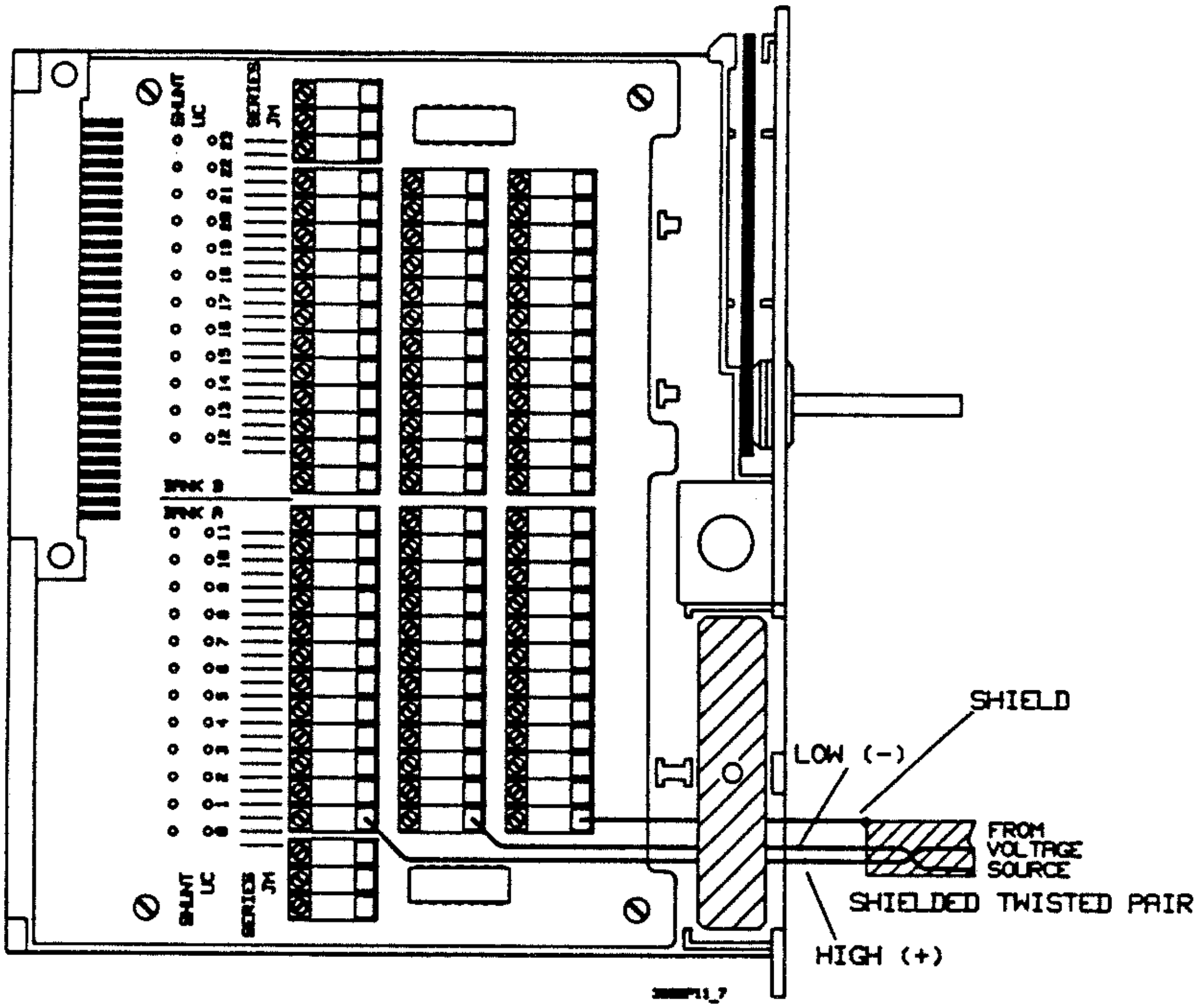


Figure 11-7. Connecting Voltage Sources to the Terminal Module

Connections For Current Measurements

The High-Speed FET MUX/TC uses a current sensing technique to measure current. Current sensing is a method of determining current by measuring the voltage drop across a current sensing resistor which you install on the terminal module. The Multiplexer Accessory can be used to switch up to 24 AC or DC current inputs. Figure 11-8 shows the normal channel configuration and the configuration for making current measurements. Figure 11-9 shows how to install the current sensing resistors on the terminal module.

NOTE

Current sensing is not recommended when the 24-Channel FET MUX/TC will also be used to measure temperature. Heating produced by the shunt resistors can affect the accuracy of the temperature measurements.

The series jumpers (SERIES JM) must be installed on the terminal module for each channel being used to measure current.

Figure 11-8. Current Sensing Configuration.

Figure 11-9. Installing Current Shunt Resistors

Example: Installing Shunt Resistors for Current Measurements

A 250Ω shunt resistor is installed in the Channel 0 shunt position on the terminal module as shown in Figure 11-9. Connect the high (+) lead of the current source to the HIGH terminal on the terminal module. Connect the low (-) lead of the current source to the LOW terminal of the terminal module. If a shielded cable is used, connect the shield wire to the SHIELD terminal of the terminal module.

Connections For Resistance Measurements

The 24-Channel High-Speed FET MUX/TC can be configured to make 2-wire ohms measurements only. This function should only be used in applications where test lead resistance and resistance of the FET switches will not significantly affect the accuracy of the measurement. Up to twenty four 2-wire inputs can be switched by the assembly.

NOTE

The 2-wire ohms function is normally used for measuring high resistances where the resistance of the test leads and FET switches has a minimal effect on the measurement.

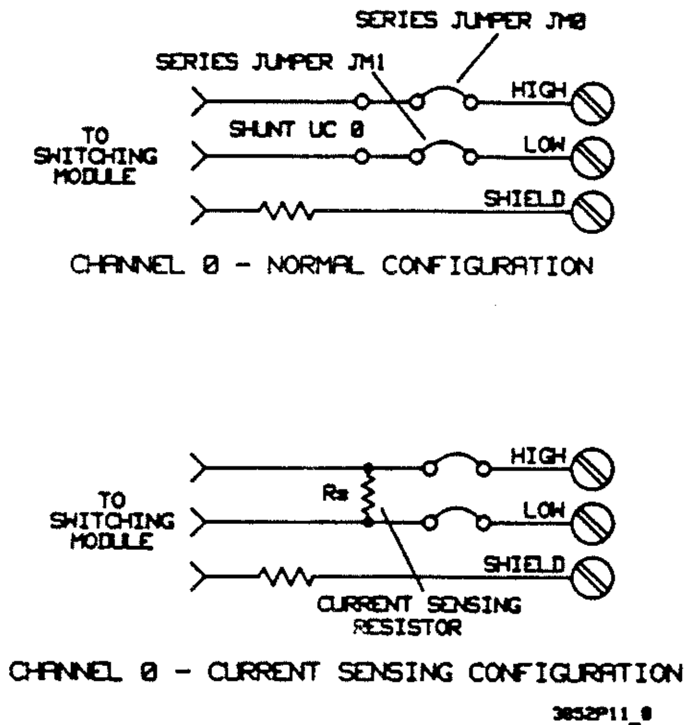


Figure 11-8. Current Sensing Configuration

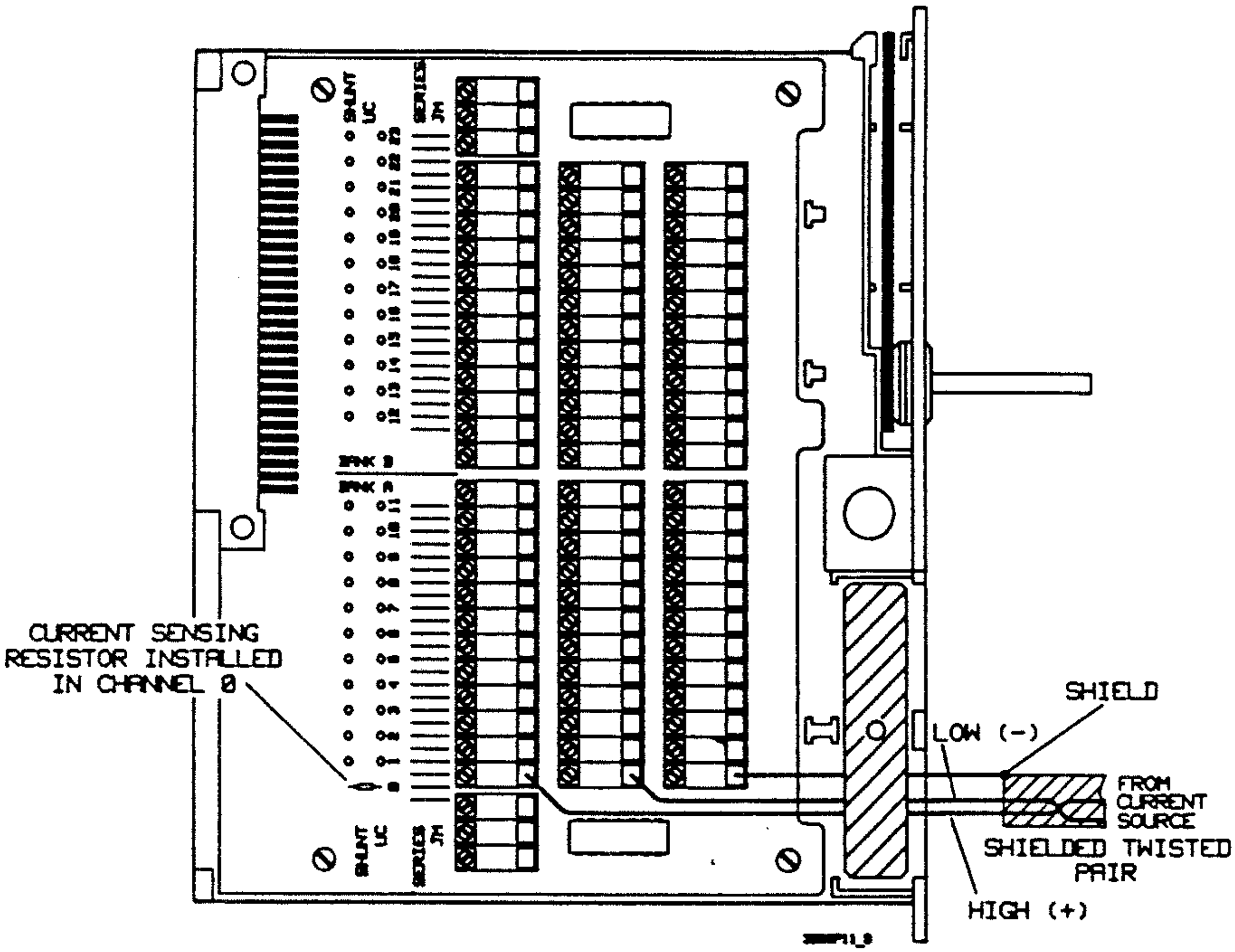


Figure 11-9. Installing Current Shunt Resistors

Example: Connecting Resistors for 2-Wire Ohms Measurements

Figure 11-10 shows the connection of a resistor (R0) to Channel 0 (BANK A, terminal 0) of the terminal module. Connect one lead of the resistor to the HIGH terminal of channel 0 and the other lead to the LOW terminal of channel 0. If a shielded cable is being used to connect the resistor, connect the shield to the channel 0 SHIELD terminal on the terminal module.

Figure 11-10. Connecting Resistors for 2-Wire Ohms Measurements

Connections For Temperature Measurements

The following paragraphs explain how to connect the 24-Channel High-Speed FET MUX/TC to make temperature measurements using thermocouples.

Thermocouples provide a simple, durable, inexpensive, and relatively accurate temperature sensor for a wide variety of applications and enviromental conditions. The thermocouple is a junction of two dissimilar metals which produce a voltage when the junction undergoes a temperature change.

Up to 24 thermocouple measurements can be made using a single High-Speed FET MUX/TC accessory. The HP-3852 temperature conversion routine supports B, E, J, K, N14, N28, R, S, and T type thermocouples.

NOTE

Since all channnels on the 24-Channel FET MUX/TC can be independently configured and software compensated, any combination of thermocouple types can be connected to the terminal module.

Table 11-3. Guidelines for Connecting Thermocouples

1. Use the largest wire possible which will not shunt heat away from the thermocouple area.
2. Use thermocouple wire which is rated for your application.
3. Avoid mechanical stress and vibration that might strain the wires.
4. For long wire runs, use a twisted shielded pair and connect the shield to the SHIELD terminal on the terminal module.
5. Avoid extreme temperature gradients.
6. In hostile enviroments, use proper sheathing material to reduce adverse effects on the thermocouple wires.

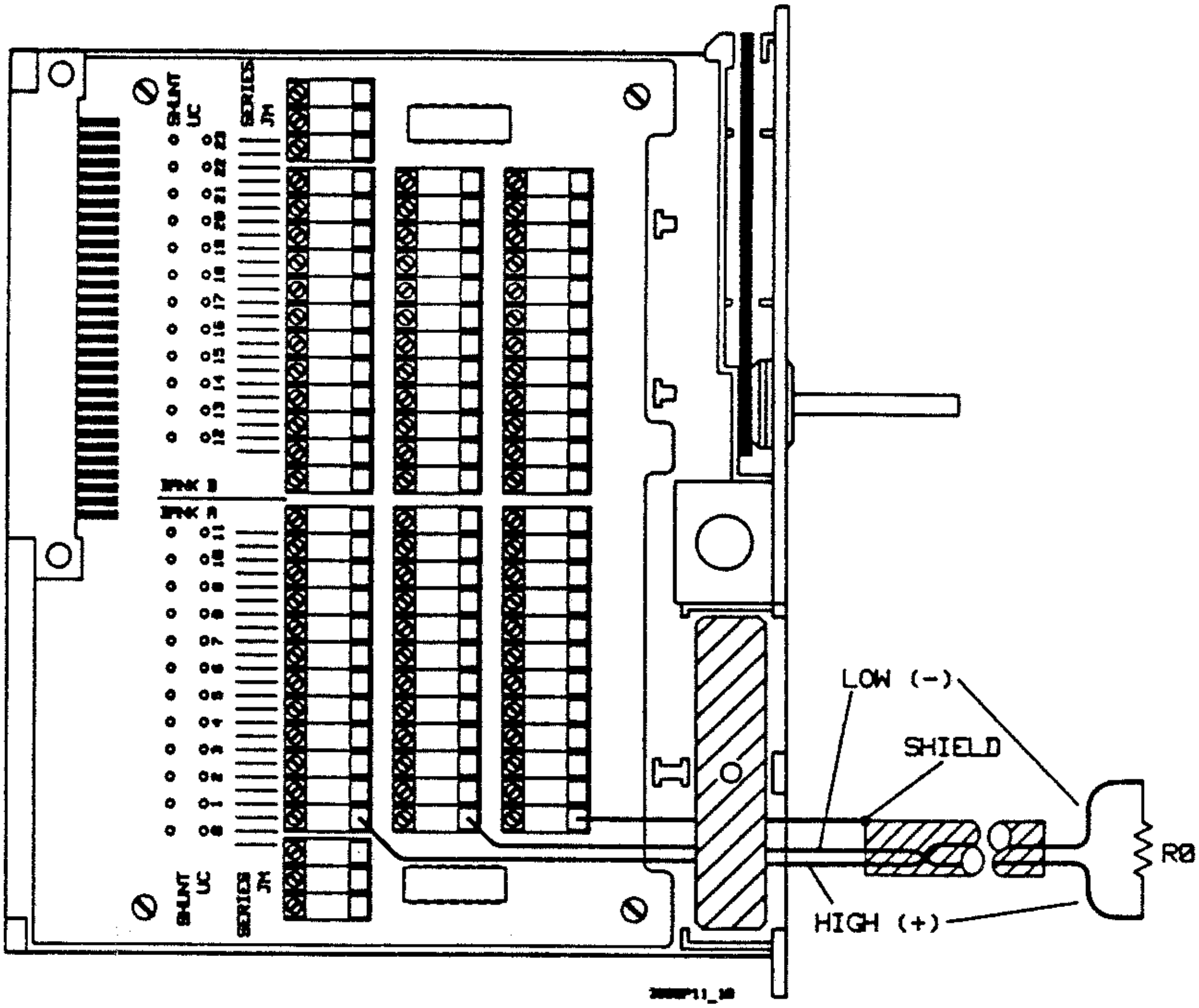


Figure 11-10. Connecting Resistors for 2-Wire Ohms Measurements

Example: Connecting Thermocouples for Temperature Measurements

Figure 11-11 shows a thermocouple (TC_0) connected to channel 0 (BANK A, terminal 0) of the terminal module. Connect the negative lead to the LOW terminal of the selected channel. Connect the positive lead to the HIGH terminal of the selected channel. If a shielded cable is used, connect the shield to the SHIELD terminal of the channel selected.

Figure 11-11. Connecting Thermocouples for Temperature Measurements

Installation/ Checkout

The following paragraphs explain how to check accessory identity, how to verify wiring connections, and how to read channel states of the 24-Channel High-Speed FET MUX/TC.

Checking the Accessory Identity

After you have connected the wiring from your application to the terminal module, reconnect the terminal module to the 24-channel switching module and install the assembled unit in the desired slot of the HP-3852 mainframe or HP-3853 extender. (Refer to the HP-3852 Mainframe Configuration and Programming Manual for installation instructions.)

To check the identity of the 24-Channel High-Speed FET MUX/TC, use the ID? (Identity?) command. The ID? command provides a way to determine, from the HP-3852 front panel or from a controller, what accessory is installed in a particular slot. The ID? command will return " 44713A" for the 24-Channel High-Speed FET MUX/TC assembly if both the switching module and terminal module were installed when the HP-3852 was "powered up". If the terminal module is not attached to the switching module at power-on, the ID? command will return " 447XXX". If the ID? command is used to interrogate a slot which does not contain an accessory, the return will be " 000000".

The following is an example program which shows how to use the ID? command to check the identity of a 24-Channel FET MUX/TC which is installed in slot 4 of the HP-3852 mainframe.

Example: Reading the Accessory Identity

```
10  !
20  !Use the ID? command to read the identity of the
30  !24-Channel FET MUX/TC installed in slot 4 of the
40  !3852 mainframe.
50  !
60  OUTPUT 709; "ID? 400"
70  ENTER 709; Identity$
80  PRINT Identity$
90  END
```

Typical output (with the terminal module installed) is:

```
44713A
```

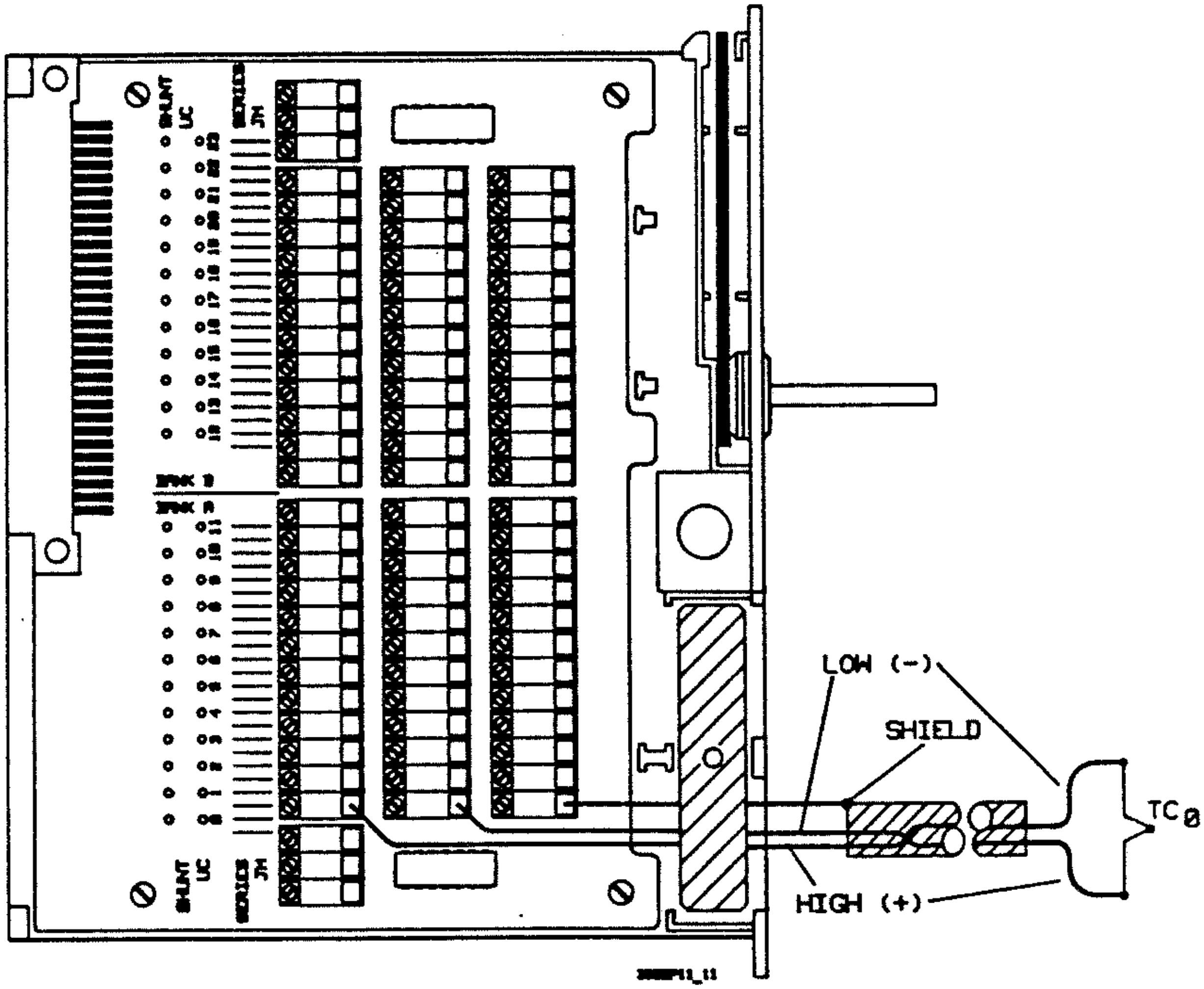


Figure 11-11. Connecting Thermocouples for Temperature Measurements

NOTE

If the 24-Channel FET MUX does not return the proper ID number, be sure that you have addressed the correct slot and that the terminal module is installed. If you have addressed the correct slot and the terminal module is installed, but the proper ID number is not returned, refer to the HP-3852A Assembly Level Service Manual for service procedures.

Verifying Wiring Connections

To verify that your wiring has been properly connected, send the MONMEAS (Monitor/Measure) command from the HP-3852 front panel key board or from a controller. This command verifies DC and AC voltage connections, 2-wire resistance connections, and thermocouple connections.

The following program statements show how to use the MONMEAS command to verify DC voltage connections on channels 0 through 23 with a controller. The CONF command configures the voltmeter accessory for DC voltage measurements. In this case, the 24-Channel FET MUX/TC is in slot 3 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  OUTPUT 709; "USE 0"
20  OUTPUT 709; "CONF DCV"
30  OUTPUT 709; "MONMEAS DCV,300-323,USE 0"
40  END
```

The 24 channels will be scanned and measured one at a time. Press the SADV key on the HP-3852 front panel to advance to the next channel. When the scan has advanced beyond the last channel (channel 23), scanning will stop and the last measurement will remain displayed.

Reading Channel State

Use the CLOSE? command to determine the state of each channel on the 24-Channel High-Speed FET MUX/TC accessory. The CLOSE? command returns one of five numbers for each channel interrogated. The number returned indicates whether a channel is open or closed and which bus the channel is connected to. Table 11-4 shows the channel state for each value that can be returned using the CLOSE? command.

Table 11-4. Values returned by the CLOSE? Command

* Value Returned	Channel State
0	Channel Open
1	Channel Closed - not connected to a Bus
2	Channel Closed - connected to Sense Bus
3	Channel Closed - connected to Source Bus
4	Channel Closed - connected to Both Busses

** Only 2, 3 or 4 will be returned for channels 0 through 23.*

Example: Reading Channel State

The following example program shows how to use the CLOSE? command to read the channel state of channels 0 through 4 on the 24-Channel FET MUX/TC. The RST command used in this program resets the accessory to its power-on state where all channels and isolation relays are open. The CLOSE command (line 30) closes channel 3, the Sense Bus Tree Switch (channel 92) and the isolation relays (channel 90). The OPEN command (line 70) is used to open all channels and disconnect them from the HP-3852 backplane after the measurements have been completed. For this example, the 24-Channel FET MUX/TC is installed in slot 1 of the mainframe.

```
10 OUTPUT 709; "RST 100"
20 INTEGER State(1:5)
30 OUTPUT 709; "CLOSE 103,192,190"
40 OUTPUT 709; "CLOSE? 100-104"
50 ENTER 709; State(*)
60 PRINT State(*)
70 OUTPUT 709; "OPEN 103,192,190"
80 END
```

Typical Output (channel 3 closed - connected to the Sense Bus):

```
0 0 0 2 0
```

Programming the 24-Channel FET MUX/TC

The 24-Channel High-Speed Thermocouple Compensated FET Multiplexer has four primary functions: voltage measurements, current measurements, resistance measurements, and temperature measurements. Its main function, however, is measuring temperature using thermocouples.

This section contains examples which show how to program the 24-Channel FET MUX/TC to perform each function. Included is a description of each function, applicable commands for the function, and programming examples. Each example includes a sample program and (where applicable) typical outputs for the assumed conditions.

NOTE

The example programs in this section use "709" as the HP-IB address for the HP-3852. Specific slot and channel numbers are used. Program syntax and data return formats apply to the HP-200 Series controllers. Modify slot and channel addresses as required for your particular configuration.

Command Summary

Table 11-5 is an alphabetical listing of commands which apply to the 24-Channel High-Speed FET MUX/TC accessory. Refer to the HP-3852 Command Reference Manual for a complete description of these commands.

Table 11-5. Commands for the 24-Channel High-Speed FET MUX/TC

CLOSE *ch list*

Closes a single FET multiplexer channel or a list of channels specified by *ch list* (channel list). This command is intended for individual switch control in special signal-routing applications. It is not the easiest way to do routine measurements since the tree switches are not automatically configured as in the scanning commands.

CLOSE? *ch list* [**,INTO** *name*] or [,*fmt*]

Queries the state of channels specified by *ch list* (channel list).

CONFMEAS *function, ch list* [**,USE** *ch*] [**,INTO** *name*] or [,*fmt*]

Configures the voltmeter accessory and scans/measures a function on the channels specified by *ch list* (channel list). This command automatically configures the tree switches for the measurement.

ID? [*slot*]

Reads the identity of the accessory in the slot specified by *slot*.

MEAS *function, ch list* [**,USE** *ch*] [**,INTO** *name*] or [,*fmt*]

Scans and measures a function on the channels specified by *ch list*. Automatically configures the tree switches for the measurement.

MONMEAS *function, ch list* [**,USE** *ch*]

Monitors and measures a function on the channels specified by *ch list*. Automatically configures the tree switches for the measurement. This command is useful in verifying wiring connections made on the terminal module.

OPEN *ch list*

Opens a single channel or a group of channels as specified by *ch list*.

RST [*slot*]

Resets the accessory in the slot specified by *slot* to its power-on state.

Making Voltage Measurements

One of the functions of the 24-Channel High-Speed FET MUX/TC is to make voltage measurements. The following paragraphs explain how to program the 24-Channel FET MUX/TC to make AC and DC voltage measurements.

DC Voltage Measurements

In the DC voltage measurement function, the High-Speed FET MUX/TC can switch up to 24 DC voltages for measurement by the HP-3852 voltmeter accessories or by external voltmeters.

Example: Measuring DC Voltage Sources

Suppose that you wish to measure the outputs from 24 DC voltage sources using the 24-Channel FET MUX/TC. (Refer to Figure 11-7 for wiring DC voltage sources to the 24-Channel FET MUX/TC terminal module).

The following program example uses the CONFMEAS command to measure 24 DC voltage sources connected to channels 0 through 23 on the 24-Channel FET MUX/TC. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and scans/measures the 24 channels once.

For this example, the 24-Channel High-Speed FET MUX/TC is installed in slot 1 of the mainframe and the voltmeter accessory used for the measurement is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure 24 DC voltages
30  !using the 24-Channel FET MUX/TC in slot 1 of the
40  !mainframe. Use the voltmeter accessory in slot
50  !0 of the mainframe.
60  !
70  REAL Volts(1:24)
80  OUTPUT 709; "CONFMEAS DCV,100-123,USE 0"
90  ENTER 709; Volts(*)
100 PRINT USING "K,/";Volts(*)
110 END
```

Typical DC voltage values for the assumed conditions:

```
4.303000  <------  Channel 0
4.333500
1.204400
4.602300
    .
    .
    .
4.595000
2.345600
4.203000
3.897400  <------  Channel 23
```

Example: Measuring a DC Voltage Source using the CLOSE Command

Suppose that you wish to measure a single voltage source using the 24-Channel FET MUX/TC. This can be accomplished by using the CLOSE command. (Refer to Figure 11-7 for wiring DC voltage sources to the 24-Channel FET MUX/TC terminal module).

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest method of doing routine measurements since the tree switches are not automatically configured as with the scanning commands. Channels are not opened and closed in break-before-make sequence with the CLOSE command.

In this program example, CLOSE is used to close Channel 0, the Sense Bus Tree switch (Channel 92), and the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the measurement result to the controller. The OPEN command is used to open the channel, tree switches and isolation relays after the measurement has been taken.

For this example, the 24-Channel High-Speed FET MUX/TC is installed in slot 1 of the mainframe and the voltmeter accessory is installed in slot 0.

```
 10  !
 20  !Use the CLOSE command to make a DC voltage measurement
 30  !of the voltage source connected to Channel 0 on the
 40  !24-channel FET MUX/TC installed in slot 1 of the
 50  !mainframe. Use the voltmeter in slot 0.
 70  !
 80  OUTPUT 709; "USE 0"
 90  OUTPUT 709; "CLOSE 100,192,190"
100  OUTPUT 709; "FUNC DCV"
110  OUTPUT 709; "TRIG SGL"
120  OUTPUT 709; "CHREAD 0"
130  ENTER 709; Volts
140  PRINT Volts
150  OUTPUT 709; "OPEN 100,192,190"
160  END
```

Typical DC voltage value for assumed conditions:

```
4.949400
```

AC Voltage Measurements

In the AC voltage measurement function, the 24-Channel High-Speed FET MUX/TC can switch up to 24 AC voltages for measurement by the HP-3852 voltmeter accessories or by external voltmeters.

Example: Measuring AC Voltage Sources

Suppose that you wish to measure the outputs of 24 AC voltage sources using the 24-Channel FET MUX/TC. (Refer to Figure 11-7 for wiring AC voltage sources to the 24-Channel FET MUX/TC terminal module).

The following program example uses the CONFMEAS command to measure 24 AC voltage sources connected to channels 0 through 23 on the 24-Channel FET MUX/TC. The CONFMEAS command configures the voltmeter accessory for AC voltage measurements and scans/measures the 24 channels once.

For this example, the 24-Channel High-Speed FET MUX/TC is installed in slot 3 of the mainframe and the HP-44701 Integrating Voltmeter Accessory is installed in slot 0 of the mainframe.

```
10  !
20  !Use CONFMEAS command to measure 24 AC voltages
30  !using the 24-channel FET MUX/TC in slot 3 of the
40  !mainframe. Use the Integrating Voltmeter
50  !Accessory in slot 0 of the mainframe.
60  !
70  REAL Volts(1:24)
80  OUTPUT 709; "CONFMEAS ACV,300-323,USE 0"
90  ENTER 709; Volts(*)
100 PRINT USING "K,/";Volts(*)
110 END
```

Typical AC voltage values for the assumed conditions:

```
4.303000  <------  Channel 0
4.333500
1.204400
4.602300
   .
   .
   .
4.595000
2.345600
4.203000
3.897400  <------  Channel 23
```

Making Current Measurements

The High-Speed FET MUX/TC uses a current sensing technique to make current measurements. Current sensing is a method to determine the current through a shunt resistor which you install on the terminal module. The following paragraphs describe how to program the accessory to make DC and AC current measurements.

NOTE

Current sensing is not recommended when the 24-Channel FET MUX/TC will also be used to measure temperature. Heating produced by the shunt resistors can affect the accuracy of the temperature measurements.

DC Current Measurements

In the DC Current measurement function, the 24-channel FET MUX/TC accessory can switch up to 24 current inputs for measurement by the HP-3852 voltmeter accessory or external voltmeters.

Example: Making a DC Current Measurement

Suppose that you want to make a DC current measurement using a 250Ω shunt resistor installed on the terminal module. (Refer to Figure 11-9 for information on installing shunt resistors on the terminal module).

The following program example uses the CONFMEAS command to scan and measure the voltage drop across the 250Ω shunt resistor installed in channel 0 of the 24-channel FET MUX/TC. The CONFMEAS command configures the voltmeter accessory for DC voltage measurements and scans and measures the channel once. The voltage value is then returned to the controller which converts the voltage measurement to a DC current value.

For this example, the 24-Channel High-Speed FET MUX/TC is installed in slot 2 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure the voltage
30  !drop across a 250 Ohm shunt resistor and calculate
40  !the DC current applied to channel 0. Use the
50  !24-channel FET MUX/TC installed in slot 2 and the
60  !voltmeter accessory installed in slot 0.
70  !
80  OUTPUT 709; "CONFMEAS DCV,200,USE 0"
90  ENTER 709; Volts
100 !
110 !Current = Voltage/Shunt Resistance
120 !
130 Current = Volts/250
140 Print Current
150 END
```

Typical DC current value (in DC amps) for the assumed conditions:

```
.030344
```

AC Current Measurements

In the AC Current measurement function, the 24-Channel FET MUX/TC accessory can switch up to 24 AC current inputs for measurement by the HP-3852 voltmeter accessories or external voltmeters.

Example: Making an AC Current Measurement

Suppose that you want to make an AC current measurement using a 250Ω shunt resistor installed on the terminal module. (Refer to Figure 11-9 for information on installing shunt resistors on the terminal module).

The following program example uses the CONFMEAS command to scan and measure the voltage drop across the 250Ω shunt resistor installed in channel 0 of the 24-Channel FET MUX/TC. The CONFMEAS command configures the voltmeter accessory for AC voltage measurements and scans and measures the channel once. The voltage value is then returned to the controller which converts the measurement to an AC current value.

For this example, the 24-Channel FET MUX/TC is installed in slot 1 of the mainframe and the voltmeter accessory is installed in slot 0.

```
 10  !
 20  !Use the CONFMEAS command to measure the voltage
 30  !drop across a 250 Ohm shunt resistor and calculate
 40  !the AC current applied to channel 0. Use the
 50  !24-channel FET MUX/TC installed in slot 1 and the
 60  !voltmeter accessory installed in slot 0.
 70  !
 80  OUTPUT 709; "CONFMEAS ACV,100,USE 0"
 90  ENTER 709; Volts
100  !
110  !Current = Voltage/Shunt Resistance
120  !
130  Current = Volts/250
140  Print Current
150  END
```

Typical AC current value (in AC amps) for the assumed conditions:

```
.034210
```

Making Resistance Measurements

The 24-Channel High-Speed FET MUX/TC can be configured to measure resistance using the 2-Wire Ohms function. This function should only be used to test for continuity or for measuring high resistances because the resistance of the FET switches and the test-leads is in series with the measurement. The "on" resistance of the FET switches is ≈ 3.0 kΩ. Up to twenty-four 2-Wire resistance inputs can be switched by this accessory.

Example: Measuring Resistance using the 2-Wire Ohms Function

Suppose you wish to measure 24 resistors connected to the High-Speed FET MUX/TC using the 2-wire Ohms function. (Refer to Figure 11-10 for information on connecting resistors to the terminal module).

The following program example uses the CONFMEAS command to measure 24 resistors connected to channels 0 through 23 on the 24-Channel FET MUX/TC. The CONFMEAS command configures the voltmeter accessory for 2-wire resistance measurements and scans and measures each of the 24 channels once.

For this example, the 24-Channel High-Speed FET MUX/TC is installed in slot 4 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure 24 resistors
30  !using the 24-Channel High-Speed FET MUX/TC in slot 4
40  !of the mainframe. Use the voltmeter accessory
50  !installed in slot 0 of the mainframe.
60  !
70  REAL Ohms(1:24)
80  OUTPUT 709; "CONFMEAS OHM,400-423,USE 0"
90  ENTER 709; OHMS(*)
100 PRINT USING "K,/";Ohms(*)
110 END
```

Typical resistance values (in Ohms) for the assumed conditions:

```
1.026701+E6   <------ Channel 0
1.014304+E6
1.213264+E6
1.000432+E6
    .
    .
    .
0.997543+E6
1.234432+E6
1.203000+E6
1.389740+E6   <------ Channel 23
```

<u>Example: 2-Wire Resistance Measurements using the CLOSE Command</u>

Suppose that you wish to make a single 2-wire resistance measurement using the CLOSE command. Refer to Figure 11-10 for information on connecting resistors to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest method of doing routine measurements since the tree switches are not automatically configured as with the scanning commands. Channels are not opened and closed in break-before-make sequence with the CLOSE command.

In this program example, the CLOSE command is used to close Channel 0, close the Source and Sense Bus Tree Switches (Channel 93), and close the isolation relays (Channel 90). The FUNC command configures the voltmeter accessory for 4-Wire ohms measurements. (The 4-Wire Ohms function is converted to a 2-Wire Ohms function on the terminal module). The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance reading from the voltmeter accessory to the controller. The OPEN command opens the input channel, tree switches, and isolation relays after the measurement has been made.

For this example the 24-Channel High-Speed FET MUX/TC is installed in slot 4 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CLOSE command to make a 2-wire ohms measurement
30  !of a resistor connected to channel 0. Use the 24-Channel
40  !FET MUX/TC in slot 4 of the mainframe. Use the voltmeter
50  !accessory in slot 0 of the mainframe.
60  !
70  OUTPUT 709; "USE 0"
80  OUTPUT 709; "CLOSE 400,493,490"
90  OUTPUT 709; "FUNC OHMF"
100 OUTPUT 709; "TRIG SGL"
110 OUTPUT 709; "CHREAD 0"
120 ENTER 709; Ohms
130 PRINT Ohms
140 OUTPUT 709; "OPEN 400,493,490"
150 END
```

Typical resistance value (in Ohms) for the assumed conditions:

```
1.623570E+6
```

Making Temperature Measurements

The 24-Channel High-Speed FET MUX/TC accessory can be configured to make temperature measurements using thermocouples. Thermocouples provide a simple, durable, inexpensive, and relatively accurate temperature sensor for a wide variety of applications and enviromental conditions. The thermocouple is a junction of two dissimilar metals which produce a voltage when the junction undergoes a temperature change. The HP-3852 temperature conversion routine supports B, E, J, K, N14, N28, R, S, and T type thermocouples.

The HP-3852 determines the temperature of the thermocouple by measuring its voltage. This voltage is a function of the actual thermocouple temperature. When using the scanning commands (such as CONFMEAS) the HP-3852 automatically converts the voltage reading to an equivalent temperature in degrees centigrade.

A problem with using thermocouples is that a voltage is generated by the terminal module connection. This voltage is measured, along with the actual thermocouple voltage, creating an error. A software compensation technique is used to eliminate this error. The 3852 determines the temperature of the terminal module by measuring the resistance of a thermistor mounted on the terminal block and converting the resistance value to temperature. The temperature of the thermocouple is then determined by subtracting the error temperature from the total temperature reading.

NOTE

Since all channels on the 24-Channel FET MUX/TC can be independently configured and software compensated, any combination of thermocouple types can be connected to the terminal module.

Example: Measuring Temperature using Thermocouples

Suppose you wish to use thermocouples to measure the temperature of 24 solar collectors. Refer to Figure 11-11 for information on connecting thermocouples to the terminal module.

The following program example uses the CONFMEAS command to measure 24 J-type thermocouples connected to channels 0 through 23 on the 24-Channel FET MUX/TC accessory. The program scans and measures the 24 channels once and returns the results (in degrees centigrade) to the controller.

For this example, the 24-Channel FET MUX/TC is installed in slot 2 of the mainframe and the voltmeter accessory is installed in slot 0.

```
10  !
20  !Use the CONFMEAS command to measure 24 J-type
30  !thermocouples using the 24-Channel FET MUX/TC
40  !in slot 2 of the mainframe. Use the voltmeter
50  !accessory in slot 0 of the mainframe.
60  !
70  REAL Temp(1:24)
80  OUTPUT 709; "CONFMEAS TEMPJ, 200-223,USE 0"
90  ENTER 709; Temp(*)
100 PRINT USING "K,/";Temp(*)
110 END
```

Typical temperature values (in degrees C) for the assumed conditions:

```
24.542970  <------- Channel 0
24.542990
24.549390
    .
    .
    .
25.535300
25.558050
25.856450  <------- Channel 23
```

Example: Measuring Thermocouples using the CLOSE Command

Suppose you wish to measure a single thermocouple using the CLOSE command. Refer to Figure 11-11 for information on connecting thermocouples to the terminal module.

NOTE

The CLOSE command is a low-level command intended for individual switch control in special signal-routing applications. It is not the easiest method of doing routine measurements since the tree switches are not automatically configured as with the scanning commands. Channels are not opened and closed in break-before-make sequence with the CLOSE command.

This program example is divided into two sections. The first section measures the voltage of a T-type thermocouple. The second section measures the resistance of the thermistor mounted on the isothermal connector block.

In the first section of the program, the CLOSE command is used to close the channel 0 FET switches, the Sense Bus Tree switch (channel 92), and the isolation relays (channel 90). The FUNC command configures the voltmeter accessory for DC voltage measurements. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the DC voltage measurement from the voltmeter to the controller. The OPEN command is used to open the channels, tree switches, and isolation relays.

In the second section, the CLOSE command is used to connect the thermistor to the Sense and Source Bus (Channel 94) and to close the isolation relays (channel 90). The FUNC command configures the voltmeter accessory to make a 4-wire ohms measurement of the thermistor. The TRIG command triggers the voltmeter accessory to take a single measurement. The CHREAD command returns the resistance reading from the voltmeter to the controller. The OPEN command opens the input channels, the tree switches, and the isolation relays.

For this example, the 24-Channel High-Speed FET MUX/TC is installed in slot 1 of the mainframe and the voltmeter accessory is installed in slot 0.

```
 10  !
 20  !Use the CLOSE command to make a DC voltage measurement
 30  !of the thermocouple connected to channel 0 of the
 40  !24-Channel FET MUX/TC in slot 1 of the mainframe.
 50  !Use the voltmeter accessory in slot 0.
 60  !
 70  OUTPUT 709; "USE 0"
 80  OUTPUT 709; "CLOSE 100,192,190"
 90  OUTPUT 709; "FUNC DCV"
100  OUTPUT 709; "TRIG SGL"
110  OUTPUT 709; "CHREAD 0"
120  ENTER 709; Volts
130  OUTPUT 709; "OPEN 100,192"
140  PRINT Volts
```

```
150 !
160 !Use the CLOSE command to make a 4-wire ohms measurement
170 !of the thermistor on the isothermal connector block.
180 !
190 OUTPUT 709; "CLOSE 194"
200 OUTPUT 709; "FUNC OHMF"
210 OUTPUT 709; "TRIG SGL"
220 OUTPUT 709; "CHREAD 0"
230 ENTER 709; Ref
240 OUTPUT 709; "OPEN 194,190"
250 PRINT Ref
260 END
```

Typical voltage reading for the assumed conditions:

-.000822 *(This DC voltage is the combination of the thermocouple voltage and the voltage from the junction created by the terminal connections.)*

Typical resistance value for the 5 kΩ thermistor:

2664E+3 *(This resistance is equivalent to a temperature of 40° C or a) thermocouple voltage of .001611 volts.)*

To find the temperature at the thermocouple, add the voltage generated by the terminal connections to the total voltage reading and convert the remainder to temperature.

```
-.000822   (Total voltage reading)
 .001611   (Voltage generated by the terminal connections)
 .000789   (Voltage generated by the thermocouple)
```

The voltage generated by the thermocouple (.000789 volts) is equivalent to a temperature of 20°C. The HP-3852 determines the temperature of the terminal module by measuring the resistance of a thermistor mounted on the terminal block and converting the resistance value to voltage. The temperature of the thermocouple is then determined by adding the error voltage to the total voltage reading and converting the results to temperature.

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