HP E1476A
64-Channel, 3-Wire Multiplexer Module

User's Manual and SCP Programming Guide

Where to Find it - Online and Printed Information:

System installation (hardware/software)	VXIbus Configuration Guide* HP VIC (VXI installation software)*
Module configuration and wiring	This Manual
SCPI programming	This Manual
SCPI example programs	This Manual, Driver Disk
SCPI command reference	This Manual
Register-Based Programming	This Manual
VXI*plug&play* programming	VXI*plug&play* Online Help
VXI*plug&play* example programs	VXI*plug&play* Online Help
VXI*plug&play* function reference	VXI*plug&play* Online Help
Soft Front Panel information	VXI*plug&play* Online Help
VISA language information	HP VISA User's Guide
HP VEE programming information	HP VEE User's Manual

**Supplied with HP Command Modules , Embedded Controllers, and VXLink.*

Manual Part Number: E1476-90004
Printed in U.S.A. E0596

Contents

HP E1476A 64-Channel, 3-Wire Multiplexer Module

Edition 4

Certification

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (formerly National Bureau of Standards), to the extent allowed by that organization's calibration facility, and to the calibration facilities of other International Standards Organization members.

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HP E1476A Multiplexer User's Manual
Edition 4

Documentation History

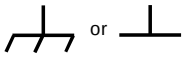
All Editions and Updates of this manual and their creation date are listed below. The first Edition of the manual is Edition 1. The Edition number increments by 1 whenever the manual is revised. Updates, which are issued between Editions, contain replacement pages to correct or add additional information to the current Edition of the manual. Whenever a new Edition is created, it will contain all of the Update information for the previous Edition. Each new Edition or Update also includes a revised copy of this documentation history page.

Edition 1 . . . . . .June 1994
Edition 2 . . . . . February 1996
Edition 3 . . . . . March 1996
Edition 4 . . . . . .May 1996

Safety Symbols

Instruction manual symbol affixed to product. Indicates that the user must refer to the manual for specific WARNING or CAUTION information to avoid personal injury or damage to the product.

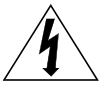
Indicates the field wiring terminal that must be connected to earth ground before operating the equipmentÅprotects against electrical shock in case of fault.



Frame or chassis ground terminal—typically connects to the equipment's metal frame.

Alternating current (AC)

Direct current (DC).



Indicates hazardous voltages.

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

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

WARNINGS

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. 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 product. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

Ground the equipment: For Safety Class 1 equipment (equipment having a protective earth terminal), an uninterruptible safety earth ground must be provided from the mains power source to the product input wiring terminals or supplied power cable.

DO NOT operate the product in an explosive atmosphere or in the presence of flammable gases or fumes.

For continued protection against fire, replace the line fuse(s) only with fuse(s) of the same voltage and current rating and type. DO NOT use repaired fuses or short-circuited fuse holders.

Keep away from live circuits: Operating personnel must not remove equipment covers or shields. Procedures involving the removal of covers or shields are for use by service-trained personnel only. Under certain conditions, dangerous voltages may exist even with the equipment switched off. To avoid dangerous electrical shock, DO NOT perform procedures involving cover or shield removal unless you are qualified to do so.

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

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

Declaration of Conformity

according to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name: Hewlett-Packard Company
Loveland Manufacturing Center

Manufacturer's Name: Hewlett-Packard Company
Loveland Manufacturing Center

declares, that the product:

Product Name: 64-Channel, 3-Wire Multiplexer

Model Number: HP E1476A

Product Options: All

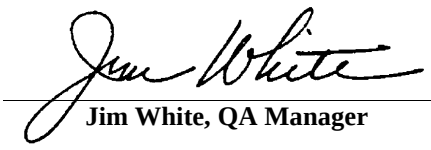
conforms to the following Product Specifications:

Safety: IEC 1010-1 (1990) Incl. Amend 1 (1992)/EN61010-1 (1993)
CSA C22.2 #1010.1 (1992)
UL 1244

EMC: CISPR 11:1990/EN55011 (1991): Group 1 Class A
IEC 801-2:1991/EN50082-1 (1992): 4kVCD, 8kVAD
IEC 801-3:1984/EN50082-1 (1992): 3 V/m
IEC 801-4:1988/EN50082-1 (1992): 1kV Power Line
.5kV Signal Lines

Supplementary Information: The product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC (inclusive 93/68/EEC) and carries the "CE" mark accordingly.

Tested in a typical configuration in an HP C-Size VXI mainframe.



May, 1996 **Jim White, QA Manager**

European contact: Your local Hewlett-Packard Sales and Service Office or Hewlett-Packard GmbH, Department HQ-TRE, Herrenberger Straße 130, D-71034 Böblingen, Germany (FAX +49-7031-14-3143)

Notes:

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	Disagree ◄				► Agree
• The documentation is well organized.	O	O	O	O	O
• Instructions are easy to understand.	O	O	O	O	O
• The documentation is clearly written.	O	O	O	O	O
• Examples are clear and useful.	O	O	O	O	O
• Illustrations are clear and helpful.	O	O	O	O	O
• The documentation meets my overall expectations.	O	O	O	O	O

Please write any comments or suggestions below–be specific.

Chapter 1
HP E1476A Multiplexer Setup

Using This Chapter

This chapter provides one page of general module information followed by WARNINGS and CAUTIONS, and the tasks you must perform to set up your Multiplexer. It also provides information to verify your installation was successful. Chapter contents are:

General Information

- The term “Multiplexer” is used in this manual to refer to the HP E1476A 64-Channel, 3-Wire Multiplexer Module.

- The HP E1476A is a VXIbus C-size register-based slave device. The Multiplexer can operate in a C-size VXIbus mainframe or a VMEbus mainframe.

- The Multiplexer “instrument” is the firmware running in the Upcoming Module (HP E1406A, for example). This firmware is the instrument driver providing SCPI (Standard Commands for Programmable Instruments) programming capability. The term “switchbox” is used to refer to an “instrument” made up of one or more switch modules.

- Programming the HP E1476A can either be through the command module using SCPI commands (see Chapter 3), through an embedded controller using Compiled SCPI (C-SCPI, see the HP catalog for details on this product) or Standard Instrument Control Language (SICL) or via direct register access (register-based programming - see Appendix B).

- Reed relays are used for each channel and tree relay.

- Maximum voltage is 120VDC/RMS or 170V peak.

- Maximum current is 35mA (non-inductive).

- Thermal offset is <4μV per channel (<2mV using maximum integration time with 10 samples averaged).

Warnings and Cautions

WARNING **SHOCK HAZARD. Only qualified, service-trained personnel who are aware of the hazards involved should install, configure, or remove the Multiplexer Module. Disconnect all power sources from the mainframe, the Terminal Modules, and installed modules before installing or removing a module.**

WARNING **When handling user wiring connected to the Terminal Module, consider the highest voltage present accessible on any terminal. Use only wire with an insulation rating greater than the highest voltage which will be present on the Terminal Module. Do not touch any circuit element connected to the Terminal Module if any other connector to the Terminal Module is energized to more than 30VACRMS or 60VDC.**

Caution **MAXIMUM VOLTAGE/CURRENT. Maximum allowable voltage per channel, terminal-to-terminal or terminal-to-chassis for the Multiplexer is 120Vdc or 120Vacrms (170Vac peak). Maximum current per channel is 35mA (non-inductive). Maximum transient voltage is 1300V peak. Exceeding any limit may damage the Multiplexer Module.**

Caution **WIRING THE TERMINAL MODULE. When wiring to the terminal connectors on the E1476A Terminal Module, be sure not to exceed a 5mm strip back of insulation to prevent the possibility of shorting to other wiring on adjacent terminals.**

Caution **STATIC ELECTRICITY. Static electricity is a major cause of component failure. To prevent damage to the electrical components in the Multiplexer, observe anti-static techniques whenever removing, configuring, and installing a module. The Multiplexer is susceptible to static discharges. Do not install the Multiplexer Module without its metal shield attached.**

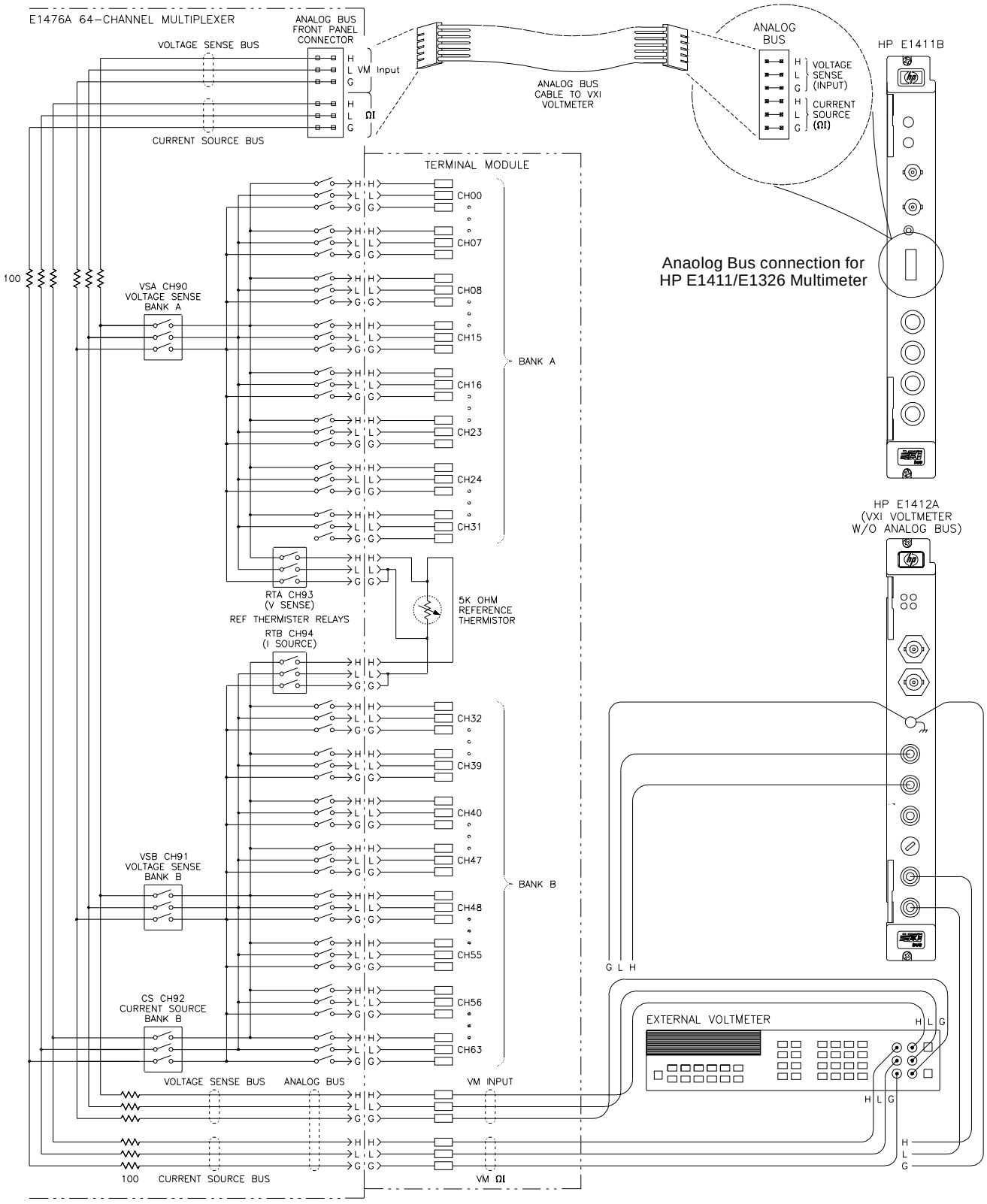
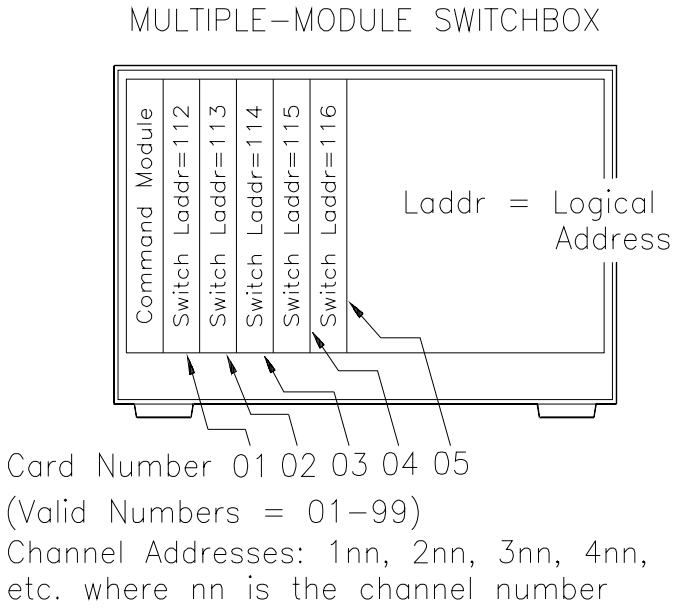


Figure 1-1. HP E1476A Simplified Schematic

Configuring the Multiplexer Module

The Multiplexer Module can be configured as a switchbox (either single-module or multiple-module), or as a scanning voltmeter with the HP E1411B (or E1326B) 5-Digit Multimeter.

Module Use and Logical Address Selection



SWITCHBOX

A switchbox configuration uses the "SWITCH" instrument driver.

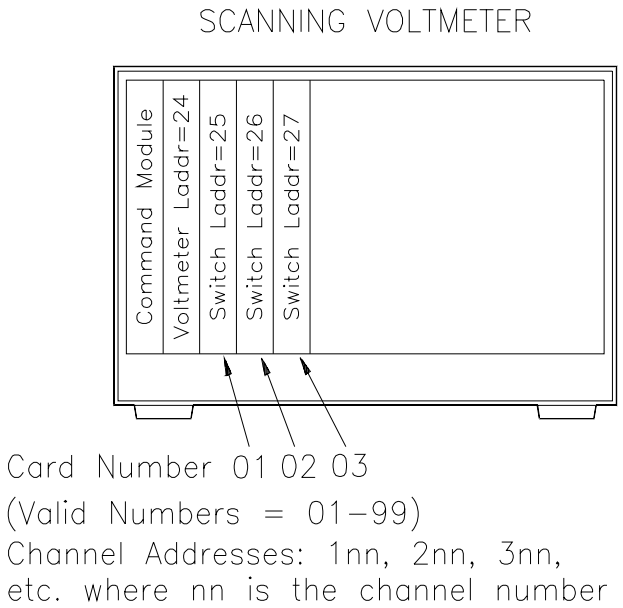
A switchbox uses the commands and command reference in Chapter 3 of this manual.

- **MULTIPLE-MODULE SWITCHBOX:**
The channel address (channel_list) has the form (@ccnn) where:
cc = card number
nn = channel number

- **SINGLE-MODULE SWITCHBOX:**
A single-module switchbox has channel addresses in the form (@nn).

Channel address example (multiple-module):
Channel 31 on card number 02 is addressed by (@231).

Switchbox applications are provided in Chapter 2



SCANNING VOLTMETER

A scanning voltmeter configuration uses the voltmeter instrument driver "VOLTMTR". The scanning voltmeter commands are different from the switchbox commands defined in Chapter 3.

A scanning voltmeter uses the commands and command reference found in the *HP E1326B/E1411B 5-Digit Multimeter User's Manual* to control the switches and make measurements. See the CONFigure and MEASure commands in the multimeter manual.

A quick reference of HP E1411B/E1326B multimeter commands is provided in Chapter 4 along with application information.

Scanning voltmeter applications are provided in Chapter 4.

Figure 1-2. Logical Address, Module (card) Number, and Channel Address

Setting the Logical Address Switch

The logical address switch factory setting is 112. Valid addresses are from 1 to 254 for static configuration (the address you set on the switch) and address 255 for dynamic configuration. The E1476A supports dynamic configuration of the address. This means the address is set programmatically by the resource manager when it encounters a module with address 255 that supports dynamic configuration.

The Multiplexer Module can be configured as a switchbox or as a scanning voltmeter in conjunction with an HP E1411B or E1326B Multimeter. Refer to the *C-Size VXIbus System Installation and Getting Started Guide* for addressing information. Refer to Figure 1-3 for switch position information.

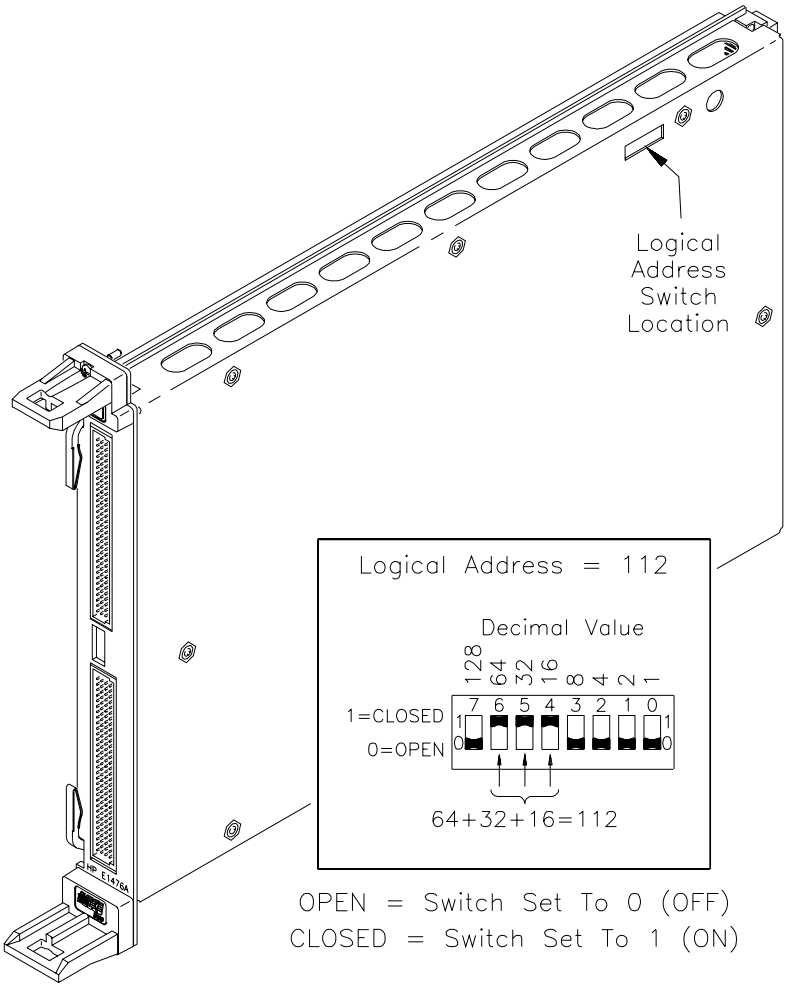


Figure 1-3. Setting the Logical Address

Note When using an HP command module (HP E1406A, for example) the address switch value must be a multiple of 8 if the module is the first module in a switchbox used with a VXIbus command module using SCPI commands. When in the scanning voltmeter configuration, the address switch value must be sequential to the voltmeter address (see "Figure 1-2. Logical Address, Module (card) Number, and Channel Address".

Setting the Interrupt Priority

For most applications this priority level should not have to be changed. Interrupts are enabled at power-up, after a SYSRESET or after resetting the module via the Control Register. An interrupt is generated after any relay Control Register is accessed when interrupts are enabled. The interrupt is generated approximately 1.3ms after one of the registers is accessed. The interrupt priority rotary switch selects which priority level will be asserted. The interrupt priority switch is set in position 1 when shipped from the factory. The interrupts are disabled when set to level “0”. Be careful when deciding to disable the interrupts, both the HP “VOLTMTR” and “SWITCH” drivers require interrupts be enabled.

The interrupt priority switch is identified on the sheet metal shield as IRQ. A hole has been cut into the shield for access. Interrupts can also be disabled using the E1476A Status/Control Register.

To change the setting, simply rotate the switch so the arrow points to the interrupt priority level you desire.

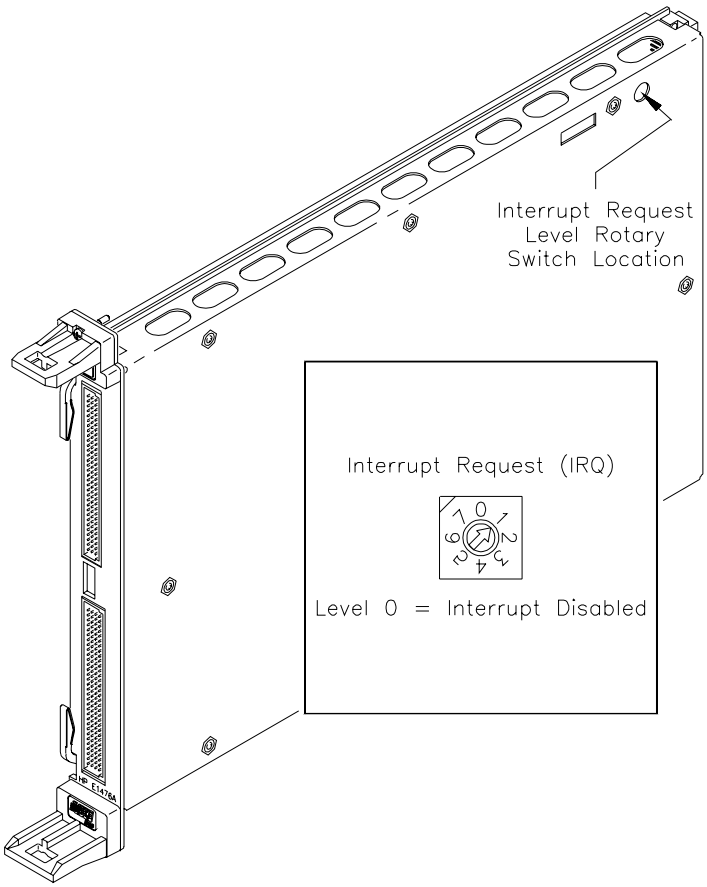


Figure 1-4. Setting Interrupt Request (IRQ) Priority

Note Older HP mainframes require backplane jumpers be set correctly for each slot you use. Consult your mainframe manual.

Installing the Multiplexer in a Mainframe

The HP E1476A may be installed in any slot (except slot 0) in a C-size VXIbus mainframe. Refer to Figure 1-5 to install the Multiplexer in a mainframe.

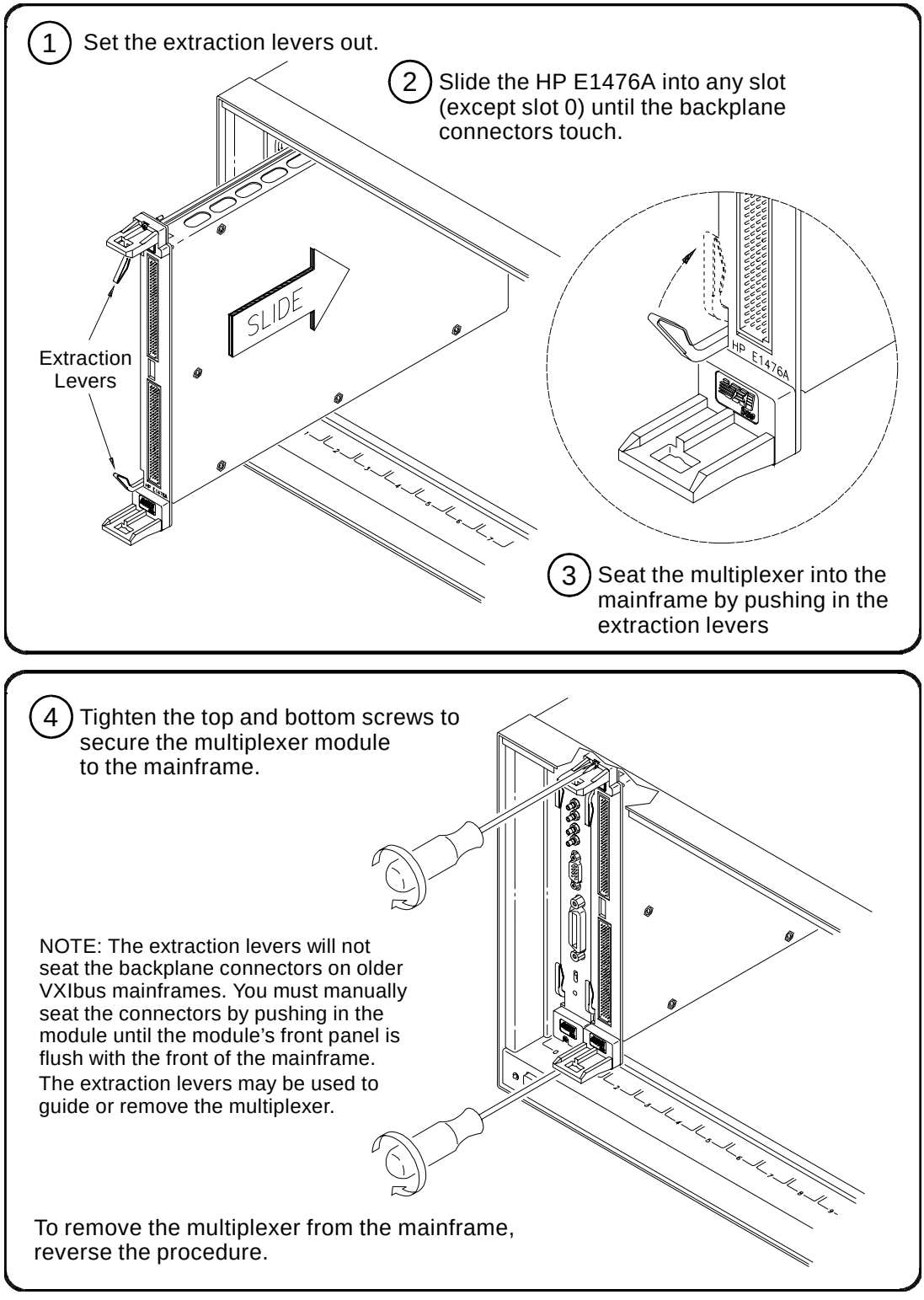


Figure 1-5. Installing the Multiplexer in a VXIbus Mainframe

Terminal Modules

The HP E1476A 64-Channel, 3-Wire Multiplexer Module is comprised of a multiplexer switch card and a spring clamp type Terminal Module. The screwless terminals utilize a spring clamp terminal for connecting solid or stranded wire. Connection is made with a simple push of a three-pronged insertion tool (HP part number 8710-2127), which is shipped with the Multiplexer. If the spring clamp type Terminal Module is not desired, a crimp-and-insert Terminal Module (Option A3E) and an interface to rack mount terminal panel (Option A3F) is available. See "Figure 1-12. HP E1476A Multiplexer Pin-out" on page 31 for the Multiplexer's connector pin-out which mates to the Terminal Module.

Spring Clamp Terminal Module

Figure 1-6 shows the HP E1476A's spring clamp standard Terminal Module connectors and associated channel numbers.

Note Refer to Page 28 and 29 before attempting to wire the Terminal Module.

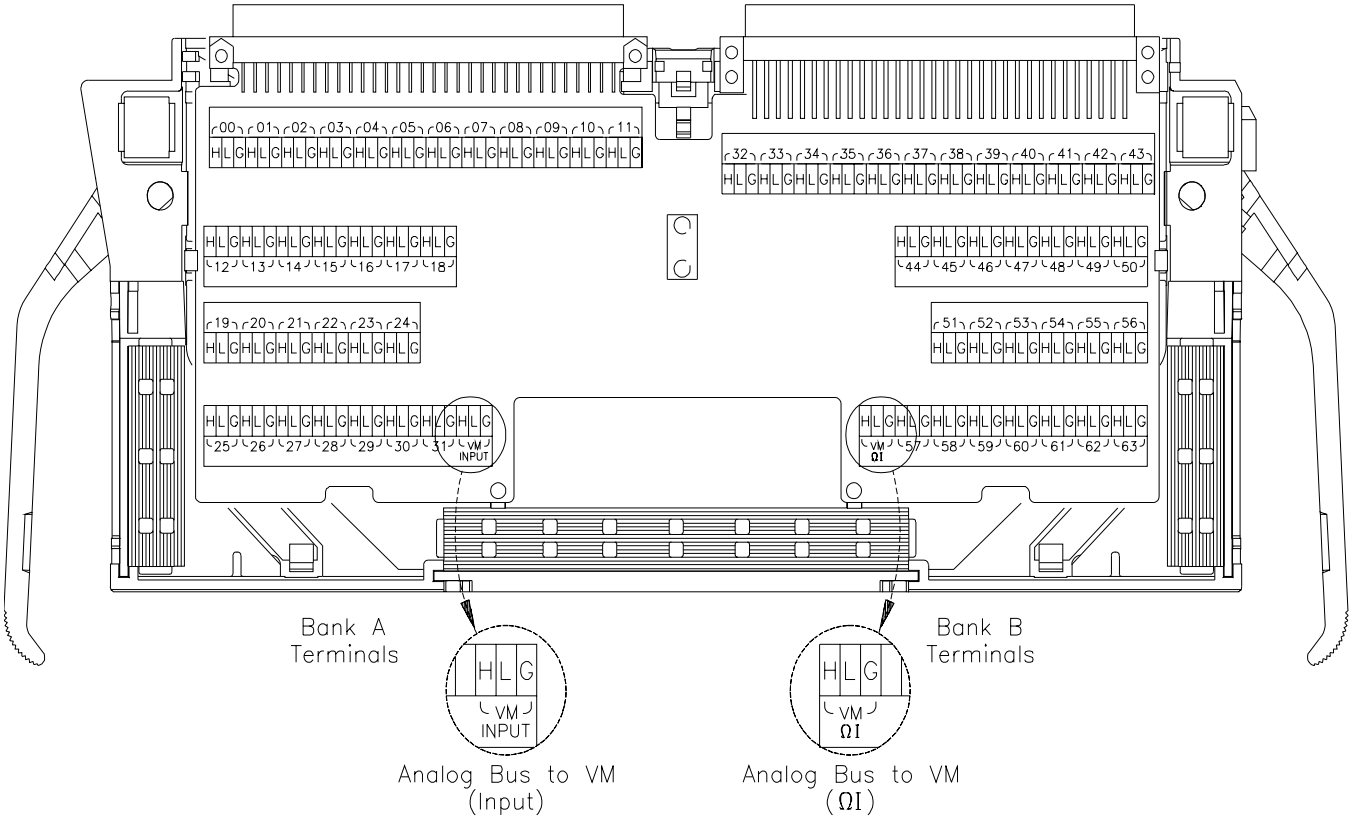


Figure 1-6. HP E1476A Standard Spring Clamp-type Terminal Module

Terminal Module Option A3E

Option A3E can be ordered if a crimp-and-insert Terminal Module is desired. This allows you to crimp connectors onto wires which are then inserted directly into the Multiplexer's mating connector. Refer to the pin-out diagram ("Figure 1-12. HP E1476A Multiplexer Pin-out" on page 31) to make the connections.

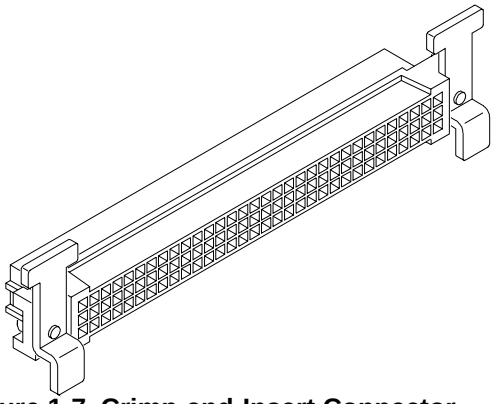


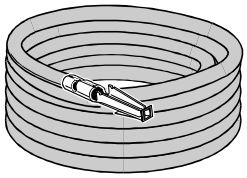
Figure 1-7. Crimp-and-Insert Connector

Crimp-and-Insert Terminal Module Accessories

The following accessories are necessary for use with crimp-and-insert Option A3E:

Single-Conductor and Contact

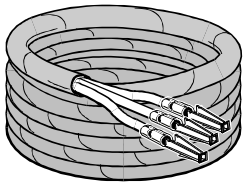
crimp-and-insert contact is crimped onto one end of a wire. The other end is not terminated. Order HP 91510A.



Length: 2 meters
Wire Gauge: 24 AWG
Quantity: 50 each
Insulation Rating: 105°C maximum
Voltage: 300 V

Shielded-Twisted-Pair and Contacts

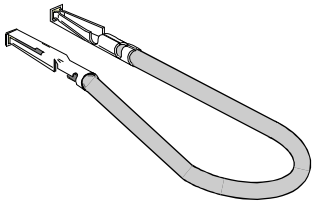
A crimp-and-insert contact is crimped onto each conductor at one end of a shielded-twisted-pair cable. The other end is not terminated.
Order HP 91511A.



Length: 2 meters
Wire Gauge: 24 AWG
Outside Diameter: 0.1 inches
Quantity: 25 each
Insulation Rating: 250°C maximum
Voltage: 600 V

Jumper Wire and Contacts

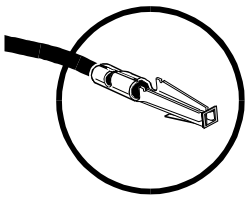
A crimp-and-insert contact is crimped onto each end of a single conductor jumper wire. This jumper is typically used to tie two pins together in a single crimp-and-insert connector. Order HP 91512A.



Length: 10 cm
Wire Gauge: 24 AWG
Quantity: 10 each
Insulation Rating: 105°C maximum
Voltage: 300V

Crimp-and-Insert Contacts

These contacts may be crimped onto a conductor and then inserted into a crimp-and-insert connector. The crimp tool kit is required to crimp the contacts onto a conductor and remove the contact from the connector. Order HP 91515A.



Quantity: 250 each
Wire Gauge Range: 20 - 26 AWG
Plating: Gold Plated Contact
Maximum Current: 2A at 70°C

Crimp-and-Insert Tools

The hand crimp tool (part number HP 91518A) is used for crimping contacts onto a conductor. The pin extractor tool (part number HP 91519A) is required for removing contacts from the crimp-and-insert connector. **These products are not included with Option A3E or with the terminal option accessories listed earlier.**

Extra Crimp-and-Insert Connectors

The crimp-and-insert connector is normally supplied with Option A3E. Contact Hewlett-Packard Company if additional connectors are needed. Order HP 91484B.

Terminal Module Option A3F

Option A3F allows an HP E1476A to be connected to an HP E1586A Rack Mount Terminal Panel. The option provides 4 SCSI plugs on a Terminal Module. This enables connection to a rack mount terminal panel using four Terminal Module. Figure 1-9 shows how to connect the Terminal Module to the HP E1476A Multiplexer Module. See “Mounting and Connecting the HP E1586A Rack Mount Terminal Panel” on page 24 for information on connecting the HP E1586A Rack Mount Terminal Panel. .

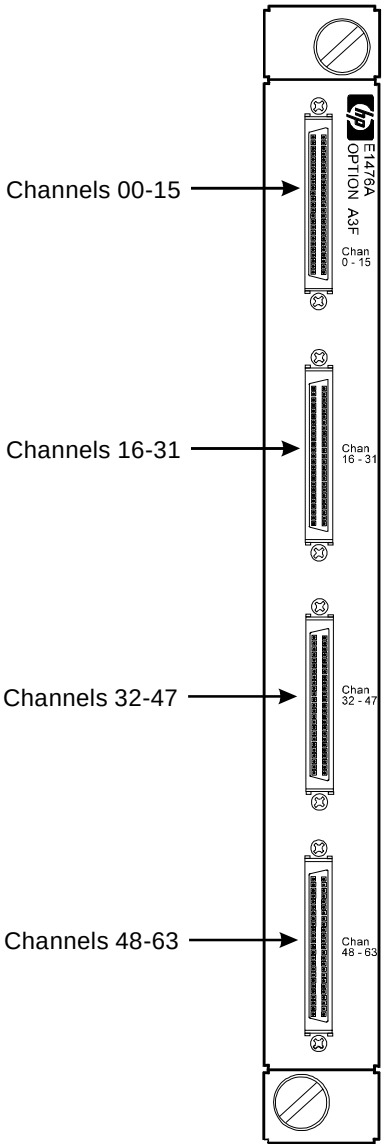


Figure 1-8. HP E1476A Option A3F

Mounting and Connecting the HP E1586A Rack Mount Terminal Panel

The HP E1586 Rack Mount Terminal Panel provides extended connections to the HP E1476A Multiplexer Module. The Terminal Panel is recommended if the HP E1476A is located a distance away from the measurement connections. The Terminal Panel provides up to 32 3-wire connections to allow for 32 channel connections to the Multiplexer Module. See Chapter 2 “Using the HP E1586A Rack Mount Terminal Panel” on page 56 for operating information.

Connecting the HP E1586A Rack Mount Terminal Panel

Figure 1-9 shows how to connect the HP E1586A Rack Mount Terminal Panel to the HP E1476A Multiplexer.

Interconnect Cables

There are two different SCSI cables available for connecting the HP E1586A Rack Mount Terminal Panel to the HP E1476A OptionA3F. In both cases, four cables are required if all 64 channels are needed. This also requires two HP E1586A Rack Mount Terminal Panels to since a single Terminal Panel only connects 32 channels. The cables do not come with the HP E1476A Option A3F and must be ordered separately. The cables are described in the following.

Standard Cable

This cable (HP E1588A) is a 16-channel twisted pair cable with an outer shield. This cable is suitable for relatively short cable runs.

Custom Length Cable

This cable (HP Z2220A Option 050) is available in custom lengths. It is a 16-channel twisted pair cable with each twisted pair individually shielded to provide better quality shielding for longer cable runs.

HP E1586A Option 001 HF Common Mode Filters

Optional high frequency common mode filters on the HP E1586A Rack Mount Terminal Panel's input channels filter out AC common mode signals present in the cable that connects the terminal panel and the device under test. These filters are useful for filtering out small common mode signals below 5Vp-p. To order these filters, order HP E1586A Option 001

Mounting the HP E1586A Rack Mount Terminal Panel

The Terminal Panel can be mounted in a standard size instrument rack. To minimize temperature gradients across the panel, it should be mounted in the rack such that it is away from the other heat sources. The bottom of the rack is usually the preferred location. Take particular care to minimize the temperature differences across the horizontal width of the Terminal Panel, since it is most susceptible to horizontal temperature gradients across its

longest dimension.

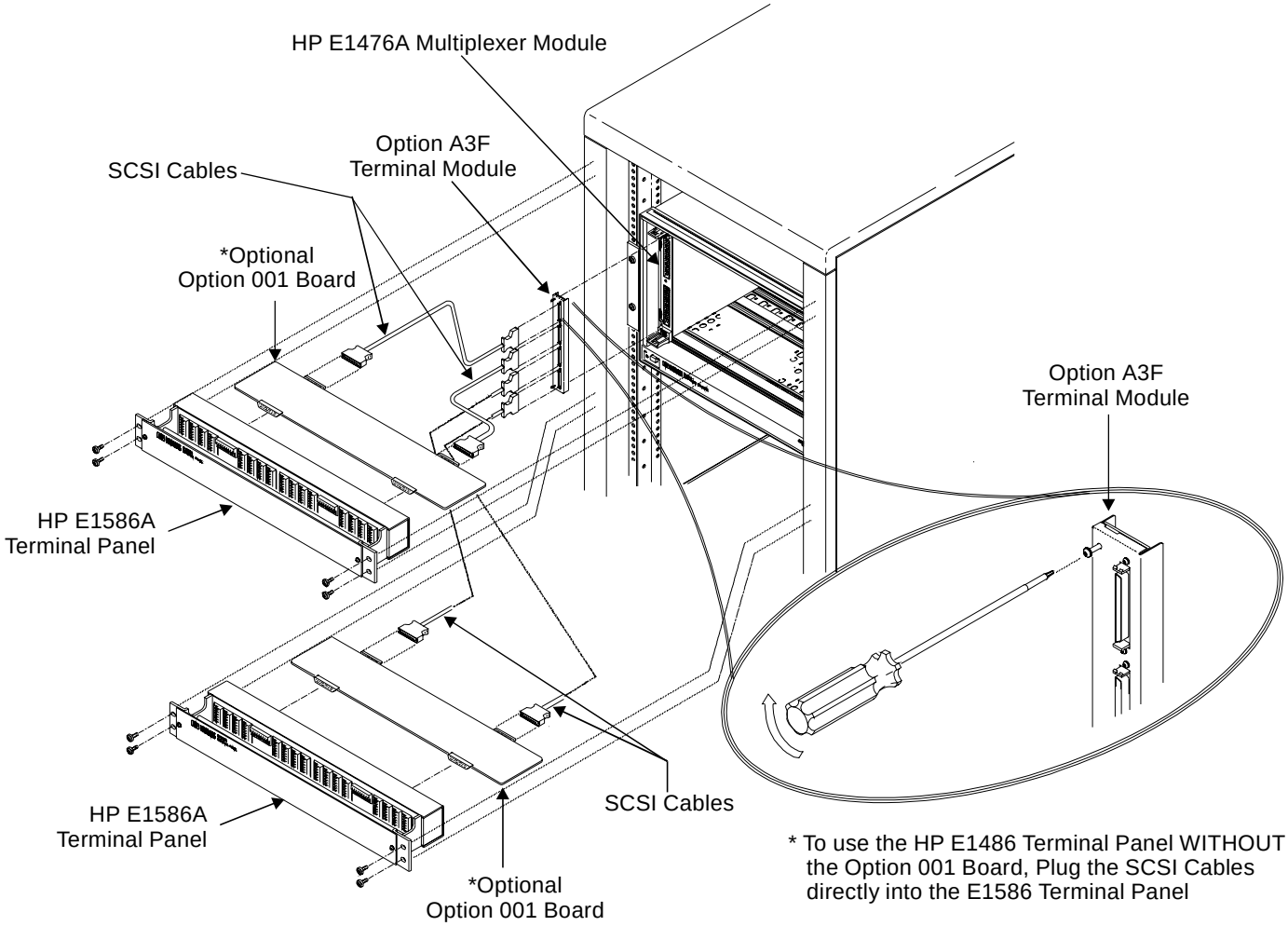


Figure 1-9. Connecting the HP E1586A Rack Mount Terminal Panel

Connecting the Analog Bus

The analog bus provides a common bus to all switch modules in a "switchbox" or "scanning voltmeter" to which a single voltmeter can be connected. You must connect the flat ribbon analog bus cables between Multiplexers and other HP VXI modules that have an analog bus (both C-size modules or B-size modules in a C-size adapter). HP E1411A/B 5-Digit Multimeter users (and HP E1326 in a C-size adapter) must continue the analog bus connection between Multiplexers and switch modules to the multimeter in order to use the scanning and measurement capability the multimeter has to offer. These cables provide the input to the multimeter from the multiplexer/switch channels. See Figure 1-10.

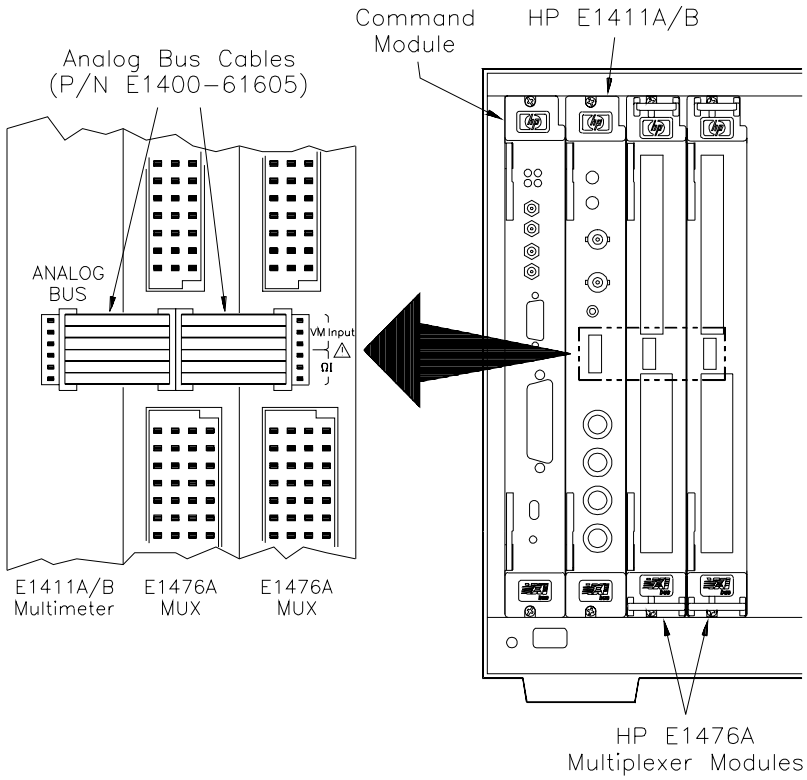


Figure 1-10. HP E1411A/B Connections to the Analog Bus

Note An external measuring device can be connected to the analog bus through the Terminal Module's "VM Input" and "VM WI" terminals.
See "Figure 1-11. Externally Connecting to the Analog Bus" for more information.

NOTE to user's of the HP E1326A/B 5½-Digit Multimeter in a C-size adapter:

Use the 19.5 inch analog bus cable P/N E1326-61611 for analog bus connection between your E1326 and the E1476A; the cable described above in Figure 1-10 will be too short for connection to the E1326.

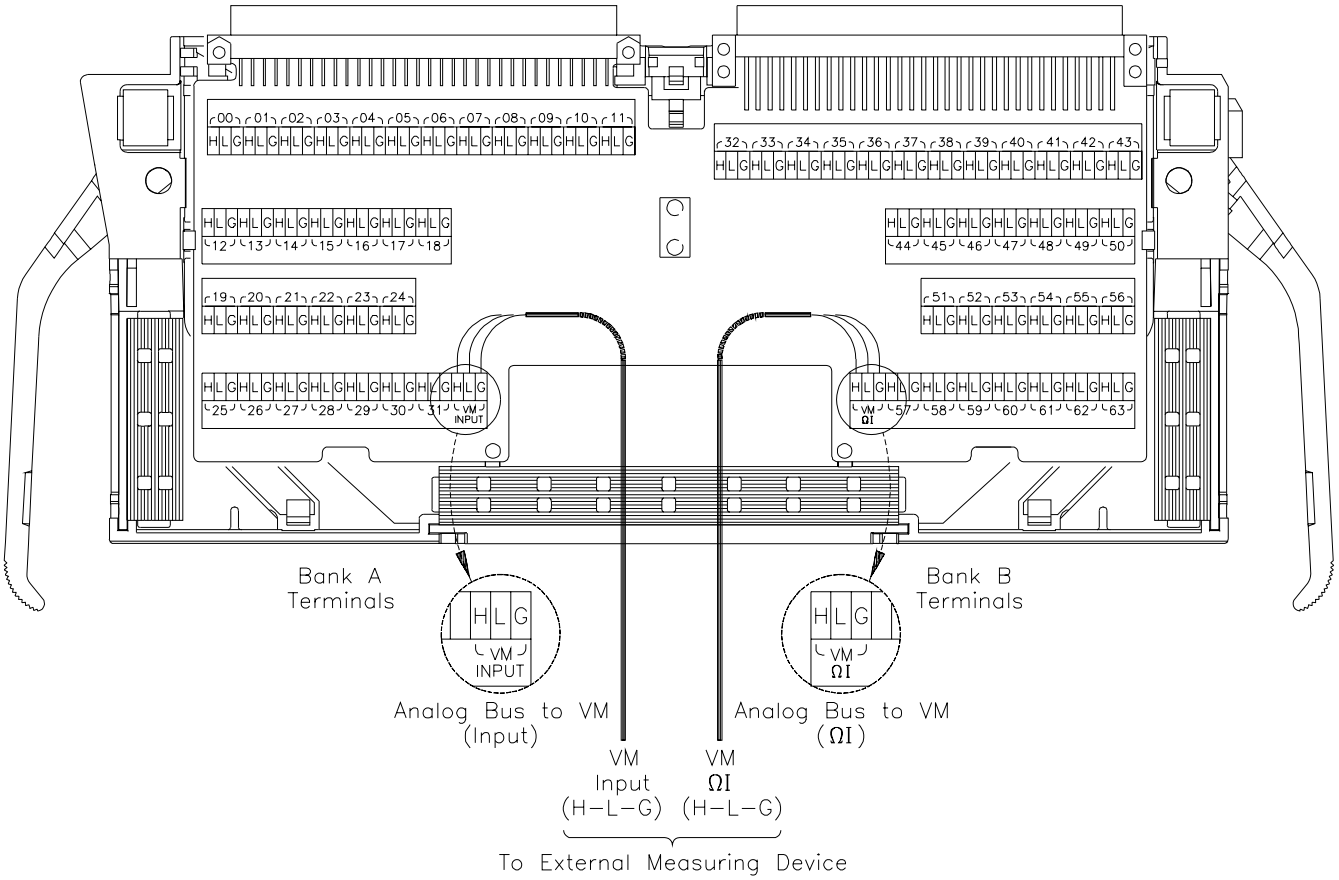
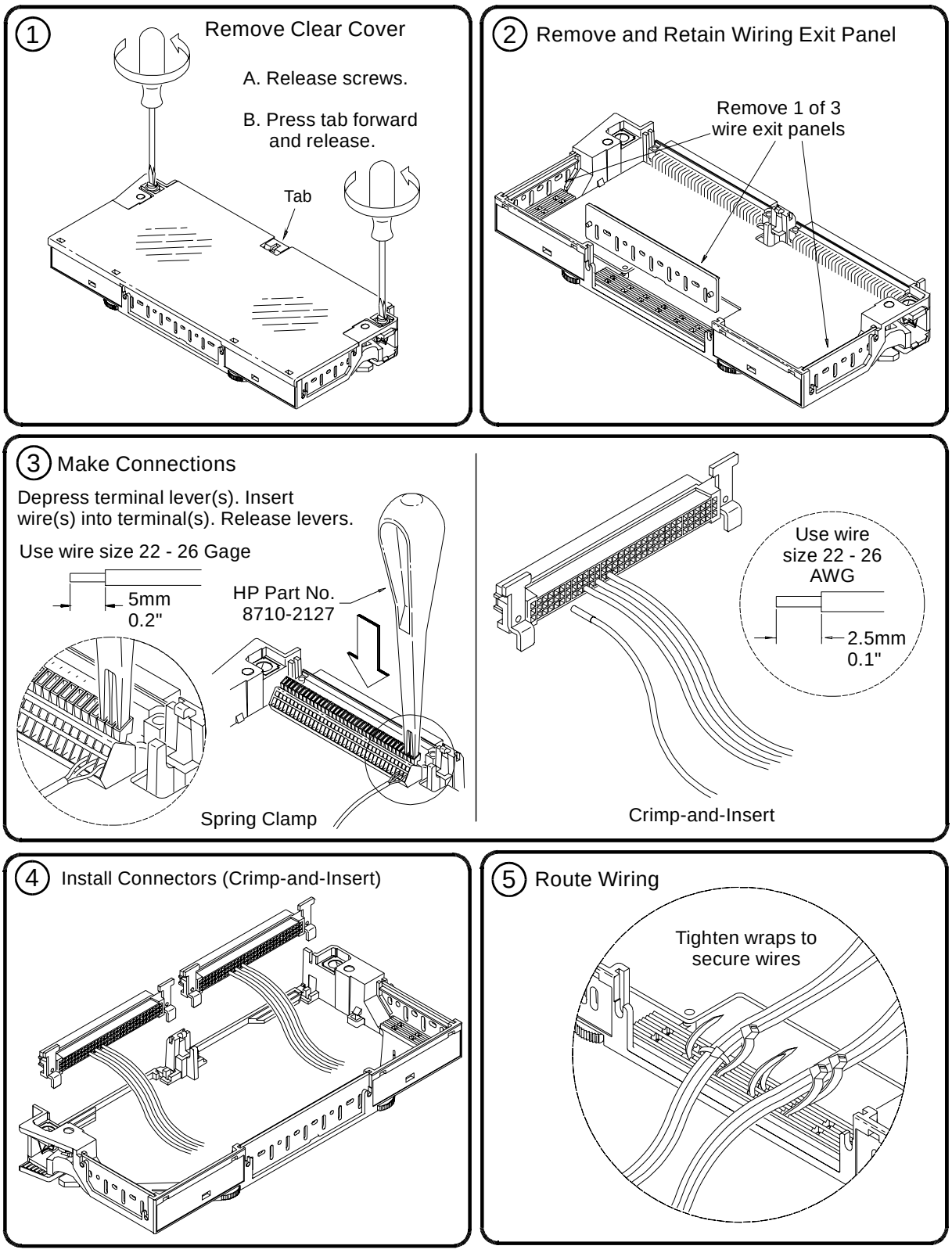


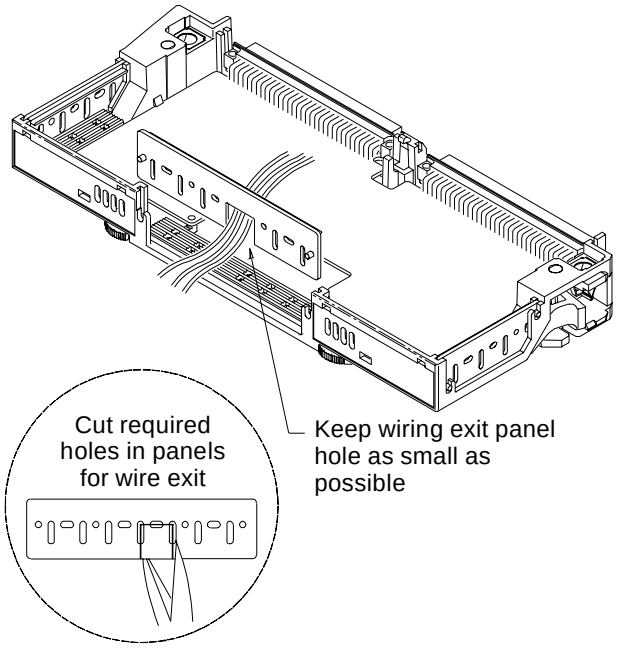
Figure 1-11. Externally Connecting to the Analog Bus

Wiring a Terminal Module

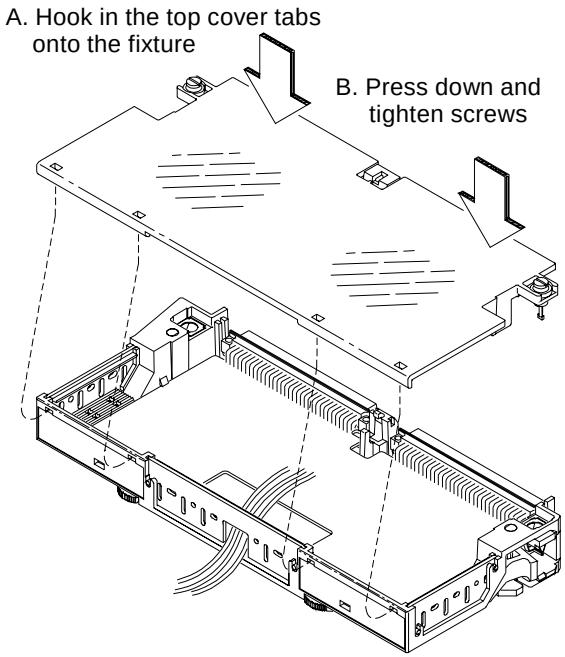
The following illustrations show how to connect field wiring to the Terminal Module.



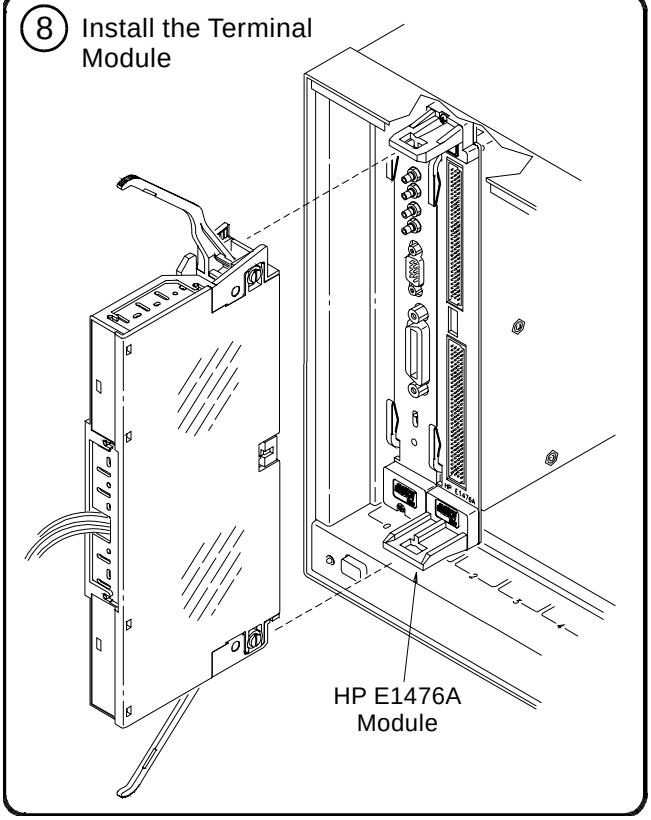
6 Replace Wiring Exit Panel



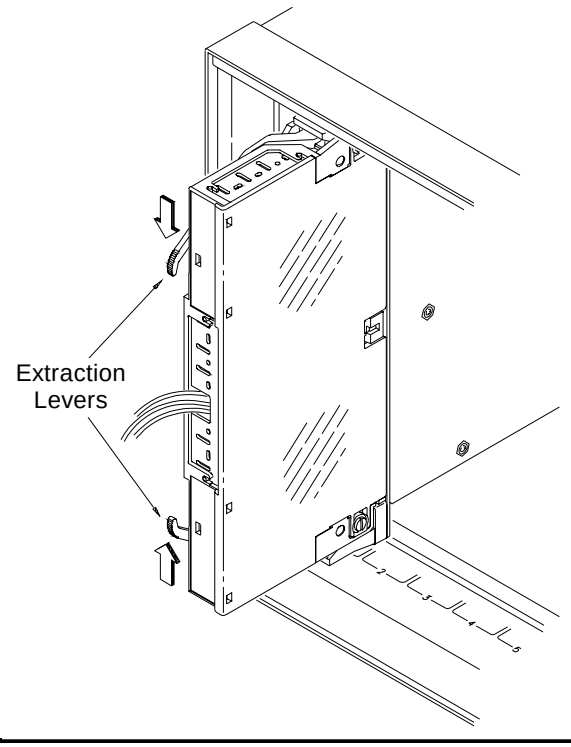
7 Replace Clear Cover



8 Install the Terminal Module

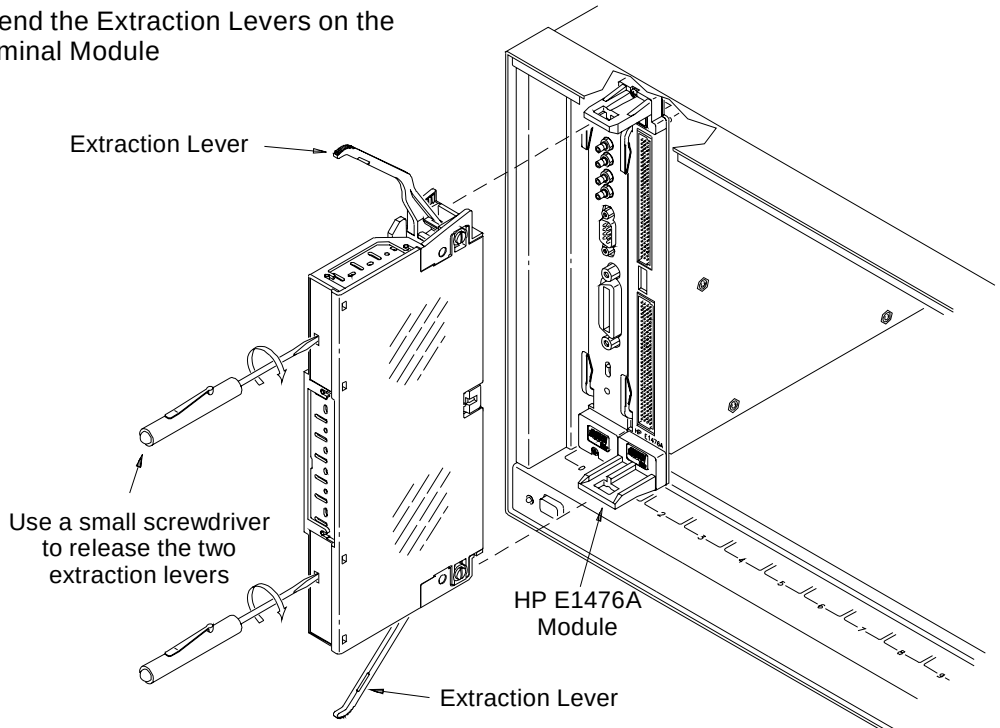


9 Push in the Extraction Levers to Lock the Terminal Module onto the HP E1476A



Attaching a Terminal Module to the Multiplexer

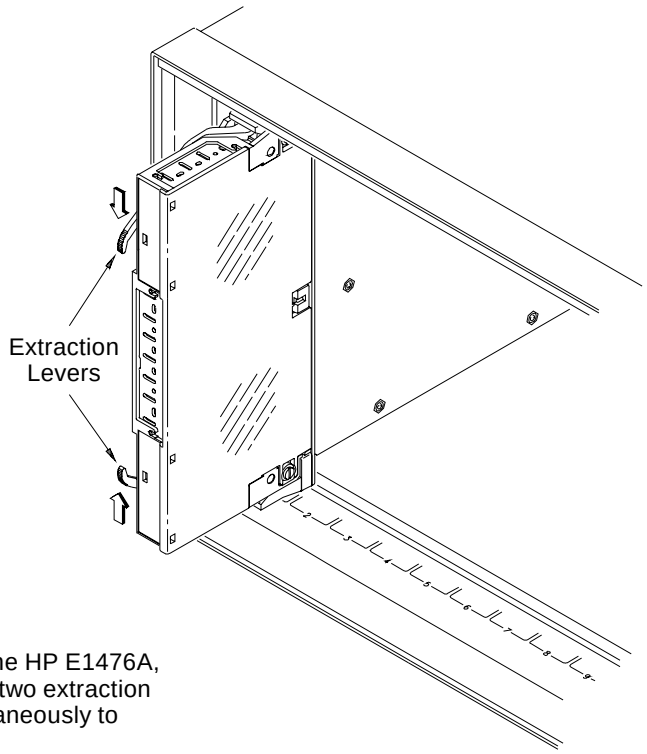
1 Extend the Extraction Levers on the Terminal Module



2 Align the Terminal Module Connectors to the HP E1476A Module Connectors

3 Apply Gentle Pressure to Attach the Terminal Module to the HP E1476A Module

4 Push the Extraction Levers to Lock the Terminal Module onto the HP E1476A Module



To remove the Terminal Module from the HP E1476A, use a small screwdriver to release the two extraction levers and push both levers out simultaneously to fre it from the HP E1476A Module

Connecting User Inputs

The HP E1476A consists of a switch module and a Terminal Module. The user connects inputs to the Multiplexer's H, L and G terminal connections on the Terminal Module. "Figure 1-1. HP E1476A Simplified Schematic" on page 15 shows a simplified schematic for both the Multiplexer and the Terminal Module. Figure 1-12 shows the Multiplexer's front panel and the connector pin-out which mates to the Terminal Module and Figure 1-13 shows the pinout of the Option A3F Connector.

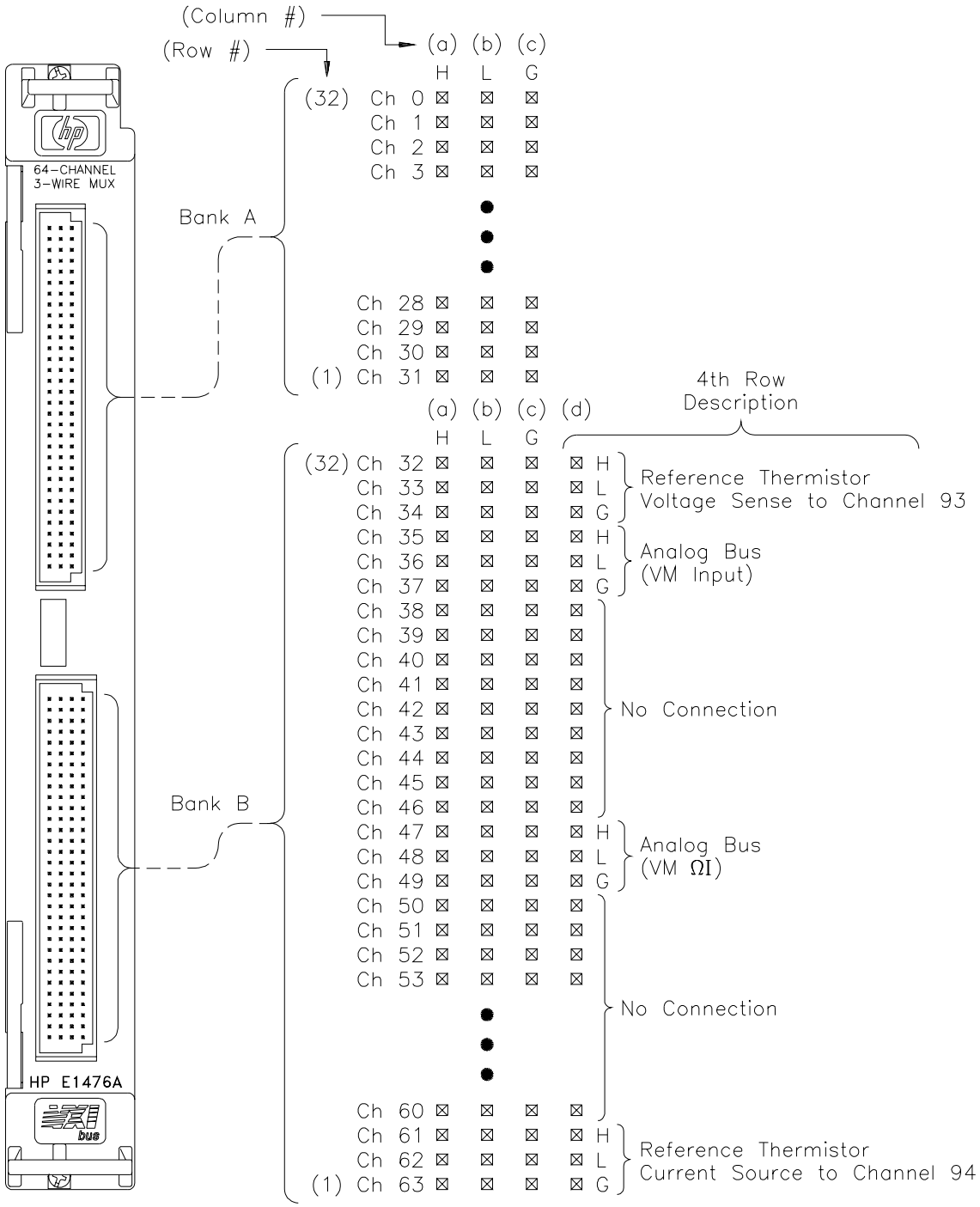


Figure 1-12. HP E1476A Multiplexer Pin-out

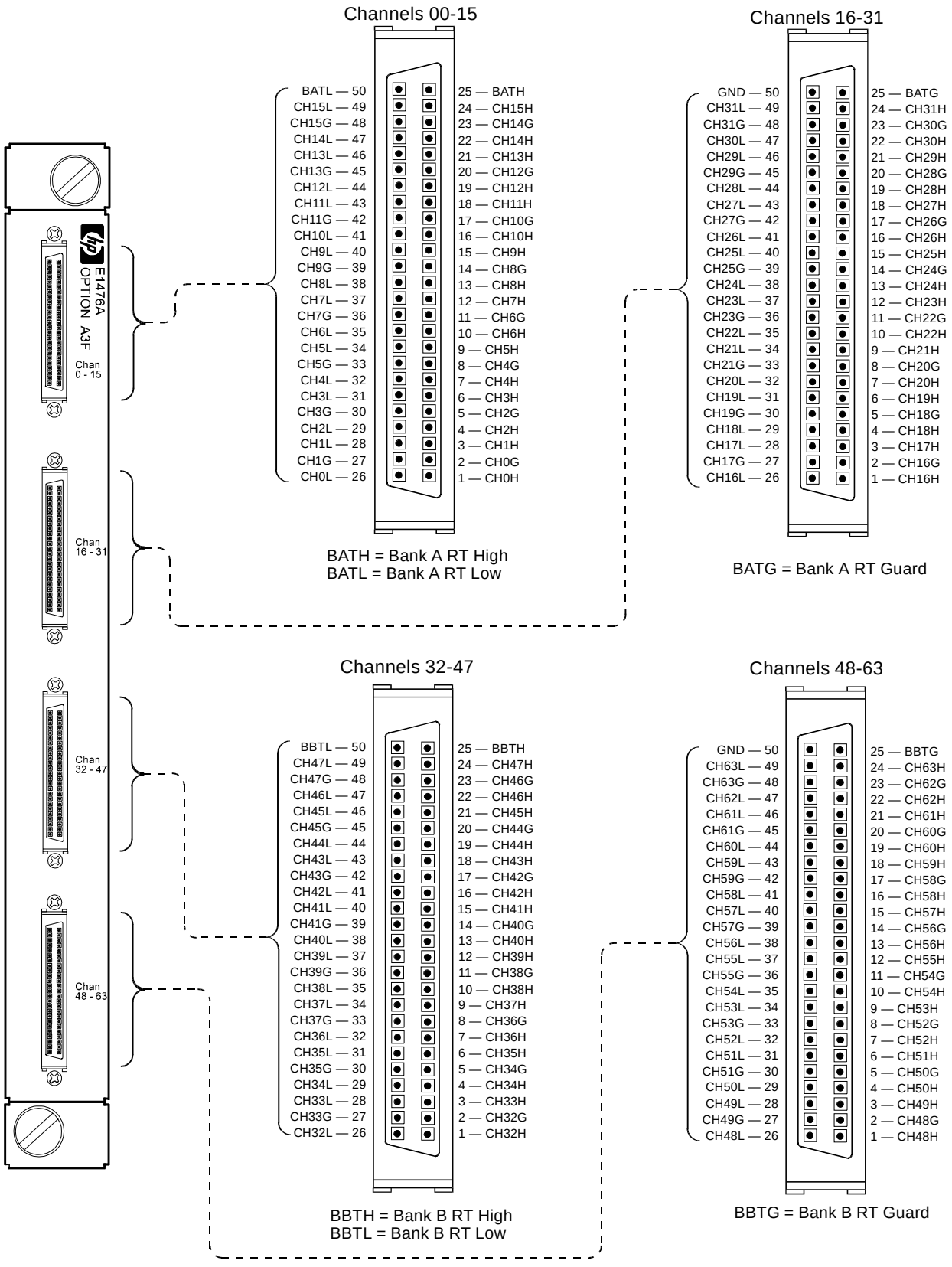


Figure 1-13. Option A3F Pinout

Programming the Multiplexer

To program the Multiplexer using SCPI, you must select the interface address and SCPI commands to be used. Guidelines to select SCPI commands for the Multiplexer follow. See the *HP 75000 Series C Installation and Getting Started Guide* for interface addressing.

Note This discussion applies only to SCPI (Standard Commands for Programmable Instruments) programming. See Appendix B for information on the Multiplexer's registers.

Specifying SCPI Commands

To address specific channels within a Multiplexer, you must specify the SCPI command and channel address. Use CLOSe *channel_list* to close the channels specified, OPEN *channel_list* to open the channels specified, and SCAN *channel_list* to close and open the set of channels specified, one channel at a time.

Channel Address

The Multiplexer's channel address (nn of the *channel list*) has the form (@ccnn) where cc = module (card) number (01-99) and nn = channel numbers (00-63 and 90-94). Channels 90 through 94 are tree relays related to the analog bus and the reference thermistor used for thermocouple measurements. The channels can be addressed using channel numbers or channel ranges. You can address the following:

- single channels (@ccnn);
- multiple channels (@ccnn,ccnn,...);
- sequential channels (@ccnn:ccnn);
- groups of sequential channels (@ccnn:ccnn,ccnn:ccnn);
- or any combination of the above.

Card Numbers

The card number (cc of the *channel list*) identifies the module within a switchbox. The card number assigned depends on the switch configuration used. Leading zeroes can be ignored for the module (card) number.

Single-module Switchbox. In a single-module switchbox configuration, the card number is always 01.

Multiple-module Switchbox. In a multiple-module switchbox configuration, modules are set to successive logical addresses. The module with the lowest logical address is always card number 01. The module with the next successive logical address is card number 02, and so on. "Figure 1-14. Card Numbers in a Multiple-module Switch" on page 34 illustrates the card numbers and logical addresses of a typical multiple-module switchbox configuration. See the *C-Size VXIbus System Installation and Getting Started Guide* for additional switchbox instrument information.

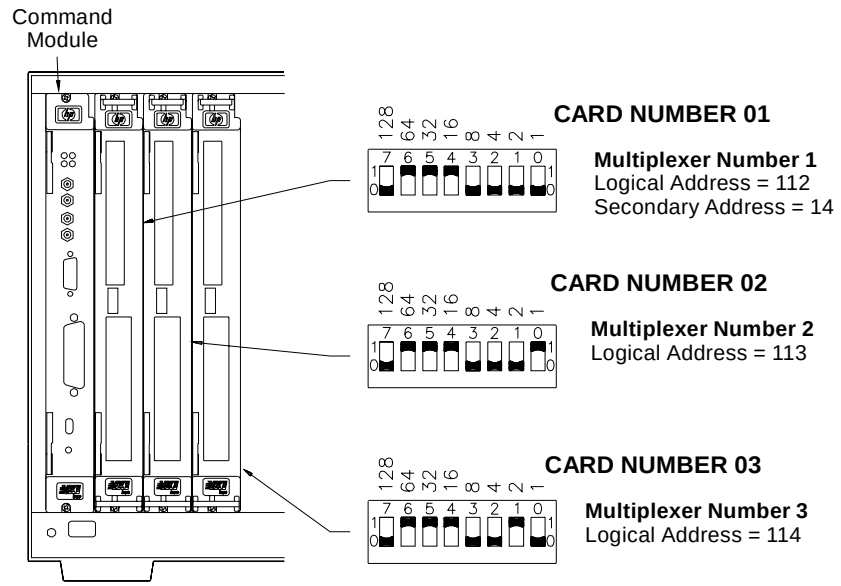


Figure 1-14. Card Numbers in a Multiple-module Switch

Channel Numbers, Ranges, and Lists

The E1476A Multiplexer channel numbers are 00 through 63. The channels can be addressed using channel numbers or channel ranges. For a single-module switchbox, channel ranges can span across the channels. For multiple-module switchboxes, channel ranges can span across the channels of all modules.

Use commas (,) to form a channel list or use a colon (:) to form a channel range. Only valid channels can be accessed in a channel list or channel range. Also, the channel list or channel range must be from a lower channel number to a higher channel number. For example, CLOS(@100:215) is acceptable, but CLOS(@215:100) generates an error.

Using the channel range (@n00:n99) with the SCAN command causes all channels to be scanned except the tree relays which are channels 90 through 94. These are not typical scan channels and therefore are not included in a scan list. You can however, include channel 93 in a scan list, e.g. (@100:193) when making a four-wire resistance measurement. The only restriction is that SCAN:MODE must be FRES (four-wire resistance) for channel 93, which is the voltage sense. The current source channel is 94 and is automatically switched.

Below are some SCPI commands and a description of their effect on channel lists and ranges.

Channel Lists:

CLOS(@100,112)	*Close channels 00 and 12 on card 01.*
OPEN(@203,210)	*Open channels 03 and 10 on card 02.*

Channel Ranges:

OPEN(@100:163)	*Open all channels on card 01.*
SCAN(@100:163)	*Scan all channels on card 01.*
SCAN(@100:199)	*Scan all channels on card 01.*
SCAN(@100:223)	*Scan all channels on card 01 and channels 00 through 23 on card 02.*
SCAN(@100:104, 200:204, 300)	*Scan channels 0 through 4 on module 1, scan channels 0 through 4 on module 2 and scan channel 0 on module 3.*

Initial Operation

You must install the appropriate device driver into the HP E1405/E1406 Command Module if you are planning to use the E1476A as a switchbox or scanning voltmeter instrument using SCPI commands. Both of these drivers are shipped with the E1476A module in both LIF (HP's Logical Interchange Format) and DOS formats. Choose the correct driver disc and install it into your command module as described in the *Installing Device Drivers Installation Note.*

For switchbox applications,
install "SWITCH" driver Rev A.08.00 or later
For scanning voltmeter applications,
install "VOLTMTR" driver Rev A.06.00 or later.

At power-on or following a reset of the module (*RST command), all channels are open. A *RST command invalidates the current scan list (that is, you must specify a new scan list). Command parameters are set to the default conditions as shown below.

Parameter	Default Value	Description
ARM:COUNt	1	Number of scanning cycles is one.
TRIGger:SOURce	IMM	Advances through a scanning list automatically.
INITiate:CONTinuous	OFF.	Number of scanning cycles is set by ARM:COUNt
OUTPut[:STATe]	OFF	Trigger output from EXT, TTL, or ECL sources is disabled.
[ROUTe:]SCAN:MODE	NONE	Channel list is set up for volts measurement.
[ROUTe:]SCAN:PORT	NONE	Analog bus connections are disabled from channels.

Execute SCAN:PORTABUS to enable use of the analog bus for the SCAN command. A CLOSe command requires that you also close the appropriate tree relay to make connection to the analog bus (see "Figure 1-1. HP E1476A Simplified Schematic" on page 15).

An example program follows which uses Hewlett-Packard BASIC and SCPI language to get you started using the Multiplexer. The example assumes an HP 9000 Series 200/300/400 (or equivalent) computer and a Hewlett-Packard Interface Bus (HP-IB). [HP-IB is the Hewlett-Packard implementation of the IEEE 488.2-1987 standard.]

This program closes channel 02 of a Multiplexer at logical address 112 (secondary address = 112/8 = 14) and queries the channel closure state. The result is returned to the computer and displayed ("1" = channel closed, "0" = channel open). See the *HP 75000 Series C Installation and Getting Started Guide* for information on addressing.

Example: Close Multiplexer Switch Channel

```
 10      !Connect bank A to the analog bus.
 20      OUTPUT  70914;"CLOS(@190)"
 30      !Close channel 02.
 40      OUTPUT  70914;"CLOS(@102)"
 50      !Query channel 02 state.
 60      OUTPUT  70914;"CLOS?(@102)"
 70      !Enter result into Value.
 80      ENTER  70914;Value
 90      !Display result.
100      PRINT  Value
110      END
```

Chapter 2
HP E1476A Switchbox Application Examples

This chapter gives application information and examples for using the E1476A 3-wire Multiplexer in the “switchbox” configuration. The “switchbox” can be a single Multiplexer Module or multiple Multiplexer Modules. It can also include other HP switch modules which are controlled by the same “switchbox” device driver. This chapter contains the following sections:

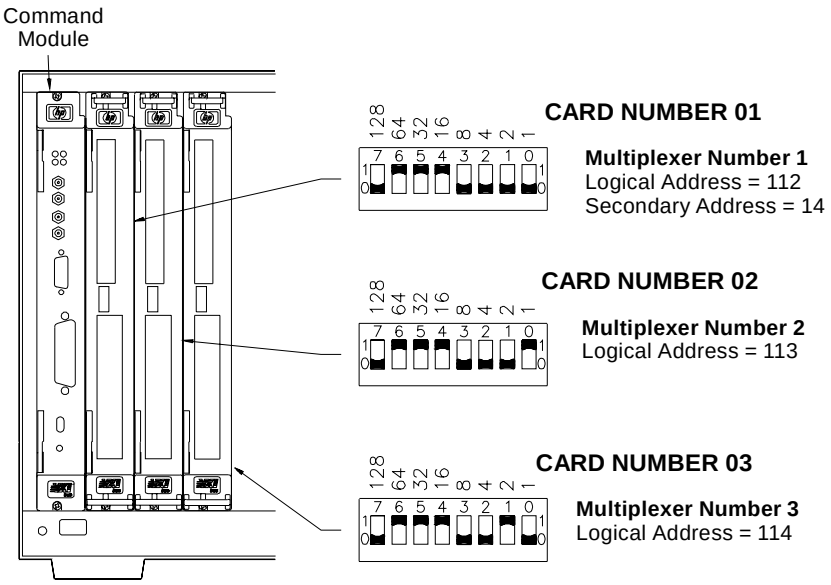


Figure 2-1. Switchbox Configuration

Reset Conditions

At power-on or following the reset of the module (*RST command), all 64 channels and the tree relays are open. In addition, after a *RST command, the current scan channel list is invalidated. Table 2-1 lists the parameters and default values for the functions following turn-on or reset.

Table 2-1. HP E1476A Default Conditions for Power-on and Reset

Parameter	Default Value	Description
ARM:COUNt	1	Number of scanning cycles is one.
TRIGger:SOURce	IMM	Advances through a scanning list automatically.
INITiate:CONTinuous	OFF.	Number of scanning cycles is set by ARM:COUNt
OUTPut[:STATe]	OFF	Trigger output from EXT, TTL, or ECL sources is disabled.
[ROUTe:]SCAN:MODE	NONE	Channel list is set up for volts measurement.
[ROUTe:]SCAN:PORT	NONE	Analog bus connections are disabled from channels.
Channel state	All 64 channels are open (channels 00 - 63)	
Tree relay state	All tree relays are open (channels 90 - 94)	
Channel list from SCAN command (after *RST)	Current channel list is invalidated following a reset of the module with *RST command.	

Switching or Scanning

The Multiplexer is easily configured in the switchbox configuration to perform voltage, 2-wire ohms, 4-wire ohms or temperature measurements over the module's internal analog bus.

Switching. All of these measurements can be made by individually switching the channels with CLOSe and OPEN commands. Individually switching the channels requires that you also close appropriate tree relay(s) to connect channels to the analog bus (see channels 90, 91 and 92 in "Figure 2-1. Switchbox Configuration" on page 37).

Scanning. All of these measurements can be made by scanning a list of channels. The advantage to scanning is the appropriate tree relays are closed automatically when you scan a channel list with the SCAN command and set SCAN:PORTABUS.

Switching Channels to the Analog Bus

You use the OPEN and CLOSe commands to individually switch channels. You must also close the appropriate tree relay (VSA, VSB or CS) to connect channels to the analog bus if you want to make your measurement from the

analog bus. Once closed, a tree relay remains closed until specifically opened (OPEN command, remove power from the module or reset the module with a *RST command). Tree relays are listed in Table 2-2, which also provides a description of each tree relay function. Most applications of the E1476A Multiplexer will have you closing the VSA, VSB or both VSA and VSB tree relays when using the OPEN and CLOSe commands.

Table 2-2. Tree Relay Descriptions

Tree Relay Channel	Designation	Functional Description
90	VSA	Connects the Voltage Sense H-L-G terminals of the Analog Bus to the Bank A channels (channels 00 to 31)
91	VSB	Connects the Voltage Sense H-L-G terminals of the Analog Bus to the Bank B channels (channels 32 to 63)
92	CS	Connects the Current Source H-L-G terminals of the Analog Bus to the Bank B channels (channels 32 to 63)
93	RTA	Connects the Reference Thermistor to Bank A for voltage sense (4-wire resistance measurement of the thermistor)
94	RTB	Connects the Reference Thermistor to Bank B for current source (4-wire resistance measurement of the thermistor)

Connecting a Channel to the Analog Bus

Use the CLOSe *<channel_list>* command to close a channel (channel 00 - 63) or tree relay (channel 90 - 94). A channel or tree relay remains closed until you specifically give it an OPEN command or reset the module using the *RST command (removing power will open all channels and tree relays because they are non-latching).

You must close a tree relay to connect a channel to the analog bus. For example, close channel 23 on module number 1 and connect it to the analog bus by closing the voltage sense bank A tree relay (channel 90). Refer to "Figure 2-2. Channel Switching to the Analog Bus" on page 40.

```
CLOS(@123, 190)
Make measurement
OPEN(@123, 190)
```

Channel 90 can be left closed and other bank A channels closed for measurement.

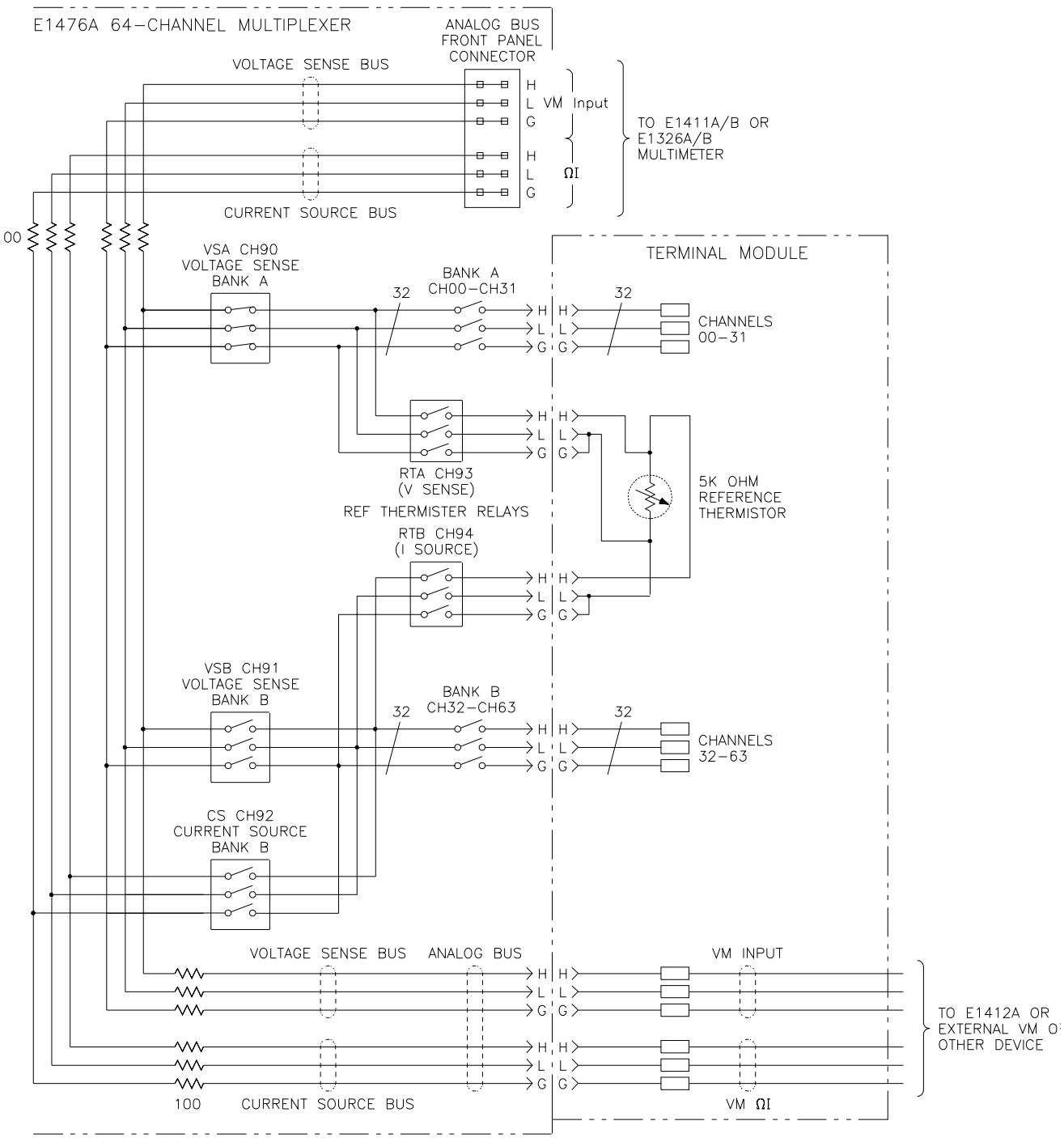


Figure 2-2. Channel Switching to the Analog Bus

Three-Wire Channel Switching (Two-Wire Measurement)

This example illustrates three-wire switching and a method for making accurate 2-wire resistance measurements. The E1476A analog bus contains current-limiting protection resistors which can introduce measurement error if the measuring instrument does not have a suitable high impedance. This example describes a method to make measurements that avoids the protection resistors all together. In particular, this method makes accurate 2-

wire resistance measurements.

Making two-wire measurements from the analog bus introduces the internal bus protection resistors which will introduce about 100Ω per lead to the resistance measurement. Use Channel 00 as your common terminals to make two-wire measurements from channels 01 through 31 on bank A. Close tree relays VSA and VSB (channels 90 and 91) to connect bank B channels (32 through 63) to channel 00 through the bank A bus. You can now make two-wire measurements from 63 channels using channel 00 as the common. No current-limiting resistors are in the path. Refer to "Figure 2-3. 64 Channels of Two-wire Measurements" on page 42.

```
CLOS(@190, 191, 100)          Closes all paths through channel 00.
CLOS(@1cc)                    "cc" = channel number to be measured (01 to 63).

Make measurement
OPEN(@1cc)                    Open channel cc after measurement is made.
```

Four-Wire Channel Switching

To make four-wire resistance measurements when not scanning, you must use a channel from bank A for the voltage sense and close the voltage sense bank A tree relay (VSA). Additionally, you use a channel from bank B for the current source and you must close the current source relay (CS) on bank B. The VSA and CS relays connect the device under test to the analog bus. Typically you pair the first channel of bank A with the first channel of bank B (e.g. channels 00 and 32, 01 and 33, 02 and 34, etc.). Refer to "Figure 2-4. Typical 4-wire Measurement Pairs" on page 43.

```
CLOS(@100, 190, 132, 192)     Channels 100 and 132 are a 4-wire pair.

Make measurement in four-wire mode
OPEN(@100, 132)               Open measurement channels except tree relays.
```

NOTE: Using the SCAN command automatically pairs channels 00 and 32, 01 and 33, 02 and 34, etc. for four-wire measurements.

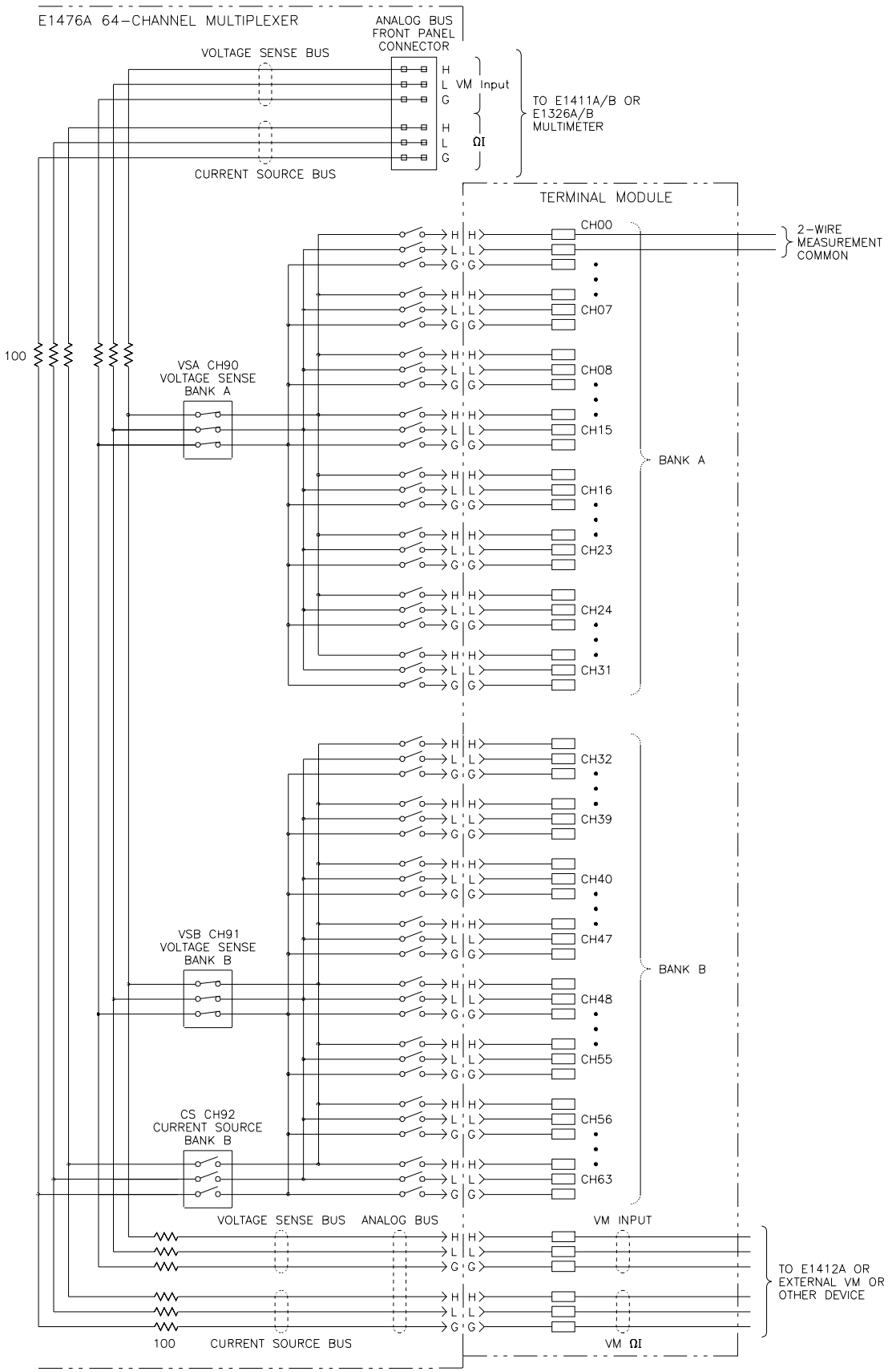


Figure 2-3. 64 Channels of Two-wire Measurements

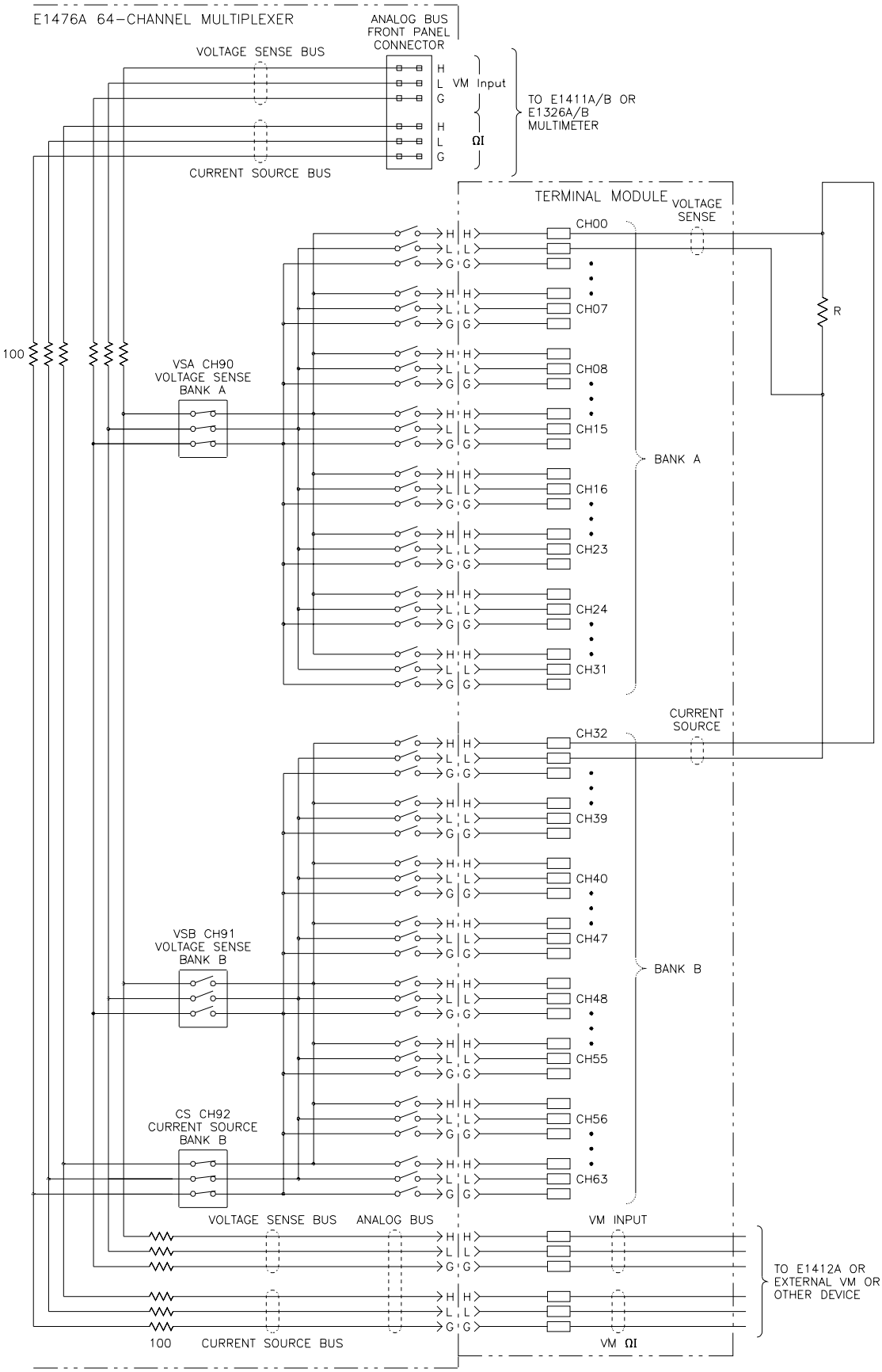


Figure 2-4. Typical 4-wire Measurement Pairs

Temperature Measurements By Channel Switching

The E1476A allows you to make temperature measurements from any channel of the Multiplexer. A 5KΩ reference thermistor is provided on the E1476A Terminal Module. You measure the resistance of this reference thermistor to calculate the temperature of the thermocouple junctions within the Terminal Module to compensate thermocouple temperature measurements.

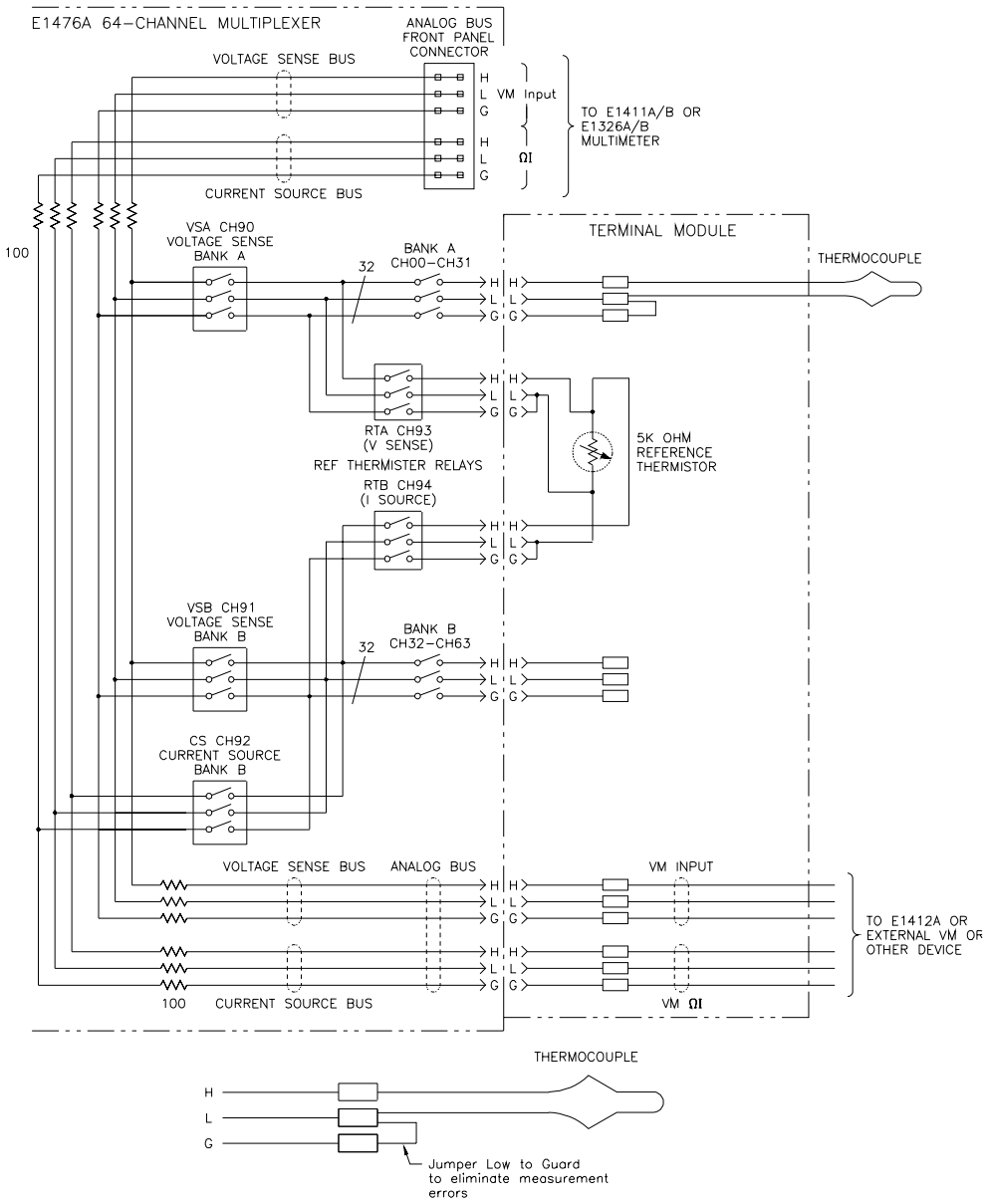


Figure 2-5. Temperature Measurements

Comments

- Temperature measurements using thermistors consists of 2-wire or 4-wire ohms measurements.
- Refer to Chapter 4 for making temperature measurements with the HP E1326/E1411 Multimeters. These multimeters can make temperature measurements directly from single or multiple

Multiplexer Modules. In the scanning voltmeter configuration described in Chapter 4, the instrument driver "VOLTMTR" controls the Multiplexer switches.

- Thermocouple measurements are compensated by the thermistor on the E1476A Terminal Module. The temperature of the thermocouple lead junctions inside the Terminal Module affects the temperature reading taken from a thermocouple. Use the thermistor inside the Terminal Module to determine the temperature inside the Terminal Module and compensate the thermocouple temperature measurements. Do the following:

1. Measure the resistance of the 5KΩ thermistor on the Terminal Module (Thr_ohms). NOTE: A 4-wire ohms measurement should be made to avoid measurement errors by the 100Ω protection resistors (see "Figure 2-1. Switchbox Configuration" on page 37).

2. Compute the temperature of the terminal module (Tref) from the reading (Thr_ohms). For values of resistance between 92.7 to 3.685e6, use the following equations to calculate the temperature of the terminal module:

   Tref = temperature in degrees C.

   Thr_ohms = the resistance of the 5K ohm thermistor

   A = 1.28463e-3

   B = .23625e-3

   C = 9.2697e-8

   W = ln(Thr_ohms)

   Tref ={ 1/(A + W * (B + C * W * W)) } - 273.15

3. Measure the voltage on the thermocouple connected to a channel (Vt).

4. Compute the effective temperature at the external thermocouple junction by doing the following two steps:

   a. Compute the actual voltage across the external thermocouple junction using the following equation:

   $$\mathbf{V}tc_{Texternal} = \mathbf{V}_{meter} - \mathbf{V}tc_{Tref}$$

   where:

   $\mathbf{V}_{meter}$ is the actual voltmeter reading and $\mathbf{V}tc_{Tref}$ is the voltage across the selected thermocouple type at the terminal module temperature ($_{Tref}$). This voltage must be evaluated from tabular data for the selected thermocouple.

   b. Evaluate the actual thermocouple temperature using the $\mathbf{V}tc_{Texternal}$ value and the tabular data for the selected thermocouple.

5. Compute the compensated voltage (V) by the formula: V=(Vt-Vref).

6. Convert the compensated voltage (V) calculated in step 4 to temperature. This is the actual temperature measured by the thermocouple.

Scanning Channels Using the Analog Bus

Scanning the Multiplexer Module channels consists of closing a channel and its associated bank analog bus tree relay. You can make a single scan through the channel list or scan a multiple number of times. You also can scan the channel list continuously until the scan is aborted.

The TRIGger:SOURce command specifies the source to advance the scan. The OUTPut command can be used to enable the HP E1406A Command Module's “Trig Out” port, TTL Trigger bus line (0-7) or ECL Trigger bus lines (0-1). Figure 2-6 illustrates the commands in the scanning sequence.

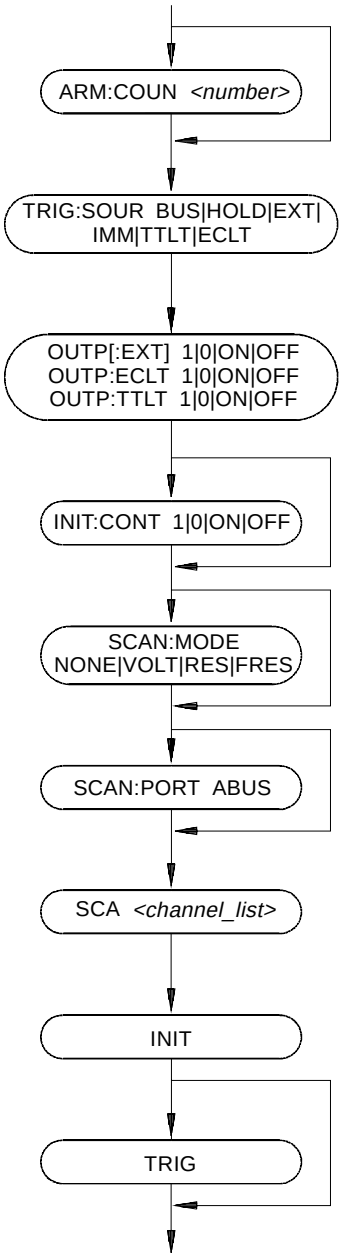


Figure 2-6. Command Sequence for Scanning Channels

You can scan a channel or a list of channels using the SCAN command. The tree relays listed in "Table 2-2. Tree Relay Descriptions" on page 39 are automatically switched when you specify the command SCAN:PORTABUS. This command is required for the tree relays to function during the scan through the channel list. The default value is SCAN:PORT NONE which does not allow these relays to operate and connect channels to the analog bus.

At power-on or after resetting the module with the *RST command, connection to the analog bus is disabled for scan operations. You must execute the command SCAN:PORT ABUS to enable analog bus tree relay operation. The analog bus provides access to all three wires of the channel (High, Low and Guard). Access is through the front panel analog bus connector (usually connected to other multiplexers or to the E1411A/B multimeter) or through the terminal module “VM Input” and “VMΩI” terminals.

Note Scan analog bus connections are disabled at power-on or following a module reset (*RST command). You must execute the SCAN:PORT ABUS command to enable tree relay operation (channels 90, 91 and 92) during a scan operation.

Notes on Scanning

Scanning Requirements of a Switchbox (in an HP mainframe with an HP command module). To scan modules in a switchbox, you must form a valid "SWITCHBOX" instrument as described in "Figure 2-2. Channel Switching to the Analog Bus" on page 40.

Channel List Can Be Extended Across Boundaries. For multiple module switchbox configurations, the channels to be scanned can extend across switch modules. For example, for a two module switchbox instrument, SCAN (@100:263) will scan all channels of both Multiplexer Modules.

Setting Multiple Continuous Scans. Use ARM:COUNt <*number*> to set from 1 to 32767 scans. Use INITiate:CONTinuous ON to set continuous scanning.

Tree Relay Switching. Tree relays (channels 90 through 94) are controlled automatically by the “SWITCH” driver SCAN command when used in conjunction with the SCAN:MODE or SCAN:PORT ABUS commands (see “[ROUTe:]SCAN:MODE” on page 79 and “[ROUTe:]SCAN:PORT” on page 80 for more details).

Synchronizing the Multiplexer with a Multimeter

This example uses the TTL VXIbus triggers (TTLT 0-7) to synchronize channel closures with the E1412A 6-Digit Multimeter. A 2-wire ohms measurement is performed. Measurement synchronization is attained by:

-- **HP E1406A TTL Trig In**
used by the multimeter to trigger the Multiplexer to change channels.

-- **HP E1406A TTL Trig Out**
used by the Multiplexer to trigger the voltmeter for a measurement.

-- **HP E1412A TTL Ext Trig**
used by the Multiplexer to signal the multimeter to initiate a measurement.

-- **HP E1412A TTL VM Complete**
used the multimeter to signal the Multiplexer that measurement is complete and the Multiplexer Module should change channels.

Measurement Set-Up

- E1412A has an HP-IB select code = 7, primary address = 09 and secondary address = 03 (it is addressed as 70903).
- E1476A has an HP-IB select code = 7, primary address = 09 and secondary address = 14 (it is addressed as 70914).
- Controller is an HP Series 200/300/400 Computer with HP BASIC.

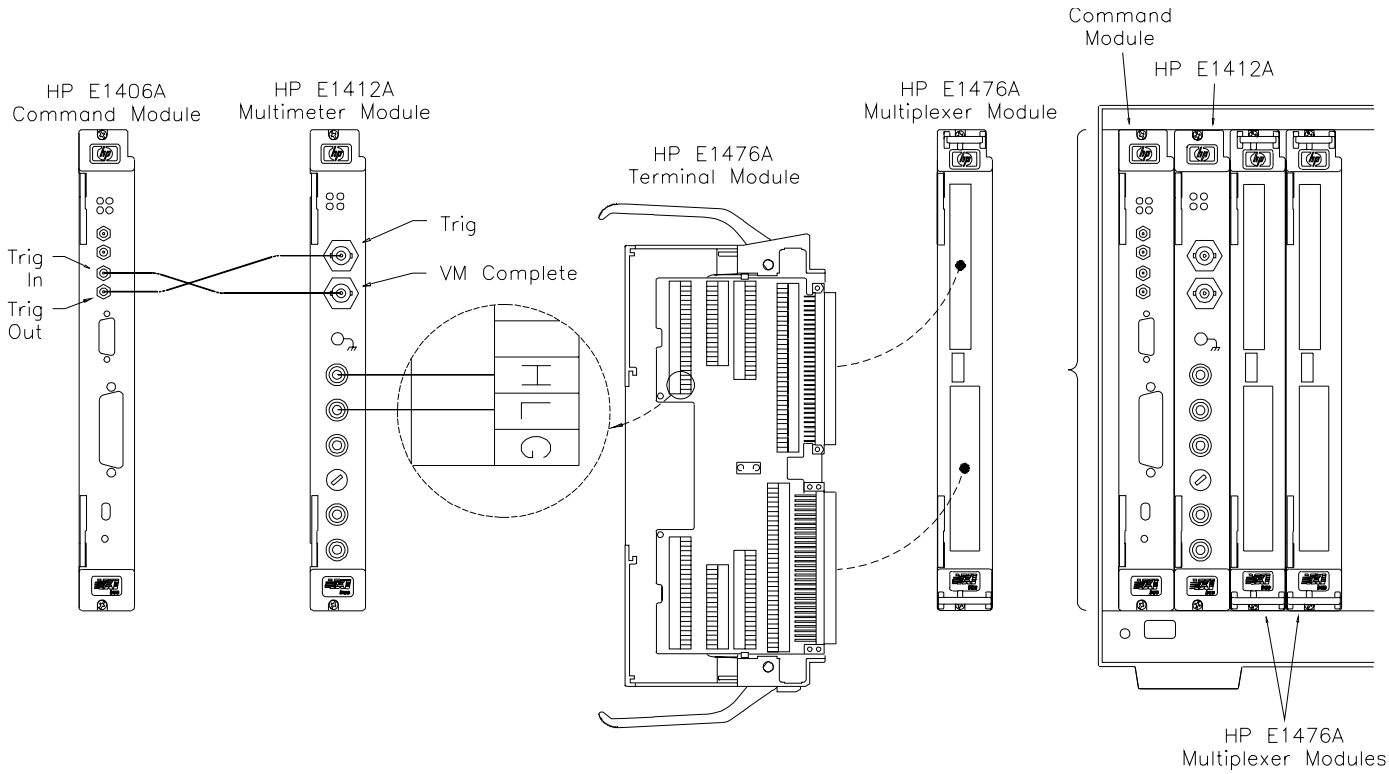


Figure 2-7. Scanning with VXIbus Triggers

```
10   !Assign Switchbox logical address.
20   ASSIGN @Switchbox TO 70914

30   !Assign Voltmeter logical address.
40   ASSIGN @Voltmeter TO 70903

50   !Dimension array for readings
60   DIM Results(1:64)
70   INTEGER Opc_value

80   !Reset voltmeter, clear status system.
90   OUTPUT @Voltmeter;"*RST;*CLS"

100  !Configure for 2-wire ohms.
110  OUTPUT @Voltmeter;"CONF:RES"

120  !Set voltmeter to receive trigger from TTLT2 line.
130  OUTPUT @Voltmeter;"TRIG:SOURTTLT2"

140  !Output VM Complete on TTLT1 line.
150  OUTPUT @Voltmeter;"OUTP:TTLT1ON"

160  !Accept 64 triggers.
170  OUTPUT @Voltmeter;"TRIG:COUN64"

180  !Pause until voltmeter is ready.
190  OUTPUT @Voltmeter;"*OPC?"

200  !Fetch the *OPC? response.
210  ENTER @Voltmeter;Opc_value

220  !Initialize multimeter; put in "wait-for-trigger" state.
230  OUTPUT @Voltmeter;"INIT"

240  !Reset switchbox, clear status system.
250  OUTPUT @Switchbox;"*RST;*CLS"

260  !Enable switchbox trigger output TTLT2.
270  OUTPUT @Switchbox;"OUTP:TTLT2ON"
280  !Set for TTLT1 trigger input.
290  OUTPUT @Switchbox;"TRIG:SOURTTLT1"

300  !Set multiplexer for 2-wire ohms.
310  OUTPUT @Switchbox;"SCAN:MODERES"

320  !Enable analog bus tree relay control during scan.
330  OUTPUT @Switchbox;"SCAN:PORTABUS"

340  !Set 64 channel scan list.
350  OUTPUT @Switchbox;"SCAN(@100:163)

360  !Pause until switch is ready.
370  OUTPUT @Switchbox;"*OPC?"

380  !Fetch the *OPC? response.
390  ENTER @Switchbox;Opc_value

400  !Initialize switch scan.
410  OUTPUT @Switchbox;"INIT"
420  !Transfer readings to output buffer
430  OUTPUT @Voltmeter;"FETC?"
440  !Read all 64 readings from voltmeter.
450  ENTER @Voltmeter;Results(*)
460  !Print the Results array (all 64 readings).
470  PRINT Results(*)
480  !Reset switch to open all channels.
490  OUTPUT @Switchbox;"*RST"
500  END
```

Using BUS Triggers with an External Device to Scan Channels

This example uses the BUS trigger (GET or *TRG) to synchronize channel closures with the HP 3457A Multimeter. A DC voltage measurement is performed. Measurement synchronization is attained by:

-- **HP E1406A TTL Trig Out**
used by the Multiplexer to trigger the multimeter for a measurement.

-- **HP 3457A TTL Ext Trig**
used by the multimeter to know when to initiate a measurement.

Measurement Set-Up

- Digital Multimeter has an HP-IB select code = 7, primary address = 22 (it is addressed as 722).
- E1476A has an HP-IB select code = 7 and primary address = 09 and secondary address = 14 (it is addressed as 70914).
- Controller is an HP Series 200/300/400 Computer with HP BASIC.

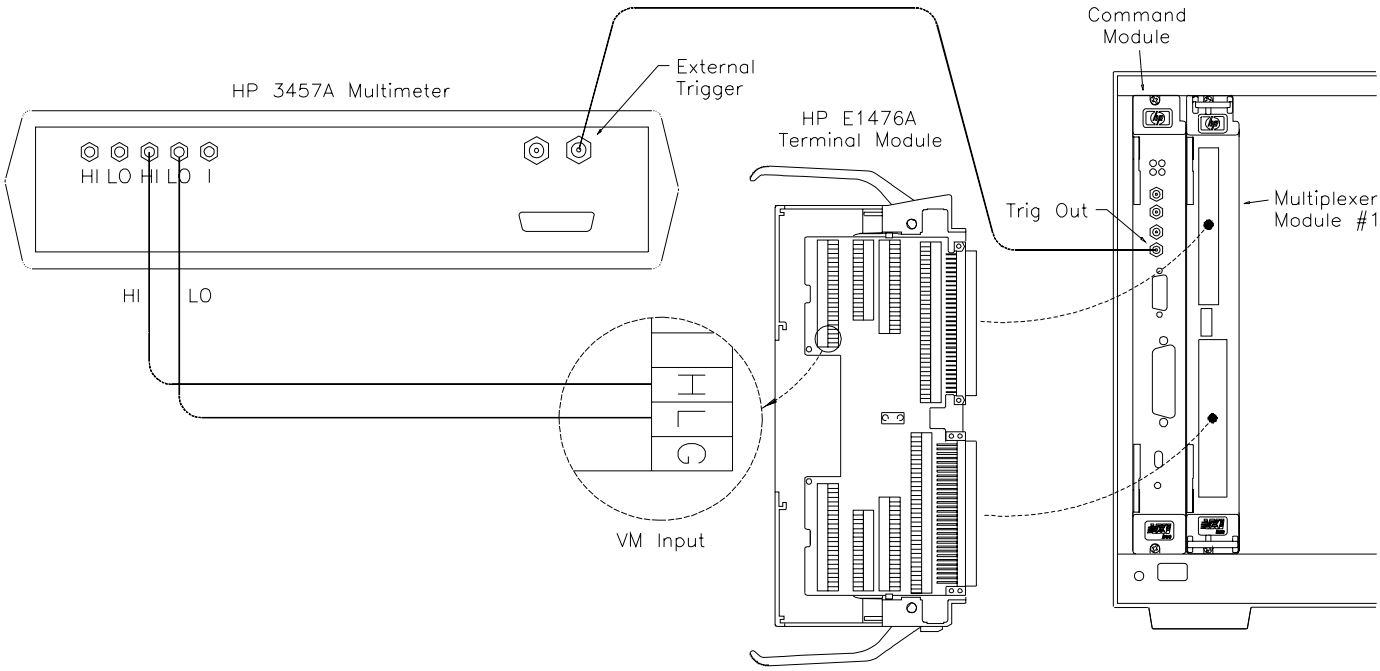


Figure 2-8. Scanning with an External Device

```
10   !Assign Switchbox logical address.
20   ASSIGN @Switchbox TO 70914

30   !Assign Voltmeter logical address.
40   ASSIGN @VM3457 TO 722
50   INTEGER Opc_value

60   !Reset voltmeter.
70   OUTPUT @VM3457;"*RESET"

80   !Set VM for external trigger.
90   OUTPUT @VM3457;"TRIG EXT"

100  !Set VM measurement mode.
110  OUTPUT @VM3457;"DCV"

120  !Enable VM reading memory mode.
130  OUTPUT @VM3457;"MEM FIFO"

140  !Reset the switch.
150  OUTPUT @Switchbox;"*RST;*CLS"

160  !Enable the switchbox trigger output.
170  OUTPUT @Switchbox;"OUTPON"

180  !Set switchbox to be triggered by the bus.
190  OUTPUT @Switchbox;"TRIG:SOURBUS"

200  !Set switchbox to scan in voltage mode.
210  OUTPUT @Switchbox;"SCAN:MODEVOLT"

220  !Enable ABUS tree switch control during scan.
230  OUTPUT @Switchbox;"SCAN:PORTABUS"

240  !Set scan list for all 64 channels.
250  OUTPUT @Switchbox;"SCAN(@100:163)"

260  !Start the scan.
270  OUTPUT @Switchbox;"INIT"

280  !Pause until switchbox is set up.
290  OUTPUT @Switchbox;"*OPC?"

300  !Read response to *OPC? command.
310  ENTER @Switchbox;Opc_value

320  !Read the first VM reading.
330  ENTER @VM3457;Results

340  !Print first reading.
350  PRINT "Channel 0",Results

360  !Set up loop for other 63 channels.
370  FOR Chan = 1 TO 63

380  !Trigger switchbox to change channels.
390  OUTPUT @Switchbox;"*TRG"

400  !Enter VM measurement result.
410  ENTER @VM3457;Results

420  !Print results.
430  PRINT "Channel",Chan,Results

440  !Loop back for next channel.
450  NEXT Chan

460  !Reset the switchbox to open all channels.
470  OUTPUT @Switchbox;"*RST"
480  END
```

Example: Using the Scan Complete Bit

The scan complete bit (bit 8) can be used in the Operation Status Register of the "SWITCHBOX" driver to determine when a scanning cycle completes. Bit 8 has a decimal value of 256 and you can read it directly with the STAT:OPER? command (refer to the STATus:OPERation[:EVENt]? command on page 77 for an example).

The scan complete bit will be reported as bit 7 of the Status Register when it is enabled by the STAT:OPER:ENAB 256 command. Use the HP-IB Serial Poll or the IEEE 488.2 Common Command *STB? to read the Status Register.

The following example monitors bit 7 in the Status Register to determine when the scanning cycle completes. The example uses:

- an HP-IB select code of 7, primary address of 09, and secondary address of 14 for the Multiplexer.
- an HP Series 200/300 Computer with HP BASIC.

```
 10   !Clear to talk to the switch.
 20   OUTPUT70914;"*CLS"
 30   !Set so scan complete causes an event.
 40   OUTPUT70914;"STAT:OPER:ENAB256"
 50   !Set to external trigger mode.
 60   OUTPUT70914;"TRIG:SOUREXT"
 70   !Set scan list for 64 channels.
 80   OUTPUT70914;"SCAN(@100:163)"
 90   !Start scanning cycle.
100   OUTPUT70914;"INIT"
110   !Loop unit bit 7 is set.
120   WHILE NOT BIT(SPOLL(70914),7)
130   !Do other things until bit 7 is set.
140   PRINT ©DO OTHER OPERATION HERE[a]
150   ENDWHILE
160   END
```

You can interrupt the computer after a scanning cycle is finished and the scan complete bit is set if you enable bit 7 of the Status Byte Register with the *SRE 128 command. This allows the computer to do other operations while the scanning cycle is in progress.

Recalling and Saving States

This section contains information about saving and recalling a Multiplexer Module state. The switchbox driver can store up to 10 states.

Saving States

The *SAV <*numeric_state*> command saves the current instrument state. The state number (0-9) is specified in the state parameter. The following settings are saved:

Channel Relay State (channels 00 through 63 open or closed)

Control Relay States (channels 90 through 94 open or closed)

- ARM:COUNt
- TRIGger:SOURce
- OUTPut[:STATe]
- INITiate:CONTinuous
- [ROUTe:]SCAN:MODE
- [ROUTe:]SCAN:PORT

Recalling States

The *RCL <*numeric_state*> command recalls a previously saved state. Enter the number (0-9) in the state parameter of the desired saved state. If *SAV was not previously executed using the selected number, the Multiplexer Module will configure to the reset values (see "Table 2-1. HP E1476A Default Conditions for Power-on and Reset" on page 38).

Note Scan lists are not saved when a state is saved. You must re-enter your scan list after recalling a state.

Detecting Error Conditions

There are two general approaches to error checking. The simplest, but most time consuming, is to ask the instrument whether there are errors at every step of the switching process. This is called “polling” and is illustrated in the example shown below.

```
 10   DIMErr$[256]
 20   !Close channel 1.
 30   OUTPUT 70914;"CLOS(@101)"
 40   !Query for error.
 50   OUTPUT 70914;"SYST:ERR?"
 60   !Read response.
 70   ENTER 70914;Err$
 80   !If an error is found (Err$ not 0).
 90   IF VAL (Err$) > 0 THEN
100   !Print the error.
110   PRINT "Error";Err$
120   !Quit if error encountered.
130   STOP
140   END IF
150   ... (PROGRAM CONTINUES)
```

Using Interrupts With Error Checking

The second approach involves the use of interrupts. The following program is a method of checking for errors using interrupts as you program the Multiplexer. The program monitors the Multiplexer's Standard Event Status Register for an error condition. If no errors occur, the Multiplexer functions as programmed. If errors do occur, the Multiplexer interrupts the computer, and the error codes and messages are read from the error queue.

The following HP BASIC programming example has a single Multiplexer at address 70914.

```
 10   !Add your application's code here.
  .
  .
 90   !Call to print out error message.
100   ON INTR 7 CALL Errmsg
110   ENABLE INTR7:2
120   !Add your application's code here.
  .
  .
200   !Enables the standard event summary bit SRE.
210   OUTPUT 70914;"*SRE32"
220   !Enables all parser generated errors.
230   OUTPUT 70914;"*ESE60"
240   !See STATus command figure.
250   !Add your application's code here.
  .
  .
300   END
310   !Add your application's code here.
  .
  .
350   !Define interrupt service routine.

360   SUB Errmsg
370   !Declare response string.
380   DIM A$[256]
390   !Clear the multiplexer.
400   CLEAR 70914
410   !Fetch status byte.
420   B = SPOLL(70914)
430   !Repeat.
440   REPEAT
450   !Query for error.
460   OUTPUT 70914;"SYST:ERR?"
470   !Read response.
480   ENTER 70914;Code,A$
490   !Print error.
500   PRINT Code,A$
510   !Keep querying for an error until error code = 0.
520   UNTIL Code=0
530   !Clears status registers and error queue.
540   OUTPUT 70914;"*CLS"
550   STOP
560   SUBEND
```

Using the HP E1586A Rack Mount Terminal Panel

The HP E1586A Rack Mount Terminal Panel provides extended connections to the HP E1476A Multiplexer Module. The Terminal Panel is used in place of the HP E1476A Terminal Module, thus all operations previously explained in this chapter, except temperature measurements, apply to the Terminal Panel. Since the Terminal has three Thermistors to make Reference Temperature measurements, this operation is different than explained using the E1476A Terminal Module.

All channel and Analog Bus connections to make measurements have corresponding connections on the Terminal Panel. The following explains the channel and analog bus connections to the Terminal Panel and shows the connections for Reference Temperature measurements.

Channel Connections

The channels on the Terminal Panel correspond directly to the channels on the Terminal Panel. For example, the channel 2 H, L, and G connections on the Multiplexer Module have corresponding channel 2 H, L, and G connections on the Terminal Panel.

Since a single Terminal Panel has a total of 32 channels, two Terminal Panels are required to make connections to all channels of the Multiplexer Module. The Bank A channels (00-31) connect to channels 0-31 on the first Terminal Panel, and the Bank channels (32-63) connect to channels 32-63, shown in parenthesis, of the second Terminal Panel. Figure 2-9 shows the channel numbering on the HP E1586A Rack Mount Terminal Panel.

Analog Bus Connections

The Terminal Panel also provides Analog Bus connections to the Multiplexer Module. However, since the Terminal Module is used with other Modules, the Analog Bus connections are labeled different on the Terminal Panel. Figure x shows the Analog Bus connections to the Terminal Panel.

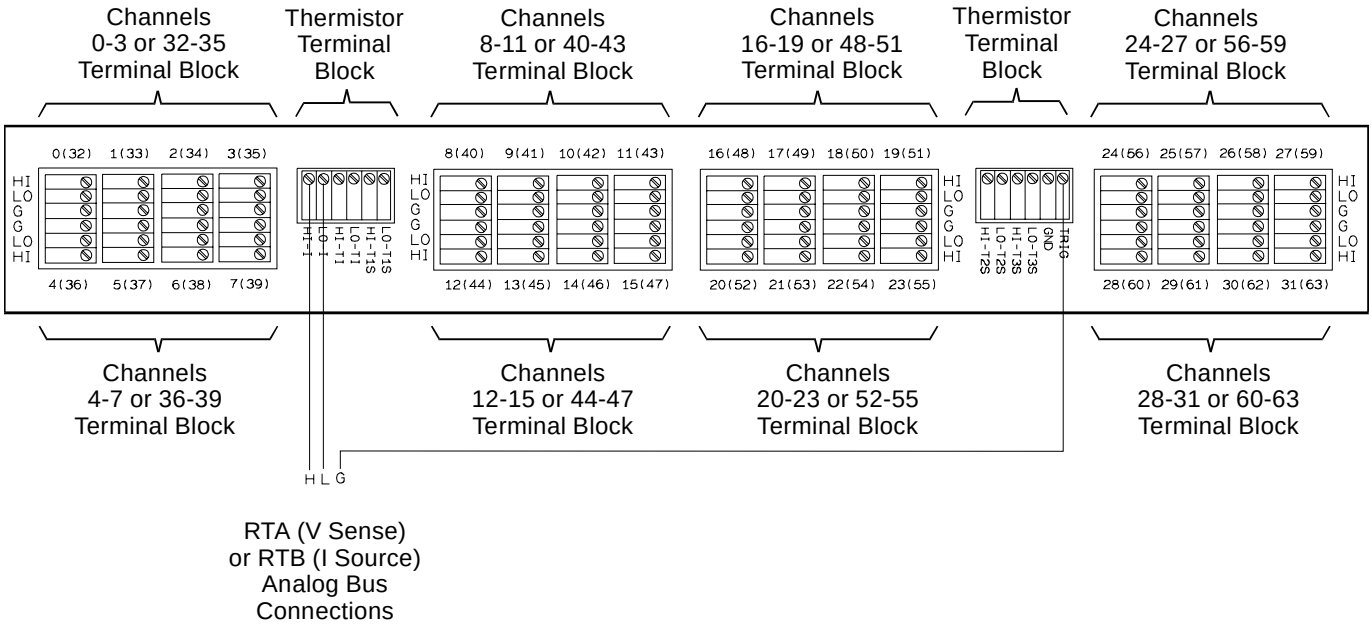


Figure 2-9. HP E1586A Rack Mount Terminal Panel Connections

Reference Thermistor Connections and Operations

The HP E1586 Terminal Panel's three thermistors are located next to the channel 3 terminal block, between channels 11 and 16, and next to channel 24 (see Figure 2-9 on page 56).

Thermistor Excitation Sources

The excitation is usually supplied by an externally connected multimeter or voltmeter, like the HP E1326/E1411 5½-Digit Multimeter. When using an E1326/E1411, the excitation is available on the Terminal Panel's terminals labeled HI-I and LO-I. The HP E1326/E1411 generates this excitation using the 2-wire or 4-wire Ohms measurement functions

Caution

If using a single HP E1326/E1411 Multimeter to supply the excitation for multiple HP E1586A Terminal Panels, the resultant voltage sum of the voltages developed across the Thermistors could exceed the compliance voltage of the Multimeter. This is especially true if attempting to excite all three Thermistors on the Terminal Panels.

The following shows how to connect the thermistors to the current source on the Analog Bus.

Connecting One Terminal Panel for Reference Temperature Measurements

In this configuration, a single Terminal Panel is used to provide up to 32 channels for temperature measurements. This provides the excitation current to all three on-board thermistors on the Terminal Panel. Figure 2-10 shows the connection for a single Terminal Panel.

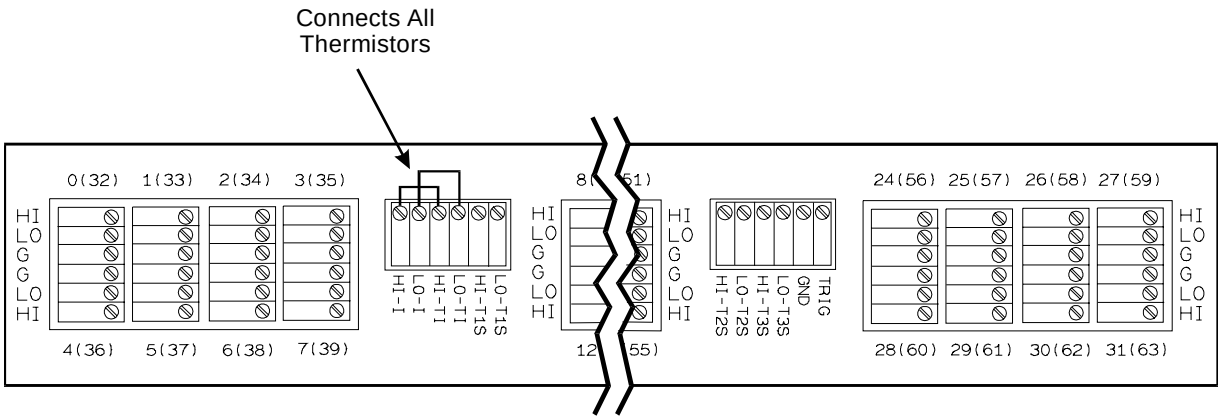
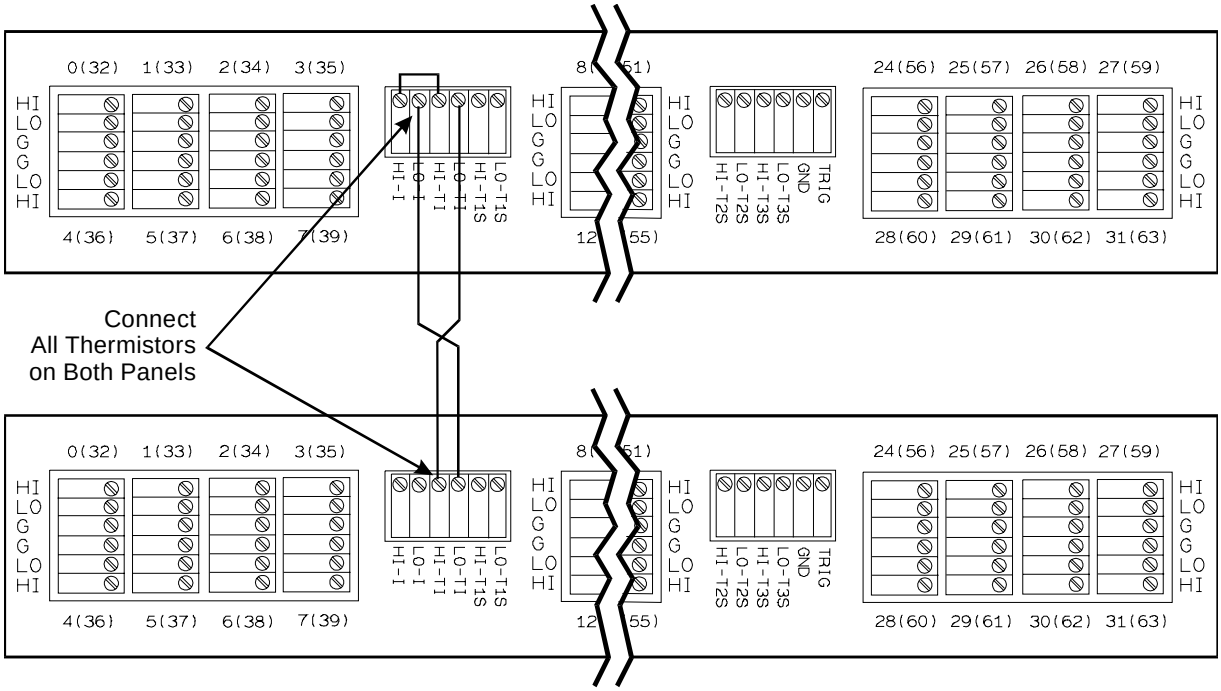


Figure 2-10. Connecting Three Thermistors on a Single Panel

Connecting Two Terminal Panels for Reference Temperature Measurements

In this configuration, two Terminal Panels are used to provide up to 64 channels for temperature measurements. This provides the excitation current to all six on-board thermistors on the Terminal Panels. Figure 2-11 shows the connection for two Terminal Panels.



Two HP E1586 Terminal Panels
using All Thermistors on Each Panel

Figure 2-11. Connecting Six Thermistors on Two Panels

Chapter 3
HP E1476A Switchbox Command Reference

Using This Chapter

This chapter describes Standard Commands for Programmable Instruments (SCPI) and summarizes IEEE 488.2 Common (*) commands applicable to the 64-Channel 3-Wire Relay Multiplexer Module when used in the switchbox configuration. This chapter contains the following sections.

Command Types

Commands are separated into two types: IEEE 488.2 Common Commands and SCPI Commands.

Common Command Format

The IEEE 488.2 standard defines the common commands that perform functions such as reset, self-test, status byte query, and so on. Common commands are four or five characters in length, always begin with the asterisk character (*), and may include one or more parameters. The command keyword is separated from the first parameter by a space character. Some examples of common commands are shown below:

```
*RST        *ESR 32     *STB?
```

SCPI Command Format

The SCPI commands perform functions like closing switches, making measurements, and querying instrument states or retrieving data. A subsystem command structure is a hierarchical structure that usually consists of a top level (or root) command, one or more lower level commands, and their parameters. The following example shows part of a typical subsystem:

```
[ROUTe:]
    CLOSe <channel_list>
    SCAN <channel_list>
        :MODE?
```

[ROUTe:] is the root command, CLOSe and SCAN are second level commands with parameters, and :MODE? is a third level command.

Command Separator

A colon (:) always separates one command from the next lower level command as shown below:

```
ROUTe:SCAN:MODE?
```

Colons separate the root command from the second level command (ROUTe:SCAN) and the second level from the third level (SCAN:MODE?).

Abbreviated Commands

The command syntax shows most commands as a mixture of upper and lower case letters. The upper case letters indicate the abbreviated spelling for the command. For shorter program lines, send the abbreviated form. For better program readability, you may send the entire command. The instrument will accept either the abbreviated form or the entire command.

For example, if the command syntax shows MEASure, then MEAS and MEASURE are both acceptable forms. Other forms of MEASure, such as MEASU or MEASUR will generate an error. You may use upper or lower case letters. Therefore, MEASURE, measure, and MeAsUrE are all acceptable.

Implied Commands

Implied commands are those which appear in square brackets ([ ]) in the command syntax. (Note that the brackets are not part of the command and are not sent to the instrument.) Suppose you send a second level command but do not send the preceding implied command. In this case, the instrument assumes you intend to use the implied command and it responds as if you had sent it. Examine the partial [ROUTe:] subsystem shown below:

```
[ROUTe:]CLOSe <channel_list>
    CLOSe? <channel_list>
    OPEN <channel_list>
    OPEN? <channel_list>
    SCAN <channel_list>
        :MODE <mode>
        :MODE?
```

The root command [ROUTe:] is an implied command. To close relays in a channel list, you can send either of the following command statements:

```
ROUT:CLOS (@100:107, 201, 225)   or   CLOS (@100:107, 201, 225)
```

These commands function the same closing channels 00 through 07 on card 1 and channels 01 and 25 on card 2.

Parameters

Parameter Types. The following table contains explanations and examples of parameter types you might see later in this chapter.

Parameter Type	Explanations and Examples
Numeric	Accepts all commonly used decimal representations of number including optional signs, decimal points, and scientific notation. 123, 123E2, -123, -1.23E2, .123, 1.23E-2, 1.23000E-01.Special cases include MINimum, MAXimum, and DEFault.
Boolean	Represents a single binary condition that is either true or false .ON, OFF, 1, 0
Discrete	Selects from a finite number of values. These parametersuse mnemonics to represent each valid setting. An example is the TRIGger:SOURce <*source*> command where source can be BUS, EXT, HOLD, or IMM.

Optional Parameters. Parameters shown within square brackets ([ ]) are optional parameters. (Note that the brackets are not part of the command and are not sent to the instrument.) If you do not specify a value for an optional parameter, the instrument chooses a default value. For example, consider the ARM:COUNt?[<MIN | MAX>] command. If you send the command without specifying a parameter, the present ARM:COUNt setting is returned. If you send the MIN parameter, the command returns the minimum count available. If you send the MAX parameter, the command returns the maximum count available. Be sure to place a space between the command and the parameter.

Linking Commands

Linking IEEE 488.2 Common Commands with SCPI Commands. Use a semicolon between the commands. For example:

```
*RST;OUTP  ON    or   TRIG:SOUR  HOLD;*TRG
```

Linking Multiple SCPI Commands. Use both a semicolon and a colon between the commands. For example:

```
ARM:COUN1;:TRIG:SOUR  EXT
```

SCPI Command Reference

This section describes the Standard Commands for Programmable Instruments (SCPI) commands for the E1476A Multiplexer Module. Commands are listed alphabetically by subsystem and also within each subsystem.

There are two ways to send commands to the instrument. The most often used way is from a controller over the HP-IB interface, this method will be referred to as the “HP-IB interface” in the following command reference. The second way to send commands is from a terminal connected to the HP E1405/1406 command module (RS-232). Commands sent this way will be referred to as “from the terminal” in the following command reference.

The ABORt command stops a scan in progress when the trigger sources are either TRIGger:SOURceBUS or TRIGger:SOURceHOLD. See the comments below for how to get out of a scan if trigger source is not BUS or HOLD.

Subsystem Syntax

```
ABORt
```

Comments

- **Channel Status After an ABORt:** Aborting a scan will leave the last channel it closed in the closed position.
- **Affect on Scan Complete Status Bit:** Aborting a scan will not set the "scan complete" status bit.
- **Stopping Scans Enabled from HP-IB Interface:** When a scan is enabled from the HP-IB interface, and the trigger source is not HOLD or BUS, you can clear the interface to stop the scan. In the BASIC programming language, this is done by executing the CLEAR command for your interface (CLEAR 7, for example).When the scan is enabled from the HP-IB interface and the trigger source is TRIGger:SOURceBUS or TRIGger:SOURceHOLD, send the ABORt command over the HP-IB bus.

Note

Clearing the HP-IB interface during a scan leaves the last channel the scan closed in the closed position and does not set the "scan complete" status bit.

- **Stopping Scans by using the terminal:** You may use a terminal connected to the HP E1405/1406 command module to stop any scan.

  If the scan was started from the terminal, and the trigger source is HOLD or BUS, send the ABORt command to halt the scan. If the scan was started from the terminal and some other trigger source is being used, a **Ctrl-c** will send an interface CLEAR to the instrument and abort the scan. Sending **Ctrl-r** also sends an interface CLEAR to the instrument and additionally performs a reset (*RST) on the instrument. (See your *HP E1405/E1406 Command Reference* for details on the terminal interface.)

  If the scan was started from the HP-IB interface, but you wish to stop it by using the terminal, first make sure that the correct instrument (e.g.,SWITCH at desired logical address) is selected by using the terminal soft keys. Then send a **Ctrl-r**. This will send an interface CLEAR to the HP-IB task, but will not place the instrument in the reset state with respect to the HP-IB task. These actions will occur regardless of the trigger source setting.

Note Clearing the interface using a **Ctrl-c** from the terminal during a scan leaves the last channel it closed in the closed position and does not set the "scan complete" status bit.

- **Related Commands:** ARM, INITiate:CONTinuous, [ROUTe:]SCAN, TRIGger

Example

Stopping a Scan with ABORt

```
TRIG:SOUR  BUS                  Bus is trigger source.
INIT:CONT  ON                   Set continuous scanning.
SCAN  (@100:115)                Set channel list.
INIT                            Start scanning cycle.
 .
 .
ABOR                            Abort scan in progress.
```

The ARM subsystem allows a scan list to be scanned multiple times (1 through 32,767) with one INITiate command.

Subsystem Syntax

```
ARM
    :COUNt  <number>  MIN|MAX
    :COUNt?  [<MIN|MAX>]
```

ARM:COUNt

ARM:COUNt *<number>* MIN|MAX allows scanning cycles to occur a multiple of times (1 to 32,767) with one INITiate command when INITiate:CONTinuousOFF|0 is set. MIN sets 1 cycle and MAX sets 32,767 cycles.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<number>	numeric	1 - 32,767 | MIN | MAX	1

Comments

- **Number of Scans:** Use only values between 1 (MIN) to 32767 (MAX) for the number of scanning cycles.
- **Related Commands:** ABORt, INITiate[:IMMediate], INITiate:CONTinuous
- ***RST Condition:** ARM:COUNt1

Example

Setting Ten Scanning Cycles

```
ARM:COUN  10          Set 10 scanning cycles.
SCAN  (@100:115)      Set channel list.
INIT                  Start scanning cycle.
```

ARM:COUNt?

ARM:COUNt? [<MIN|MAX>] returns the current number of scanning cycles set by ARM:COUNt. If a value between MIN and MAX is set, that value for ARM:COUNt is returned. The optional parameters MIN and MAX allow you to query the module for these values instead of looking them up in the command reference. “1” is returned for the MIN parameter; “32767” is returned for the MAX parameter regardless of the ARM:COUNt value set.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<MIN | MAX>	numeric	MIN = 1, MAX = 32,767	current cycles

Comments

- **Related Commands:** INITiate[:IMMediate]

Example

Query Number of Scanning Cycles

```
ARM:COUN  55          Set 10 scanning cycles.
ARM:COUN?             Query number of scanning cycles;
                      returned value is 55.
```

The DISPlay subsystem monitors the channel state of a selected module (or card) in a switchbox. The DISPlay command subsystem only operates with a RS-232 terminal connected to the HP E1405/1406 command module's RS-232 port. These commands control the display on the terminal, and would in most cases be typed directly from the terminal keyboard. It is possible however, to send these commands over the HP-IB interface, and control the terminal's display. In this case, care must be taken that the instrument receiving the DISPlay command is the same one that is currently selected on the terminal; otherwise, the HP-IB command will have no visible affect.

Subsystem Syntax

```
DISPlay
    :MONitor
        :CARD  <number> | AUTO
        :CARD?
        [:STATe]  <mode>
        [:STATe]?
```

DISPLay:MONitor:CARD

DISPlay:MONitor:CARD *<number>* | AUTO selects the module in a switchbox to be monitored. NOTE: You must use DISP:MON:STAT ON to actually display the monitored module state to the RS-232 terminal.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<number> | AUTO	numeric	1 - 99	AUTO

Comments

- **Selecting a Specific Module to be Monitored:** Send the card number in a switchbox with the DISPlay:MONitor:CARD command.
- **Selecting the Present Module to be Monitored:** Use the DISPlay:MONitor:CAR DAUTO command to select the last module addressed by a switching command ([ROUTe:]CLOSe, for example).
- ***RST Conditions:** DISPlay:MONitor:CARD AUTO

Example

Select Module #2 in a Switchbox for Monitoring

```
DISP:MON:CARD 2          Select module #2 in a switchbox.
```

DISPLay:MONitor:CARD?

DISPlay:MONitor:CARD? queries the setting of the DISPlay:MONitor:CARD command and returns the module in a switchbox to be monitored.

DISPLay:MONitor[:STATe]

DISPlay:MONitor[:STATe] <mode> turns the monitor mode ON or OFF. When monitor mode is on, the RS-232 terminal display presents an array of values indicating the open/close state of every switch on the module. This display is dynamically updated each time a switch is opened or closed.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<mode>	boolean	ON | OFF | 1 | 0	OFF | 0

Comments

- **Monitoring Switchbox Channels:** DISPlay:MONitor:STATe ON or DISPlay:MONitor:STATe 1 turns the monitor mode ON to show the channel state of the selected module.

  DISPlay:MONitor:STATe OFF or DISPlay:MONitor:STATe 0 turns the channel monitor OFF.

- Typing in another command on the terminal will cause the DISPlay:MONitor[:STATe] to automatically be set to OFF (0).
  NOTE: Use of the OFF parameter is useful only if the command is issued across the HP-IB interface.

- **Selecting the Module to be Monitored:** Use the DISPlay:MONitor:CARD *<number>* AUTO command to select the module.

- **Monitor Mode on an HP E1405/1406 Command Module Display:** A typical display for the HP E1476A 64-Channel Multiplexer with all channels (that is, all relays) closed follows. The "#H" indicates data is in hexadecimal format. Each channel is represented as a bit in the hex value. The channels are grouped into four blocks of 16 channels each. The tree relays (channels 90 - 94) are in the fifth group.

  15-0 #HFFFF 31-16 #HFFFF 47-32 #HFFFF 63-48 #HFFFF 94-90 #H1F

  Closing only channel 3 would appear as 15-0: #H0008.

- ***RST Condition:** DISPlay:MONitor[:STATe] OFF|0. A *RST also opens all switches on the card. A DISP:MON ON command following a *RST will display the following:

  15-0 #H0000 31-16 #H0000 47-32 #H0000 63-48 #H0000 94-90 #H00

Example

Enabling the Monitor Mode

```
DISP:MON:CARD 2          Select module #2 in a switchbox.
DISP:MON 1               Turn the monitor mode on.
```

DISPLay:MONitor[:STATe]?

DISPlay:MONitor[:STATe]? queries the monitor mode. The command returns a “1” if monitor mode is on or a “0” if monitor mode is off.

The INITiate command subsystem selects continuous scanning cycles and starts the scanning cycle.

Subsystem Syntax

```
INITiate
    :CONTinuous <mode>
    :CONTinuous?
    [:IMMediate]
```

INITiate:CONTinuous

INITiate:CONTinuous *<mode>* enables or disables continuous scanning cycles for the switchbox.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<mode>	boolean	ON | OFF | 1 | 0	OFF | 0

Comments

- **Continuous Scanning Operation:** Continuous scanning is enabled with the INITiate:CONTinuous ON or INITiate:CONTinuous 1 command. Sending the INITiate:IMMediate command closes the first channel in the channel list. Each trigger from the trigger source specified by the TRIGger:SOURce command advances the scan through the channel list. A trigger at the end of the channel list closes the first channel in the channel list and the scan cycle repeats.
- **Noncontinuous Scanning Operation:** Noncontinuous scanning is enabled with the INITiate:CONTinuous OFF or INITiate:CONTinuous 0 command. Sending the INITiate:IMMediate command closes the first channel in the channel list. Each trigger from the trigger source specified by the TRIGger:SOURce command advances the scan through the channel list. A trigger at the end of the channel list opens the last channel in the list and the scanning cycle stops.
- The INITiate:CONTinuous command does not start a scanning cycle (see INITiate[:IMMediate] on page 70).
- **Stopping Continuous Scan:** See the ABORt command on page 62.
- Related Commands: ABORt, ARM:COUNt, INITiate[:IMMediate], TRIGger:SOURce
- ***RST Condition:** INITiate:CONTinuous OFF|0

Example Enabling Continuous Scans

```
INIT:CONT  ON          Enable continuous scanning.
SCAN  (@100:163)       Set channel list.
INIT                   Start scanning cycle.
```

INITiate:CONTinuous?

INITiate:CONTinuous? queries the scanning state. With continuous scanning enabled, the command returns “1” (ON). With continuous scanning disabled, the command returns “0” (OFF).

Example Query Continuous Scanning State

```
INIT:CONT  ON          Enable continuous scanning.
INIT:CONT?             Query continuous scanning state.
```

INITiate[:IMMediate]

INITiate[:IMMediate] starts the scanning process and closes the first channel in the channel list. Successive triggers from the source specified by the TRIGger:SOURce command advances the scan through the channel list.

Comments

- **Starting the Scanning Cycle:** The INITiate:IMMediate command starts scanning by closing the first channel in the channel list. Each trigger received advances the scan to the next channel in the channel list. An invalid channel list generates an error (see [ROUTe:]SCAN on page 77).
- **Stopping Scanning Cycles:** See the ABORt command on page 62.
- **Related Commands:** ABORt, ARM:COUNt, INITiate:CONTinuous, TRIGger, TRIGger:SOURce
- ***RST Condition:** None

Example Starting a Single Scan

```
SCAN  (@100:163)       Set channel list.
INIT                   Start scanning cycle by closing channel
                       00 and proceeding.
```

The OUTPut command subsystem enables one trigger line of the HP E1405A/B or E1406A Command Module. It also can disable the active line.

Subsystem Syntax

```
OUTPut
    :ECLTrgn (:ECLTrg0 or :ECLTrg1
        [:STATe]  <mode>
        [:STATe]?
    [:EXTernal
        [:STATe]  <mode>
        [:STATe]?
    :TTLTrgn (:TTLTrg0 through :TTLTrg7
        [:STATe]  <mode>
        [:STATe]?
```

OUTPut:ECLTrg*n*[:STATe]

OUTPut:ECLTrg*n*[:STATe] *<mode>* enables (ON or 1) or disables (OFF or 0) the ECL trigger bus pulse on the VXI bus line specified by n. There are two ECL trigger lines on the VXI bus allowing valid values for n to be 0 and 1. “mode” enables (ON or 1) or disables (OFF or 0) the specified ECL Trigger bus line.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
n	numeric	0 or 1	N/A
<mode>	boolean	0 | 1 | OFF | ON	OFF | 0

Comments

- When OUTPut:ECLTrg*n*:STATe ON is set, a trigger pulse occurs each time a channel is closed during a scan.

OUTPut:ECLTrgn[:STATe]?

OUTPut:ECLTrg*n*[:STATe]? queries the state of the ECL trigger bus line specified by n. A “1” is returned if the line is enabled; a “0” is returned if it is disabled. Valid values for n are 0 and 1.

OUTPut[:EXTernal][:STATe]

OUTPut[:EXTernal][:STATe] *<mode>* enables or disables the “Trig Out” port on the HP E1406A command module.

- OUTPut[:EXTernal][:STATe] ON|1 enables the port
- OUTPut[:EXTernal][:STATe] OFF|0 disables the port.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<mode>	boolean	ON | OFF | 1 | 0	OFF | 0

Comments

- **Abbreviated Syntax:** OUTPut subsystem commands :EXTernal and :STATe are optional subcommands. The OUTPut command can be abbreviated by simply executing OUTPut ON or OUTPut OFF.
- Enabling "Trig Out" Port: When enabled, the "Trig Out" is pulsed each time a channel is closed during scanning. When disabled, the "Trig Out" is not pulsed.
- Output Pulse: The pulse is a +5 V negative-going pulse.
- **"Trig Out" Port Shared by Switchboxes:** Once enabled, the "Trig Out" port may be pulsed by the switchbox each time a channel is closed in a switchbox during scanning. To disable the output for a specific switchbox, send the OUTPut[:EXTernal][:STATe] OFF or OUTPut[:EXTernal][:STATe] 0 command for that switchbox. The OUTP OFF command must be executed following use of this port to allow other instrument drivers to control the "Trig Out" port.
- **Related Commands:** [ROUTe:]SCAN, TRIGger:SOURce
- ***RST Condition:** OUTPut:EXTernal[:STATe] OFF (port disabled)

Example **Enabling "Trig Out" Port**

```
OUTP ON                    Enable "Trig Out" port for pulse output.
```

OUTPut[:EXTernal][:STATe]?

OUTPut[:EXTernal][:STATe]? queries the present state of the "Trig Out" port on the E1405/E1406. The command returns "1" if the port is enabled, or "0" if disabled.

Example **Query "Trig Out" Port State**

```
OUTP ON                    Enable "Trig Out" port for pulse output.
OUTP:STAT?                 Query port enable state.
```

OUTPut:TTLTrgn[:STATe]

OUTPut:TTLTrg*n*[:STATe] *<mode>* selects and enables which TTL Trigger bus line (0 to 7) will output a trigger when a channel is closed during a scan. This is also used to disable a selected TTL Trigger bus line. "*n*" specifies the TTL Trigger bus line (0 to 7) and "mode" enables (ON or 1) or disables (OFF or 0) the specified TTL Trigger bus line.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
n	numeric	0 to 7	N/A
<mode>	boolean	ON | OFF | 1 | 0	OFF | 0

Comments

- When OUTPut:TTLTrg*n*:STATe ON is set, a trigger pulse occurs each time a channel is closed during a scan.
- **Related Commands:** [ROUTe:]SCAN, TRIGger:SOURce, OUTPut:TTLTrgn[:STATe]?
- ***RST Condition:** OUTPut:TTLTrg*n*[:STATe] OFF (disabled)

Example

Enabling TTL Trigger Bus Line 7

```
OUTP:TTLT7:STAT 1
```

Enable TTL Trigger bus line 7 to output pulse after each scanned channel is closed.

OUTPut:TTLTrgn[:STATe]?

OUTPut:TTLTrg*n*[:STATe]? queries the present state of the specified TTL Trigger bus line. The command returns “1” if the specified TTLTrg bus line is enabled or “0” if disabled.

Example

Query TTL Trigger Bus Enable State

This example enables TTL Trigger bus line 7 and queries the enable state. The OUTPut:TTLTrgn? command returns “1” since the port is enabled.

```
OUTP:TTLT7:STAT 1
OUTP:TTLT7?
```

Enable TTL Trigger bus line 7.
Query bus enable state.

The [ROUTe:] command subsystem controls switching and scanning operations for the Multiplexer Modules in a switchbox.

Subsystem Syntax

```
[ROUTe:]
    CLOSe <channel_list>
    CLOSe? <channel_list>
    OPEN <channel_list>
    OPEN? <channel_list>
    SCAN <channel_list>
        :MODE <mode>
        :MODE?
    :PORT <port>
```

[ROUTe:]CLOSe

[ROUTe:]CLOSe *<channel_list>* closes multiplexer channels specified in the channel_list. Channel_list is in the form (@ccnn), (@ccnn,ccnn), or (@ccnn:ccnn) where cc = card number (00-99) and nn = channel number (00-63 and 90-94).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<channel_list>	numeric	cc00 - cc31, cc90 - cc94	N/A

Comments

- **Closing Channels:** To close:

  -- a single channel use ROUT:CLOS (@ccnn);
  -- multiple channels use ROUT:CLOS (@ccnn,ccnn,...);
  -- sequential channels use ROUT:CLOS (@ccnn:ccnn);
  -- groups of sequential channels use ROUT:CLOS (@ccnn:ccnn,ccnn:ccnn);
  -- or any combination of the above.

  Closure order for multiple channels with a single command is not guaranteed. A list of channels will not all close simultaneously. The order channels close when specified from a single command is not guaranteed. Use sequential CLOSe commands if needed.

- **Special Case of Using Upper Range 99 in the Channel List:** Specifying the last channel as 99 e.g., (@100:199) automatically closes all channels on the card number specified by cc including tree relays 90 through 94 (see following table for tree relay information).

- **Closing the VSA, VSB, CS, RTA and RTB Tree Relays:**

Tree Relay Name	Channel Number	Tree RelayFunction
VSA	90	Connects bank A to the voltage sense bus
VSB	91	Connects bank B to the voltage sense bus
CS	92	Connects bank B to the current source bus
RTA	93	Connects reference thermistor to bank A
RTB	94	Connects reference thermistor to bank B

- **Closing VSA and/or VSB Tree Relays:** Closing tree relays VSA and/or VSB is typically required for most uses of this multiplexer. This connects channels to the voltage sense lines of the analog bus. See "Figure 3-1. HP E1476A Multplexer Module Status System" on page 82 for VSA and VSB connections to the analog bus.

- **Closing the CS Tree Relay:** Closing the CS tree relay connects channels in bank B to the current source lines of the analog bus. This is required for four-wire measurements.

- **Related Commands:** [ROUTe:]OPEN, [ROUTe:]CLOSe?

- ***RST Condition:** All multiplexer channels are open.

Example Closing Multiplexer Channels

This example closes channel 00 of a card number 1 Multiplexer Module and channel 15 of a card number 2 Multiplexer Module in a single switchbox.

```
CLOS (@100,215)
```

Close channels 100 and 215. 100 closes channel 00 of multiplexer #1; 215 closes channel 15 of multiplexer #2.

[ROUTe:]CLOSe?

[ROUTe:]CLOSe? ***<channel_list>*** returns the current state of the channel(s) queried. Channel_list is in the form (@ccnn). The command returns “1” if the channel is closed or returns “0” if the channel is open. If a list of channels is queried, a comma delineated list of 0 or 1 values is returned in the same order of the channel list.

Comments

- **Query is Software Readback:** The ROUTe:CLOSe? command returns the current state of the hardware controlling the specified channel. It does not account for a failed switch element or a relay closed by direct register access (see Appendix B).

Example Query Multiplexer Channel Closure

```
CLOS (@100,215)          Close channels 100 and 215.
CLOS? (@215)             Query channel 215.
```

[ROUTe:]OPEN

[ROUTe:]OPEN *<channel_list>* opens the multiplexer channels specified in the channel_list. The channel_list is in the form (@ccnn), (@ccnn,ccnn), or (@ccnn:ccnn) where cc = card number (00-99) and nn = channel number (00-63, 90-94 and 99). Channel numbers 95, 96, 97 and 98 will generate an error.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<channel_list>	numeric	cc00 - cc63, cc90 - cc94	N/A

Comments

- **Using Upper Range 99 in the Channel List:** Specifying the last channel as 99, e.g., (@100:199), automatically opens all channels on the card number specified by cc including tree relays 90 through 94.
- **Opening Channels:** To open:

  -- a single channel use ROUT:OPEN (@ccnn);
  -- multiple channels use ROUT:OPEN (@ccnn,ccnn,...);
  -- sequential channels use ROUT:OPEN (@ccnn:ccnn);
  -- groups of sequential channels use ROUT:OPEN (@ccnn:ccnn,ccnn:ccnn);
  -- or any combination of the above.

  Opening order for multiple channels with a single command is not guaranteed. A list of channels will not all open simultaneously. Use sequential OPEN commands if needed.
- **Opening the VSA, VSB, CS, RTA and RTB Tree Relays:** Use channel numbers 90, 91, 92, 93 and 94 to open the VSA (ch 90), VSB (ch 91), CS (ch 92), RTA (ch 93) and RTB (ch94) Tree Relays. See [ROUTe:]CLOSe for a table describing these channels.
- **Related Commands:** [ROUTe:]CLOSe, [ROUTe:]OPEN?
- ***RST Condition:** All channels open.

Example Opening Multiplexer Channels

This example opens channel 00 of a card number 1 Multiplexer Module and channel 63 of a card number 2 Multiplexer Module in a single switchbox.

```
OPEN (@100,263)          Open channels 100 and 263. 100 opens
                         channel 00 of multiplexer #1; 263 opens
                         channel 63 of multiplexer #2.
```

[ROUTe:]OPEN?

[ROUTe:]OPEN? ***<channel_list>*** returns the current state of the channel(s) queried. Channel_list has the form (@ccnn). The command returns "1" if the channel is open or returns "0" if the channel is closed. If a list of channels is queried, a comma delineated list of 0 or 1 values is returned in the same order of the channel list.

Comments

- **Query is Software Readback:** The ROUTe:OPEN? command returns the current state of the hardware controlling the specified channel. It does not account for a failed switch element.

Example

Query Multiplexer Channel Open State

```
OPEN  (@100,263)        Open channels 100 and 263. 100 opens
                        channel 00 of multiplexer #1; 263 opens
                        channel 63 of multiplexer #2.
OPEN?  (@263)           Query channel 263
```

[ROUTe:]SCAN

[ROUTe:]SCAN ***<channel_list>*** defines the channels to be scanned. Channel_list is in the form (@ccnn), (@ccnn,ccnn), or (@ccnn:ccnn) where cc = card number (00-99) and nn = channel number (00-63 and 99). See the first bullet comment for explanation of using the special case of 99 in the channel list.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<channel_list>	numeric	cc00-cc63 (or cc99)	N/A

Comments

- **Special Case of Using Upper Range 99 in the Channel List:** Specifying the last channel as 99, e.g., (@100:199), automatically scans all channels on the card number specified by cc **BUT DOES NOT** close tree relays 90 through 94.
- **Defining Scan List:** When ROUTe:SCAN is executed, the channel list is checked for valid card and channel numbers. An error is generated for an invalid channel list.
- **Scanning Operation:** When a valid channel list is defined, INITiate[:IMMediate] begins the scan and closes the first channel in the channel_list. Successive triggers from the source specified by TRIGger:SOURce advance the scan through the channel list.
- **Four-Wire Resistance Scanning:** ROUTe:SCAN:MODE FRES restricts the valid channel list (see [ROUTe:]SCAN:MODE command).
- **Stopping Scan:** See the ABORt command on page 62.

- **Closing the VSA, VSB, CS, RTA and RTB Tree Relays:** The proper state of channels 90 through 94 is automatically controlled by the firmware during a scan and is based on the settings of ROUTe:SCAN:PORT and ROUTe:SCAN:MODE. These are invalid channels to explicitly place in a ROUTe:SCAN *<channel_list>*.

- **Related Commands:** [ROUTe:]CLOSe, [ROUTe:]OPEN, [ROUTe:]SCAN:MODE, [ROUTe:]SCAN:PORT, TRIGger, TRIGger:SOURce

- ***RST Condition:** All channels open.

Example Scanning Using External Devices

The following example shows how to scan channels using the HP E1405/1406 command module via HP-IB and an HP3457A Digital Multimeter. This example uses the command module's "Trig Out" to synchronize the Multiplexer Module in a switchbox to the multimeter. The trigger pulse from the port triggers the multimeter for a measurement. See Chapter 2 for typical user connections to the multiplexer.

The computer used in the example is an HP Series 200/300 with HP BASIC as the program language. The computer interfaces with the mainframe over HP-IB. Assumed is an HP-IB select code of 7, an HP-IB primary address of 09 and 22 for the HP E1405/E1406 command module and HP 3457A Multimeter, respectively, and an HP-IB secondary address of 14 for the switchbox.

```
 10  OUTPUT 722;"TRIG EXT;DCV"          !Set multimeter to external trigger and
                                        to measure dc volts.
 20  OUTPUT 70914;"OUTPON"              !Enable "Trig Out" port on command
                                        module.
 30  OUTPUT 70914;"TRIG:SOURBUS"        !Set switchbox to receive Bus triggers.
 40  OUTPUT 70914;"SCAN:MODEVOLT"       !Set switchbox to measure voltage
                                        during scanning.
 50  OUTPUT 70914;"SCAN:PORTABUS"       !Set switchbox to close the appropriate
                                        tree relays during scanning.
 60  OUTPUT 70914;"SCAN(@100:163)"      !Select the channel list.
 70  OUTPUT 70914;"INIT"                !Start scanning cycle.
 80  FOR I=1 TO 64                      !Start count loop.
 90     ENTER 722;A                     !Enter voltmeter reading into variable
                                        A.
100     PRINT A                         !Print reading in variable A.
110     TRIGGER 70914                   !Trigger the switchbox to advance the
                                        channel list.
120  NEXT I                             !Increment count.
130  END
```

[ROUTe:]SCAN:MODE

[ROUTe:]SCAN:MODE *<mode>* sets the multiplexer channels defined by the [ROUTe:]SCAN *<channel_list>* command for none, volts, two-wire ohms, or four-wire ohms measurements.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<mode>	discrete	NONE | VOLT | RES | FRES	NONE

Comments

- **Order of Command Execution:** [ROUTe:]SCAN:MODE must be executed before [ROUTe:]SCAN *<channel_list>* because SCAN:MODE erases the current SCAN list.
- **NONE and VOLT Mode:** When selected, channel_list is setup for volts measurements.
- **RES Mode:** When selected, channel_list is setup for two-wire ohms measurements.
- **FRES Mode:** When selected, channel_list is setup for four-wire ohms measurements. Only Bank A channel numbers can be scanned in the FRES mode (each Bank A channel is paired with a Bank B channel to comprise four wires). Use only channels 00 to 31 when specifying the channels with the [ROUTe:]SCAN *<channel_list>* command that follow the SCAN:MODE command. Any channel that closes in Bank A channel automatically closes the paired channel in Bank B (e.g., if channel 0 closes, then channel 32 automatically closes along with it; as do channels 1 and 33, etc.). An error is generated if you specify a channel from Bank B (channels 32 to 63) in a channel list for the ROUT:SCAN command while the scan mode is SCAN:MODE FRES (4-wire resistance).
- **Related Commands:** [ROUTe:]SCAN
- ***RST Condition:** [ROUTe:]SCAN:MODE NONE

Example

Selecting the 4-Wire Ohms Mode

```
TRIG:SOUR EXT          Select external trigger source.
SCAN:MODE FRES         Select the 4-wire ohms scanning mode.
SCAN (@100:107)        Set channel list.
INIT                   Start scanning cycle.
```

[ROUTe:]SCAN:MODE?

[ROUTe:]SCAN:MODE? Returns the current state of the scan mode. The command returns NONE, VOLT, RES, or FRES if the scan mode is in the none, volts, two-wire ohms, or four-wire ohms measurement mode, respectively.

Example

Query Scan Mode

Since this example selects the FRES (4-wire ohms) mode, the query command returns FRES.

```
SCAN:MODE  FRES          Select the 4-wire ohms scanning mode.
SCAN:MODE?               Query the scanning mode
```

[ROUTe:]SCAN:PORT

[ROUTe:]SCAN:PORT *<port>* enables/disables the closing of the VSA, VSB, CS, RTA and RTB tree relays during scanning. SCAN:PORT ABUS allows the switch driver to close tree relays connecting channels to the analog bus and is required to make scanning measurements from the analog bus. For correct measurement switching, set the appropriate measurement mode with the ROUTe:SCAN:MODE command. ROUTe:SCAN:PORT NONE prevents closing the tree relays during scan operation (this is useful if your measurement instrument is not connected to the analog bus (see "Figure 2-3. 64 Channels of Two-wire Measurements" on page 42).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<port>	discrete	ABUS | NONE	NONE

Comments

- **Order of Command Execution:** The [ROUTe:]SCAN:PORT command can be executed after the [ROUTe:]SCAN *<channel_list>* command but must occur before the scan is initiated with the INIT command.
- ***RST Condition:** [ROUTe:]SCAN:PORT NONE. NOTE: *RST opens all switches on the card and resets the port to ROUTe:SCAN:PORT NONE. Most uses of this multiplexer will require use of ROUTe:SCAN:PORT ABUS to allow subsequent channel connection to the analog bus.

Example

Selecting the ABUS Port

```
TRIG:SOUR  EXT           Select external trigger source.
SCAN:MODE  FRES          Select the 4-wire ohms scanning mode.
SCAN:PORT  ABUS          Select the ABUS port.
SCAN  (@100:107)         Set channel list.
INIT                     Start scanning cycle.
```

The STATus subsystem reports the bit values of the Operation Status Register. It also allows you to unmask the bits you want reported from the Standard Event Register and to read the summary bits from the Status Byte Register.

Subsystem Syntax

```
STATus
    :OPERation
        :CONDition?
        :ENABle <unmask>
        :ENABle?
        [:EVENt?]
    :PRESet
```

The STATus system contains four registers (that is, they reside in a SCPI driver, not in the hardware), two of which are under IEEE 488.2 control; the Standard Event Status Register (*ESE?) and the Status Byte Register (*STB?). The operational status bit (OPR), service request bit (RQS), standard event summary bit (ESB), message available bit (MAV) and questionable data bit (QUE) in the Status Byte Register (bits 7, 6, 5, 4 and 3 respectively) can be queried with the *STB? command. Use the *ESE? command to query the "unmask" value for the Standard Event Status Register (the bits you want logically OR'd into the summary bit). The registers are queried using decimal weighted bit values. The decimal equivalents for bits 0 through 15 are included in "Figure 3-1. HP E1476A Multplexer Module Status System" on page 82.

A numeric value of 256 executed in a STAT:OPER:ENABle *<unmask>* command allows only bit 8 to generate a summary bit. The decimal value for bit 8 is 256.

The decimal values are also used in the inverse manner to determine which bits are set from the total value returned by an EVENt or CONDition query. The "SWITCH" driver exploits only bit 8 of Operation Status Register. This bit is called the scan complete bit which is set whenever a scan operation completes. Since completion of a scan operation is an event in time, you will find that bit 8 will never appear set when STAT:OPER:COND? is queried. However, you can find bit 8 set with the

STAT:OPER:EVEN? query command.

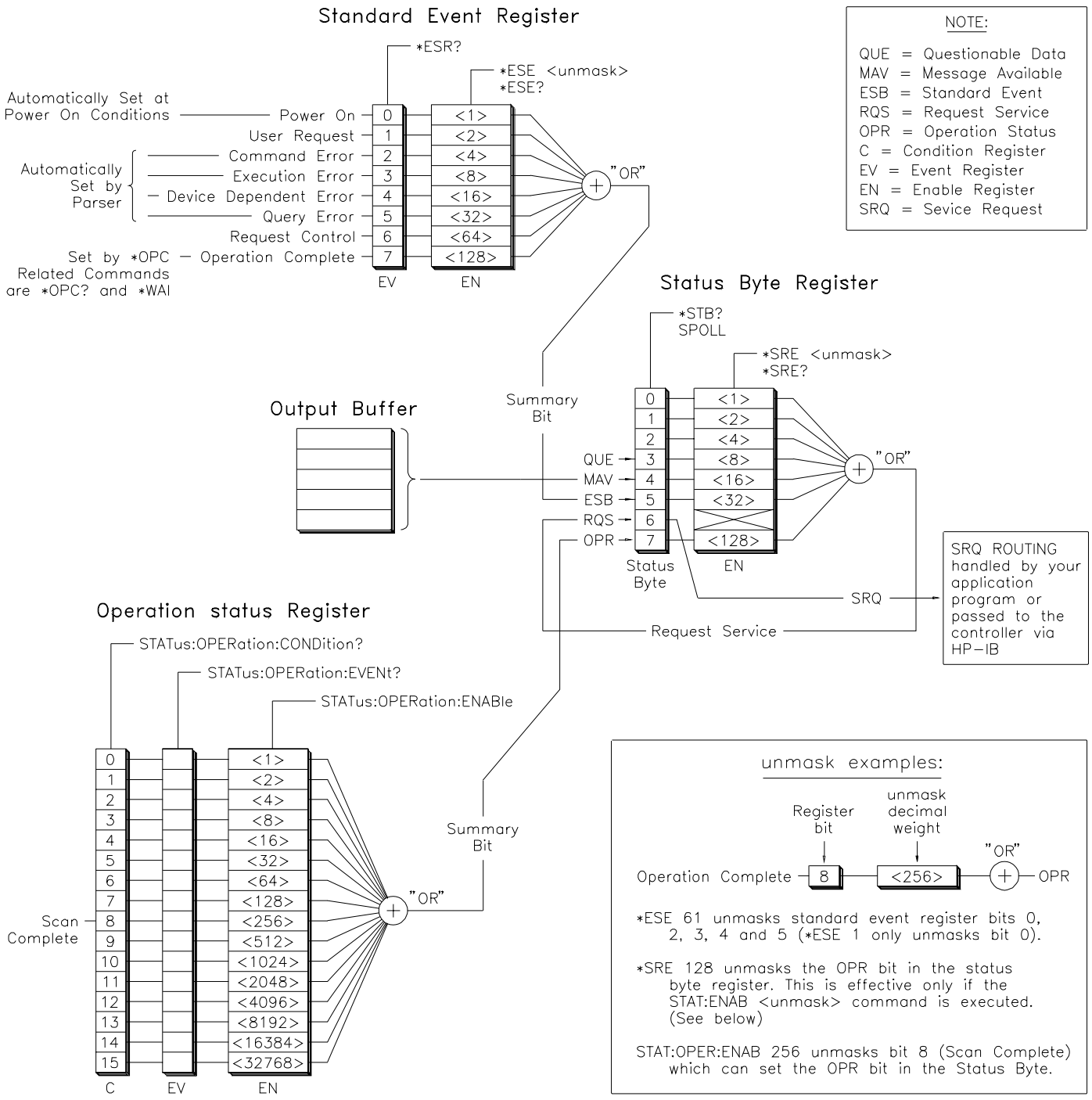


Figure 3-1. HP E1476A Multplexer Module Status System

STATus:OPERation:CONDition?

STATus:OPERation:CONDition? returns the state of the Condition Register in the Operation Status Group. The state represents conditions which are part of the instrument's operation. The “SWITCH” driver does not set bit 8 in this register (see STATus:OPERation[:EVENt]?).

STATus:OPERation:ENABle

STATus:OPERation:ENABle ***<unmask>*** sets an enable mask to allow events recorded in the Event Register to send a summary bit to the Status Byte Register (bit 7). For Multiplexer Modules, when bit 8 in the Operation Status Register is set to 1 and that bit is enabled by the STATus:OPERation:ENABle command, bit 7 in the Status Register is set to 1.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<unmask>	numeric	0 through 65,535	N/A

Comments

- **Setting Bit 7 of the Status Register:** STATus:OPERation:ENABle 256 sets bit 7 of the Status Register to 1 after bit 8 of the Operation Status Register is set to 1.
- **Related Commands:** [ROUTe:]SCAN

Example

Enabling Operation Status Register Bit 8

```
STAT:OPER:ENAB 256
```

Enable bit 8 of the Operation Status Register to be reported to bit 7 (OPR) in the Status Register.

STATus:OPERation:ENABle?

STATus:OPERation:ENABle? returns which bits in the Event Register (Operation Status Group) are unmasked.

Comments

- **Output Format:** Returns a decimal weighted value from 0 to 65,535 indicating which bits are set to true.
- **Maximum Value Returned:** The value returned is the value set by the STAT:OPER:ENAB *<unmask>* command. However, the maximum decimal weighted value used in this module is 256 (bit 8 set to true).

Example

Query the Operation Status Enable Register

```
STAT:OPER:ENAB?
```

Query the Operation Status Enable Register.

STATus:OPERation[:EVENt]?

STATus:OPERation[:EVENt]? returns which bits in the Event Register (Operation Status Group) are set. The Event Register indicates when there has been a time-related instrument event.

Comments

- **Setting Bit 8 of the Operation Status Register:** Bit 8 (scan complete) is set to 1 after a scanning cycle completes. Bit 8 returns to 0 (zero) after sending the STATus:OPERation[:EVENt]? command.
- **Returned Data after sending the STATus:OPERation[:EVENt]? Command:** The command returns "+256" if bit 8 of the Operation Status Register is set to 1. The command returns "+0" if bit 8 of the Operation Status Register is set to 0.
- **Event Register Cleared:** Reading the Event Register with the STATus:OPERation:EVENt? command clears it.
- **Aborting a Scan:** Aborting a scan will leave bit 8 set to 0.
- **Related Commands:** [ROUTe:]SCAN

Example

Reading the Operation Status Register After a Scanning Cycle

```
STAT:OPER?                  Return the bit values of the Operation
                            Status Register.
read the register value     +256 shows bit 8 is set to 1;+0 shows bit
                            8 is set to 0.
```

STATus:PRESet

STATus:PRESet affects only the Enable Register by setting all Enable Register bits to 0. It does not affect either the "status byte" or the "standard event status". PRESet does not clear any of the Event Registers.

The SYSTem subsystem returns the error numbers and error messages in the error queue of a switchbox. It can also return the types and descriptions of modules (cards) in a switchbox.

Subsystem Syntax

```
SYSTem
    :CDEScription? <number>
    :CPON <number> | ALL
    :CTYPe? <number>
    :ERRor?
```

SYSTem:CDEScription?

SYSTem:CDEScription? *<number>* returns the description of a selected module (card) in a switchbox.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<number>	numeric	1 through 99	N/A

Comments

- 6**4-Channel 3-Wire Relay Multiplexer Module Description:** The SYSTem:CDEScription? command returns:

  “64 Channel 3 Wire Relay Multiplexer”

Example

Reading the Description of a Card #1 Module

```
SYST:CDES? 1                    Return the description.
```

SYSTem:CPON

SYSTem:CPON *<number>* | ALL opens the selected module (card), or all modules in a switchbox to their power-on state.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<number>	numeric	1 through 99	N/A

Comments

Differences between *RST and CPON: SYSTem:CPON ALL and *RST opens all channels of all modules in a switchbox, while SYSTem:CPON *<number>* opens the channels in only the module (card) specified in the command.

Example Setting Card #1 Module to its Power-on State

```
SYST:CPON 1          Set module #1 channels to power-on state (open).
```

SYSTem:CTYPe?

SYSTem:CTYPe? ***<number>*** returns the module (card) type of a selected module in a switchbox.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Value
<number>	numeric	1 through 99	N/A

Comments

- **HP E1463A 64-Channel Relay Multiplexer Module Model Number:** The SYSTem:CTYPe? *<number>* command returns:

  ```
  HEWLETT-PACKARD,E1476A,0,A.08.00
  ```

  where the 0 after E1476A is the module serial number (always 0) and A.08.00 is an example of the module revision code number.

Example Reading the Model Number of a Card #1 Module

```
SYST:CTYP? 1         Return the model number.
```

SYSTem:ERRor?

SYSTem:ERRor? returns the error numbers and corresponding error messages in the error queue of a switchbox. See Appendix C for a listing of switchbox error numbers and messages.

Comments

- **Error Numbers/Messages in the Error Queue:** Each error generated by a switchbox stores an error number and corresponding error message in the error queue. The error message can be up to 255 characters long, but typically is much shorter.
- **Clearing the Error Queue:** An error number/message is removed from the queue each time the SYSTem:ERRor? command is sent. The errors are cleared first-in, first-out. When the queue is empty, each following SYSTem:ERRor? query returns +0, “No error”. To clear all error numbers/messages in the queue, execute the *CLS command.
- **Maximum Error Numbers/Messages in the Error Queue:** The queue holds a maximum of 30 error numbers/messages for each switchbox. If the queue overflows, the last error number/message in the queue is replaced by -350, “Too many errors”. The least recent error numbers/messages remain in the queue and the most recent are discarded.

Example Reading the Error Queue

```
SYST:ERR?                    Query the error queue.
```

The TRIGger command subsystem controls the triggering operation of the Multiplexer Modules in a switchbox.

Subsystem Syntax

```
TRIGger
    [:IMMediate]
    :SOURce  <source>
    :SOURce?
```

TRIGger[:IMMediate]

TRIGger[:IMMediate] causes a trigger to occur when the defined trigger source is TRIGger:SOURce BUS or TRIGger:SOURce HOLD. This can be used to trigger a suspended scan operation.

Comments

- **Executing the TRIGger[:IMMediate] Command:** A channel list must be defined with [ROUTe:]SCAN *<channel_list>* and an INITiate[:IMMediate] command must be executed before TRIGger[:IMMediate] will execute.
- **BUS or HOLD Source Remains:** If selected, the TRIGger:SOURce BUS or TRIGger:SOURce HOLD commands remain in effect after triggering a switchbox with the TRIGger[:IMMediate] command.
- **Related Commands:** INITiate, [ROUTe:]SCAN, TRIGger:SOURce

Example

Advancing Scan Using TRIGger Command

```
TRIG:SOUR  HOLD          Set trigger source to HOLD.
SCAN  (@100:163)         Define channel list.
INIT                     Start scanning cycle.
loop statement           Start count loop.
TRIG                     Advance scan to next channel.
increment loop           Increment loop count.
```

TRIGger:SOURce

TRIGger:SOURce *<source>* specifies the trigger source to advance the channel list during scanning.

Parameters

Parameter Name	Parameter Type	Parameter Description
BUS	discrete	*TRG or GET command
ECLTrg*n*	numeric	ECL Trigger bus line 0 or 1
EXTernal	discrete	"Trig In" port
HOLD	discrete	Hold Triggering
IMMediate	discrete	Immediate Triggering
TTLTrg*n*	numeric	TTL Trigger bus line 0 - 7

Comments

- **Enabling the Trigger Source:** The TRIGger:SOURce command only selects the trigger source. The INITiate[:IMMediate] command enables the trigger source. The trigger source must be selected using the TRIGger:SOURce command before executing the INIT command.

- **One Trigger Input Selected at a Time:** Only one input (ECLTrg0 or 1; TTLTrg0, 1, 2, 3, 4, 5, 6 or 7; or EXTernal) can be selected at one time. Enabling a different trigger source will automatically disable the active input. For example, if TTLTrg1 is the active input, and TTLTrg4 is enabled, TTLTrg1 will become disabled and TTLTrg4 will become the active input.

- U**sing the TRIGger Command:** You can use TRIGger[:IMMediate] to advance the scan when TRIGger:SOURce BUS or TRIGger:SOURce HOLD is selected.

- **Using External Trigger Inputs:** With TRIGger:SOURce EXTernal selected, only one switchbox at a time can use the external trigger input at the HP E1406A "Trig In" port.

- **Using TTL or ECL Trigger Bus Inputs:** These triggers are from the VXI backplane trigger lines ECL[0,1] and TTL[0-7]. These may be used to trigger the "SWITCH" driver from other VXI instruments.

- **Using EXTernal, TTLTrg*n*, and ECLTrg*n* Trigger Inputs:** After using TRIGger:SOURce EXT|TTLT*n*|ECLT*n*, the selected trigger source remains assigned to the "SWITCH" driver until it is relinquished through use of the TRIG:SOUR BUS|HOLD command. While the trigger is in use by the "SWITCH" driver, no other drivers operating on the E1405/E1406 command module will have access to that particular trigger source. Likewise, other drivers may consume trigger resources which may deny access to a particular trigger by the "SWITCH" driver. You should always release custody of trigger sources after completion of an activity by setting the trigger source to BUS or HOLD (i.e. TRIG:SOUR BUS|HOLD).

- **Using Bus Triggers:** To trigger the switchbox with TRIGger:SOURce BUS selected, use the IEEE 488.2 common command *TRG or the HP-IB Group Execute Trigger (GET) command.
- **"Trig Out" Port Shared by Switchboxes:** See the OUTPut command on page 71.
- **Related Commands:** ABORt, [ROUTe:]SCAN, OUTPut
- ***RST Condition:** TRIGger:SOURceIMMediate

Example Scanning Using External Triggers

In the following example, the trigger input is applied to the HP E1405/E1406 command module's "Trig In" port.

```
TRIG:SOUR  EXT          Set trigger source to external.
SCAN  (@100:163)        Set channel list.
INIT                    Start scanning cycle.
(trigger externally)    Advance channel list to next channel.
```

Example Scanning Using Bus Triggers

```
TRIG:SOUR  BUS          Set trigger source to bus.
SCAN  (@100:163)        Set channel list.
INIT                    Start scanning cycle.
*TRG                    Advance channel list to next channel.
```

TRIGger:SOURce?

TRIGger:SOURce? returns the current trigger source for the switchbox. Command returns BUS, EXT, HOLD, IMM, TTLT0-7, or ECLT0-1 for sources BUS, EXTernal, HOLD, IMMediate, TTLTrg*n*, or ECLTrg*n*, respectively.

Example Querying the Trigger Source

This example sets external triggering and queries the trigger source. Since external triggering is set, TRIG:SOUR? returns "EXT".

```
TRIG:SOUR  EXT          Set external trigger source.
TRIG:SOUR?              Query trigger source.
```

SCPI Command Quick Reference

The following table summarizes the SCPI commands for the HP E1476A 64-Channel Relay Multiplexer used in a switchbox.

Command		Description
ABORt	‘	Abort a scan in progress.
ARM	:COUNt *<number>* :COUNt? [MIN|MAX]	Multiple scans per INIT command. Query number of scans.
DISPlay	:MONitor:CARD *<number>* | AUTO :MONitor:CARD? :MONitor[:STATe] *<mode>* :MONitor[:STATe]?	Selects module to be monitored. Query the card number. Selects monitor mode. Query the monitor mode.
INITiate	:CONTinuous ON | OFF :CONTinuous? [:IMMediate]	Enables/disables continuous scanning. Query continuous scan state. Starts a scanning cycle.
OUTPut	:ECLTrgn[:STATe] ON | OFF | 1 | 0 :ECLTrgn[:STATe]? [:EXTernal][:STATe] ON | OFF | 1 | 0 [:EXTernal][:STATe]? :TTLTrgn[:STATe] ON |OFF | 1 | 0 :TTLTrgn[:STATe]?	Enables/disables the specified ECL trigger line. Query the specified ECL trigger line. Enables/disables the “Trig Out” port on the command module. Query the external state. Enables/disables the specified TTL trigger line. Query the specified TTL trigger line.
[ROUTe:]	CLOSe *<channel _list>* CLOSe? *<channel _list>* OPEN *<channel_list>* OPEN? *<channel _list>* SCAN *<channel_list>* SCAN:MODE *<mode>* SCAN:MODE? SCAN:PORT *<port>*	Close channel(s). Query channel(s) closed. Open channel(s). Query channel(s) opened. Define channels for scanning. Sets scan mode to NONE, VOLT, RES, or FRES. Query the scan mode. Enables channel connections to the analog bus (ABUS or NONE).
STATus	:OPERation:CONDition? :OPERation:ENABle *<unmask>* :OPERation:ENABle? :OPERation[:EVENt]? :PRESet	Returns contents of the Operation Condition Register. Enables events in the Operation Event Register to be reported. Returns the unmask value set by the :ENABle command. Returns the contents of the Operation Event RegisterSets Enable Register bits to 0.
SYSTem	:CDEScription? *<number>* :CPON *<number>* | ALL :CTYPe? *<number>* :ERRor?	Returns description of module in a switchbox. Opens all channels on specified module(s) .Returns the module type .Returns error number/message in a switchbox error queue.
TRIGger	[:IMMediate] :SOURce BUS :SOURce ECLTrg*n* :SOURce EXTernal :SOURce HOLD :SOURce IMMediate :SOURce TTLTrg*n* :SOURce?	Causes a trigger to occur. Trigger source is *TRG. Trigger is the VXIbus ECL trigger bus line n. Trigger source is “Trig In” (on the E1405 or E1406). Hold off triggering. Trigger source is the internal triggers. Trigger is the VXIbus TTL trigger bus line n. Query scan trigger source.

IEEE 488.2 Common Command Reference

The following table lists the IEEE 488.2 Common (*) Commands accepted by the HP E1476A Multiplexer Module. Examples using some of these commands are illustrated in Chapter 2 of this manual. For more information on Common Commands, refer to the HP 75000 Series C Mainframe (HP Model Number E1400/E1401) User's Manual or the ANSI/IEEE Standard 488.2-1987.

Command	Command Description
*CLS	Clears all status registers (see STATus:OPERation[:EVENt]?) and clears the error queue.
*ESE *<register value>*	Enable Standard Event.
*ESE?	Enable Standard Event Query.
*ESR?	Standard Event Register Query.
*IDN?	Instrument ID Query; returns identification string of the module.
*OPC	Operation Complete.
*OPC?	Operation Complete Query.
*RCL *<numeric state>*	Recalls the instrument state saved by *SAV. You must reconfigure the scan list.
*RST	Resets the module. Opens all channels and invalidates current channel list for scanning. Sets ARM:COUN 1, TRIG:SOUR IMM, and INIT:CONT OFF.
*SAV *<numeric state>*	Stores the instrument state but does not save the scan list.
*SRE *<register value>*	Service request enable, enables status register bits.
*SRE?	Service request enable query.
*STB?	Read status byte query.
*TRG	Triggers the module to advance the scan when scan is enabled and trigger source is TRIGger:SOURce BUS.
*TST?	Self-test. Executes an internal self-test and returns only the first error encountered. Does not return multiple errors. The following is a list of responses you can obtain where "cc" is the card number with the leading zero deleted. +0 if self test passes. +cc01 for firmware error. +cc02 for bus error (problem communicating with the module). +cc03 for incorrect ID information read back from the module's ID register. +cc05 for hardware and firmware have different values. Possibly a hardwarefault or an outside entity is register programming the E1476A. +cc10 if an interrupt was expected but not received. +cc11 if the busy bit was not held for a sufficient amount of time.
*WAI	Wait to Complete.

Note . . . These commands apply to many instruments. See the *HP 75000 Series C E1400/E1401 Mainframe User's Manual* or the ANSI/IEEE Standard 488.2-1987 for more information about these commands. The common commands *RCL, *SAV and *TST? do specific actions with the E1476A and are described in the above table.

Chapter 4
HP E1476A Scanning Voltmeter Application Examples

Using This Chapter

This chapter gives application information and examples for using the HP E1476A 64-Channel, 3-Wire Multiplexer to make measurements with the HP E1411 (or HP E1326 used with a C-size adapter installed in the C-size mainframe) 5½-Digit Multimeter in the scanning voltmeter configuration. The E1476A is capable of being used for measuring voltage, resistance or temperature.

This chapter contains the following sections:

Note The multimeter must be the HP E1411 (or the E1326 used with a C-size adapter installed in the C-size mainframe). The device driver for these two multimeters controls HP switches in the scan mode. The scanning voltmeter configuration does not use the "SWITCH" switchbox device driver and therefore, you do not use the switchbox command reference in Chapter 3. Instead you use the "VOLTMTR" device driver and the HP E1411B multimeter command reference. The "VOLTMTR" device driver was provided with the E1476A multiplexer. See "Initial Operation" on page 35 for more information on the "SWITCH" and "VOLTMTR" drivers. The multimeter's command quick reference from the *HP E1326/E1411 5½-Digit Multimeter User's Manual* is provided at the end of this chapter for your convenience. Refer to your multimeter manual for detailed descriptions of the commands.

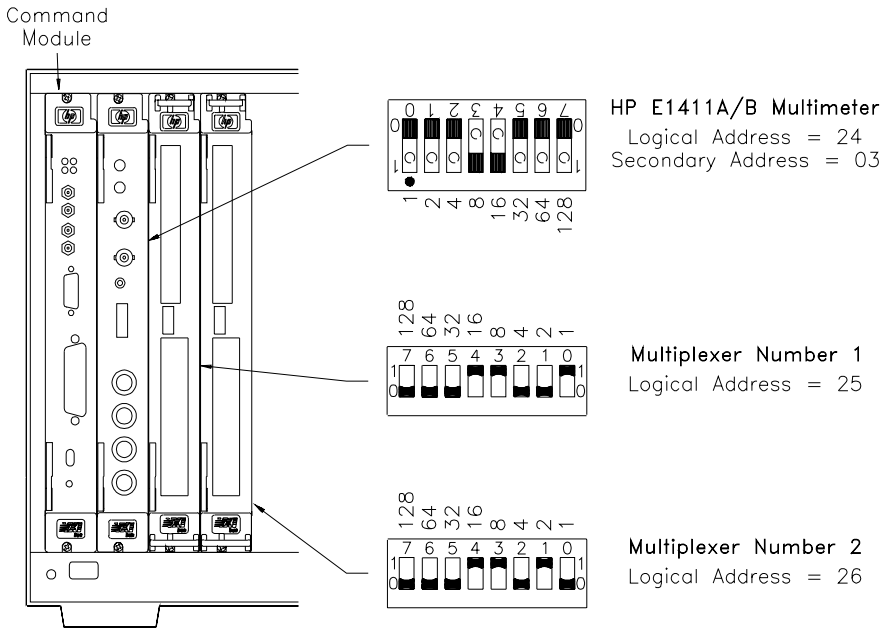


Figure 4-1. "Scanning Voltmeter" Configuration

Reset Conditions

This section describes the power-on and reset condition the E1476A switch module is in when a “scanning voltmeter” reset occurs. The “VOLTMTR” device driver controls both the voltmeter and any switch module configured with it in a scanning voltmeter configuration. At power-on or following the reset of a scanning voltmeter (*RST command sent to the voltmeter address), all 64 channels and the tree relays are open. In addition, after a *RST command, the current scan channel list is invalidated. See the *HP E1326/E1411B 5½-Digit Multimeter User's Manual* for the reset conditions of the multimeter.

Table 4-1 lists the parameters and default values for the switch module functions following power-on or reset. These are not accessible to you via the “VOLTMTR” driver but are provided so you know the switch module condition after power-on or following a reset

.

Table 4-1. HP E1476A Default Conditions for Power-on and Reset

Parameter	Default Value	Description
ARM:COUNt	1	Number of scanning cycles is one.
TRIGger:SOURce	IMM	Advances through a scanning list automatically.
INITiate:CONTinuous	OFF	Number of scanning cycles is set by ARM:COUNt.
OUTPut[:STATe]	OFF	Trigger output from EXT, TTL, or ECL sources is disabled.
[ROUTe:]SCAN:MODE	NONE	Channel list is set up for volts measurement (the default mode).
[ROUTe:]SCAN:PORT	NONE	Analog bus connections are disabled.
Channel state	All 64 channels are open (channels 00 - 63)	
Tree relay state	All tree relays are open (channels 90 - 94)	
Channel list from SCAN command (after *RST)	Current channel list is invalidated following a reset of the module with *RST command.	

The Scanning Voltmeter

The switchbox device driver discussed in Chapter 2 DOES NOT apply to the E1476A multiplexer when part of a scanning voltmeter. The note on Page 93 prescribes the use of the HP E1326/E1411 5½-Digit Multimeter device driver and command reference. The multimeter's Command Quick Reference is provided at the end of this chapter for your scanning voltmeter application reference. Use your HP E1326/E1411 5½-Digit Multimeter User's Manual for detailed information about multimeter commands used with the scanning voltmeter. The scanning voltmeter is easily configured to perform voltage, 2-wire ohms, 4-wire ohms or temperature measurements over the module's internal analog bus. The E1326/E1411 multimeter automatically controls the channels and tree relays when you use the MEASure or CONFigure commands. Tree relays are described in Table 4-2.

Table 4-2. Tree Relay Descriptions (controlled automatically by the "VOLTMTR" Scanning Voltmeter Driver)

Relay Function	Tree Relay Channel	Designation	Funfional Description
Analog Bus Relays	90	VSA	Connects the Voltage Sense H-L-G terminals of the Analog Bus to Bank A.
	91	VSB	Connects the Voltage Sense H-L-G terminals of the Analog Bus to Bank B.
	92	CS	Connects the Current Source H-L-G terminals of the Analog Bus to Bank B.
Reference Thermistor Relays	93	RTA	Connects the Reference Thermistor to Bank A for voltage sense.
	94	RTB	Connects the Reference Thermistor to Bank B for current source.

The analog bus provides access to all three wires of the channel (High, Low and Guard). Access is through the front panel analog bus connector which is used to connect to other multiplexers and to the E1411 (or E1326) multimeter. Figure 4-1 is a schematic representation of the scanning voltmeter using the E1411B multimeter with an E1476A multiplexer. The analog bus is connected from multiplexer to multiplexer in multiple switch module scanning voltmeter instruments to provide a continuous bus for the instrument.

Making Measurements

The following sections provide examples for making voltage, 2-wire ohms, 4-wire ohms and thermocouple or thermistor temperature measurements with the scanning voltmeter. The multimeter (E1326/E1411) MEASure command is used to both specify the channel list to scan and to make measurements.

Scanning Voltmeter Measurement Program

This example scans a list of multiplexer channels and makes a measurement on each channel (this example scans 32 channels of the multiplexer). The measured readings are entered into the computer and displayed after the

scan.

```
10   !Dimension a computer array to store readings.
20   DIM Rdgs(1:32)
30   !Clear and reset the scanning voltmeter (voltmeter & multiplexer).
40   !See Figure 4-1 for module addresses.
50   CLEAR 70903
60   OUTPUT 70903;"*RST"
70   !Configure the multimeter for DCV measurements and
80   !specify the channel list to scan (channels 00 through 31).
90   OUTPUT 70903;"MEAS:VOLT:DC?<~>(@100:131)"
100  !Enter and display measured readings. Note: The number of
110  !channels in the scan list must equal the number of elements in
120  !the array Rdgs to use Rdgs(*).
130  ENTER 70903;Rdgs(*)
140  PRINT Rdgs(*)
150  END
```

Note: When the multimeter buffer fills, measurements are suspended until readings are read from the buffer (by the computer) to make space available.

Voltage Measurements

Line 90 initiates a DC voltage measurement.

2-Wire Ohms Measurements

To make 2-wire measurements, change line 90 in the voltage measurement example to read:

```
90 OUTPUT 70903;"MEAS:RES?  (@100:131)"
```

4-Wire Ohms Measurements

To make 4-wire measurements, change line 90 in the voltage measurement example to read:

```
90 OUTPUT 70903;"MEAS:FRES?  (@100:131)"
```

(note: channels 32 - 63 will automatically be paired with 00 - 31 for 4-wire)

Thermocouple Temperature Measurements

To make type K thermocouple temperature measurements, change line 90 in the voltage measurement example to read:

```
90 OUTPUT 70903;"MEAS:TEMP?  TC,K,(@100:131)"
```

Thermistor Temperature Measurements

To make temperature measurements using a 4-wire, 5000Ω thermistor, change line 90 in the voltage measurement example to read:

```
90 OUTPUT 70903;"MEAS:TEMP? FTH,5000,(@100:131)"
```

Notes:

Scanning Voltmeter Command Quick Reference

The following tables summarize SCPI commands for the HP E1326 and HP E1411 5½-Digit Multimeters.

Command		Description
ABORt		Place multimeter in idle state.
CALibration	:LFRequency 50 | 60 | MIN | MAX :LFRequency? [MIN | MAX] :ZERO:AUTO OFF | 0 | ON | 1 :ZERO:AUTO?	Change line reference frequency .Query line reference frequency .Enable/disable autozero mode .Query autozero mode.
CONFigure	:FRESistance [<*range*>[,<*resolution*>]] [,<*channel_list*>] :RESistance [<*range*>[,<*resolution*>]] , <*channel_list*> :TEMPerature <*transducer*>,<*type*>,<*channel_list*> :VOLTage:AC [<*range*> [,<*resolution*>]] [,<*channel_list*>] :VOLTage[:DC] [<*range*> [,<*resolution*>]] [,<*channel_list*>]	Configure multimeter for 4-wire ohms. Configure multimeter for 2-wire ohms. Configure multimeter for temperature .Configure multimeter for AC voltage. Configure multimeter for DC voltage.
CONFigure?		Query multimeter configuration.
DIAGnostic	:FETS <*mode*> :FETS?	Selects control of FET multiplexers .Query mode of operation.
DISPlay	:MONitor:CHANnel <*channel*> | AUTO :MONitor:CHANnel? :MONitor[:STATe] OFF | 0 | ON | 1 :MONitor[:STATe]?	Monitor multiplexer channel. Query monitor channel .Enable/disable monitor mode. Query monitor mode.
FETCh?		Place stored readings in output buffer.
FORMat	[:DATA] <*type*>[,<*length*>]	Select output data format and length.
FORMat?		Query format.
INITiate	[:IMMediate]	Place multimeter in wait-for trigger state.
MEASure	:FRESistance? [<*range*>[,<*resolution*>]] [,<*channel_list*>] :RESistance? [<*range*>[,<*resolution*>]], <*channel_list*> :TEMPerature? <*transducer*>,<*type*> [,<*channel_list*>] :VOLTage:AC? [<*range*> [,<*resolution*>]] [,<*channel_list*>] :VOLTage[:DC]? [<*range*> [,<*resolution*>]] [,<*channel_list*>]	Make 4-wire ohms measurements. Make 2-wire ohms measurements .Make temperature measurements .Make AC voltage measurements .Make DC voltage measurements.
MEMory	:VME:ADDRess <*address*> :VME:ADDRess? [MIN | MAX] :VME:SIZE <*bytes*> :VME:SIZE? [MIN | MAX] :VME:STATe <*mode*> :VME:STATe?	Set address of memory on VME card. Query VME memory location (address) .Amount of memory used on VME card. Query amount of VME memory used. Direct readings to VME memory card. Query VME memory mode.
OUTPut	TTLTrg0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 [:STATe] OFF | 0 | ON | 1 :TTLTrg0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 [:STATe]?	Send voltmeter complete to VXIbus trigger lines. Query voltmeter complete destination.
READ?		Place multimeter in wait-for trigger state;place readings in output buffer.
SAMPle	:COUNt 1-16777215 | MIN | MAX :COUNt? [MIN | MAX] :SOURce IMM | TIM :SOURce? :TIMer 76 ms-65.534 ms | MIN | MAX :TIMer? [MIN | MAX]	Set number of readings per trigger. Query number of readings per trigger. Set pacing source. Query pacing source. Define period between readings. Query period between readings.

Command		Description
[SENSe:]	FUNCtion[:<*function*>] FUNCtion? RESistance:APERture <*time*> | MIN | MAX RESistance:APERture? [MIN | MAX] RESistance:NPLC <*number*> | MIN | MAX RESistance:NPLC? [MIN | MAX]RESistance:OCOMpensated OFF | 0 | ON | 1 RESistance:OCOMpensated? RESistance:RANGe <*range*> | MIN | MAX RESistance:RANGe? [MIN | MAX] RESistance:RANGe:AUTO OFF | 0 | ON | 1 RESistance:RANGe:AUTO? RESistance:RESolution <*resolution*> | MIN | MAX RESistance:RESolution? [MIN | MAX]VOLTage:AC:RANGe <range> | MIN | MAX VOLTage:AC:RANGe? [MIN | MAX] VOLTage:APERture <*time*> | MIN | MAX VOLTage:APERture? [MIN | MAX] VOLTage[:DC]:RANGe <*range*> | MIN | MAX VOLTage[:DC]:RANGe? [MIN | MAX] VOLTage:NPLC <*number*> | MIN | MAX VOLTage:NPLC? [MIN | MAX] VOLTage:RANGe:AUTO OFF | 0 | ON | 1VOLTage:RANGe:AUTO? VOLTage:RESolution <*resolution*> VOLTage:RESolution? [MIN | MAX]	Select measurement function. Query measurement function. Set aperture (integration) time in seconds. Query aperture (integration) time. Set integration time in PLCs. Query integration time. Enable/disable offset compensation. Query offset compensation mode. Select range. Query range. Enable/disable autorange function. Query autorange mode. Specify resolution. Query resolution. Select measurement range. Query range. Set aperture (integration) time in seconds. Query aperture (integration) time. Select range. Query range. Set integration time in PLCs. Query integration time. Enable/disable autoranging. Query autorange mode. Specify resolution .Query resolution.
SYSTem	:CDEScription? <*card_number*> :CTYPe? <*card_number*> :ERRor?	Return description of multiplexer in scanning multimeter. Return card type of multiplexer in scanning multimeter. Return error number/message from error queue.
TRIGger	:COUNt 1-16777215 | MIN | MAX :COUNt? [MIN | MAX] :DELay 0-16.777215 | MIN | MAX :DELay? [MIN | MAX] :DELay:AUTO OFF | 0 | ON | 1 :DELay:AUTO? [:IMMediate] :SOURce BUS | EXT | HOLD | IMM | TTLTrg0-TTLTrg7 :SOURce?	Set number of triggers or scans. Query trigger count. Set delay between trigger and start of measurement. Query trigger delay. Enable/disable automatic trigger delay. Query automatic trigger delay mode. Trigger immediately. Specify trigger source. Query trigger source.

Command	Title	Description
*RST	Reset	Sets the multimeter and associated multiplexers. Sets FUNC:VOLT:DC, VOLT:RANG 8V, RES:RANG 16384Ω, RANGE:AUTO ON, VOLT:RES 7.629mV, RES:RES 15.6mΩ, APER 16.7ms|20ms, NPLC 1, RES:COMP OFF, CAL:ZERO:AUTO ON, TRIG:COUN 1, TRIG:DELAY:AUTO ON, TRIG:SOUR IMM, SAMP:COUN 1, SAMP:SOURIMM, SAMP:TIM 200µs
*TRG	Bus Trigger	When the multimeter is in the wait-for-trigger state and the trigger source is TRIGger:SOURce BUS, use the *TRG command to trigger the multimeter.
TST	Self-Test	Should return 0. If code 1, 2, 3, or 4 occurs, return the multimeter to Hewlett-Packard for repair.

Appendix A
HP E1476A Specifications

General

Module Size/Device Type:
C-Size VXIbus, Register based, A16/D16

Interrupt Level:
1-7, selectable

Connectors Used:
P1 and P2

Relay Life (typical):

Condition	Number of Operations
Single Levels Load	500×10^7
Full Load	$> 5 \times 10^7$

NOTE: Relays are subject to normal wear out based on the number of operations.

Power-up and Power-down States:
all relays open

Reference Junction Measurement Accuracy:
(18° to 28°C operating): 0.38°C

Terminal Wire Size:
22-26AWG

Power Requirements:

	+5	+12
Voltage:		
Peak Module Current (A):	0.80*	0.01
*1.0A with all relays energized		
Dynamic Module Current (A):	0.40	0.00

Watts/slot:
4

Cooling/slot:
.10 mm H_2O @ 0.30 Liter/sec for 10°C rise

Operating Temperature:
0 - 55°C

Operating Humidity:
65% RH, 0 - 40°C

Input Characteristics

Maximum Input Voltage:
120 Vdc or acrms Terminal to Terminal
120 Vdc or acrms Terminal to Chassis

Maximum Current per Channel (non-inductive):
35 mA

Maximum Switchable Power per Channel:
4VA

DC Performance

Thermal Offset per Channel:
<4µV
<2µV (10 samples averaged)

Closed Channel Resistance:
100Ω , ±5Ω

Insulation Resistance (between any two points):
>109 W (at ≤40°C, 95% RH)

AC Performance

Closed Channel Capacitance:
< 175 pF (H-L)
<300 pF (L-G)
<1500 pF (G-C)

Minimum Bandwidth (-3dB, 50Ω source/load):
100 kHz

C**rosstalk(db) (Channel-to-Channel):**
-70 (100kHz)
-45 (10 MHz)

Relay life

Relay Life

Electromechanical relays are subject to normal wear-out. Relay life depends on several factors. The effects of loading and switching frequency are briefly discussed below:

Relay Load. In general, higher power switching reduces relay life. In addition, capacitive/inductive loads and high inrush currents (for example, turning on a lamp or starting a motor) reduces relay life.Exceeding specified maximum inputs can cause catastrophic failure.

Switching Frequency. Relay contacts heat up when switched. As the switching frequency increases, the contacts have less time to dissipate heat. The resulting increase in contact temperature also reduces relay life.

End-of-Life Detection

A preventive maintenance routine can prevent problems caused by unexpected relay failure. The end of the life of the relay can be determined by using one or more of the three methods described below. The best method (or combination of methods), as well as the failure criteria, depends on the application in which the relay is used.

Contact Resistance. As the relay begins to wear out, its contact resistance increases. When the resistance exceeds a predetermined value, the relay should be replaced.

Stability of Contact Resistance. The stability of the contact resistance decreases with age. Using this method, the contact resistance is measured several (5-10) times, and the variance of the measurements is determined. An increase in the variance indicates deteriorating performance.

Number of Operations. Relays can be replaced after a predetermined number of contact closures. However, this method requires knowledge of the applied load and life specifications for the applied load.

Replacement Strategy

The replacement strategy depends on the application. If some relays are used more often, or at a higher load, than the others, the relays can be individually replaced as needed. If all the relays see similar loads and switching frequencies, the entire circuit board can be replaced when the end of relay life approaches. The sensitivity of the application should be weighed against the cost of replacing relays with some useful life remaining.

Note

Relays that wear out normally or fail due to misuse should not be considered defective and are not covered by the product's warranty.

Appendix B
HP E1476A Register-Based Programming

About This Appendix

The HP E1476A 64-Channel, 3-Wire Multiplexer is a register-based module which does not support the VXIbus word serial protocol. When a SCPI command is sent to the multiplexer, the instrument driver resident in the HP E1406A Command Module parses the command and programs the multiplexer at the register level.

Register-based programming is a series of reads and writes directly to the multiplexer registers. This increases throughput speed since it eliminates command parsing and allows the use of an embedded controller. Also, register programming provides an avenue for users to control a VXI module with an alternate VXI controller device and eliminate the need for using an HP E1405/E1406 Command Module.

This appendix contains the information you need for register-based programming. The contents include:

Register Addressing

Register addresses for register-based devices are located in the upper 25% of VXI A16 address space. Every VXI device (up to 256 devices) is allocated a 32 word (64 byte) block of addresses. With eight registers, the HP E1476A Multiplexer uses eight of the 64 addresses allocated. Figure B-1 shows the register address location within A16 as it might be mapped by an embedded controller. Figure B-2 shows the location of A16 address space in the HP E1405A/B and E1406A Command Modules.

The Base Address

When you are reading or writing to a multiplexer register, a hexadecimal or decimal register address is specified. This address consists of a base address plus a register offset.

The base address used in register-based programming depends on whether the A16 address space is outside or inside the HP E1406A Command Module.

A16 Address Space Outside the Command Module

When the HP E1406A Command Module is not part of your VXIbus system (Figure B-1), the multiplexer's base address is computed as:[1]

$$C000_{16} + (LADDR * 64)_{16}$$

or

$$49{,}152 + (LADDR * 64)$$

where $C000_{16}$ (49,152) is the starting location of the register addresses, LADDR is the multiplexer's logical address, and 64_{10} is the number of address bytes per VXI device. For example, the multiplexer's factory set logical address is 112 (7016). If this address is not changed, the multiplexer will have a base address of:

$$C000_{16} + (112 * 64)_{16} = C000_{16} + 1C00_{16} = DC00_{16}$$

or (decimal)

$$49{,}152 + (112 * 64) = 49{,}152 + 7168 = 56{,}320$$

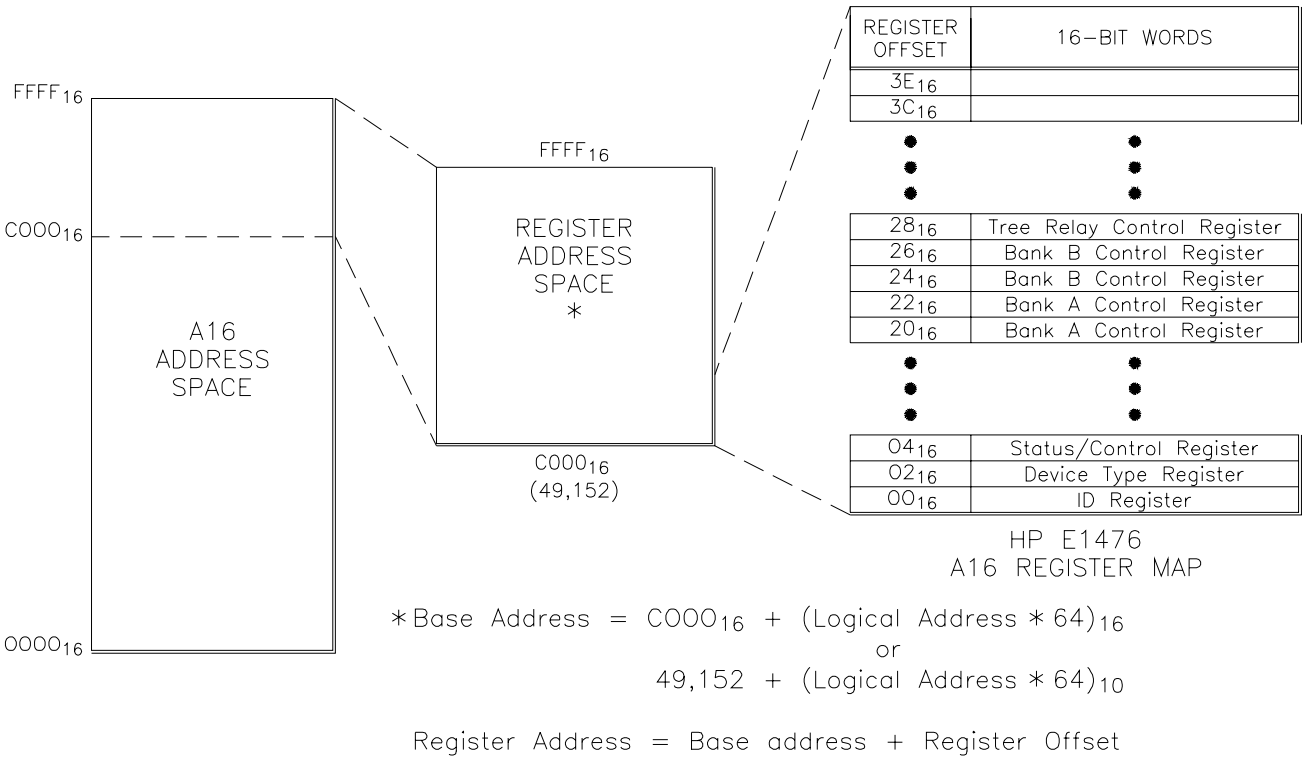


Figure B-1. Registers within A16 Address Space

1. The "16" at the end of the address indicates a hexadecimal number.

A16 Address Space Inside the Command Module or Mainframe

When the A16 address space is inside the HP E1406A Command Module (Figure B-2), the multiplexer's base address is computed as:

$$1FC000_{16} + (LADDR * 64)_{16}$$

or

$$2{,}080{,}768 + (LADDR * 64)$$

where $1FC000_{16}$ (2,080,768) is the starting location of the VXI A16 addresses, LADDR is the multiplexer's logical address, and 64 is the number of address bytes per register-based device. Again, the multiplexer's factory set logical address is 112. If this address is not changed, the multiplexer will have a base address of:

$$1FC000_{16} + (112 * 64)_{16} = 1FC000_{16} + 1C00_{16} = 1FDC00_{16}$$

or

$$2{,}080{,}768 + (112 * 64) = 2{,}080{,}768 + 1536 = 2{,}087{,}936$$

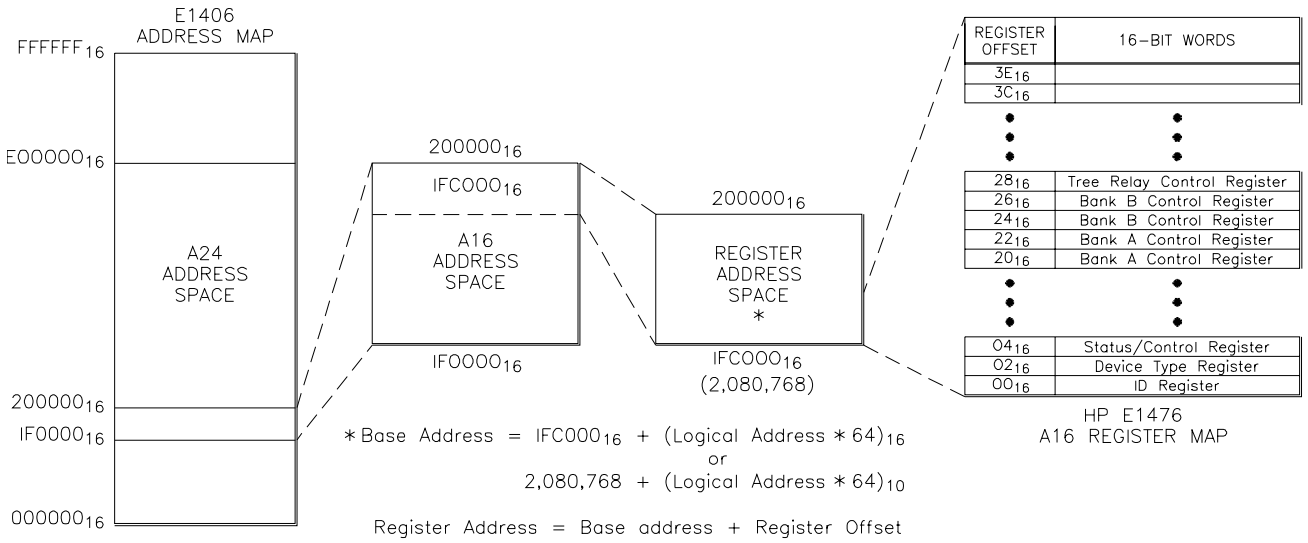


Figure B-2. Registers within Command Module's A16 Address Space

Register Offset

The register offset is the register's location in the block of 64 address bytes. For example, the multiplexer's Status/Control Register has an offset of 04_{16}. When you write a command to this register, the offset is added to the base address to form the register address:

$$DC00_{16} + 04_{16} = DC04_{16}$$

$$1FDC00_{16} + 04_{16} = 1FDC04_{16}$$

or

$$56{,}320 + 4 = 56{,}324$$

$$2{,}087{,}936 + 4 = 2{,}087{,}940$$

Register Descriptions

There are six WRITE and eight READ registers on the multiplexer. This section contains a description of the registers followed by a bit map of the registers in sequential address order. Undefined register bits appear as "1" when the register is read, and have no effect when written to.

The WRITE Registers

You can write to the following multiplexer registers:

-- Status/Control register (base + 04_{16})
-- Channels 0 through 15 Relay Control Register (base + 20_{16})
-- Channels 16 through 31 Relay Control Register (base + 22_{16})
-- Channels 32 through 47 Relay Control Register (base + 24_{16})
-- Channels 48 through 63 Relay Control Register (base + 26_{16})
-- Tree Relays 90 through 94 Control Register (base + 28_{16})

The READ Registers

You can read the following multiplexer registers:

-- Manufacturer ID Register (base + 00_{16})
-- Device Type Register (base + 02_{16})
-- Status/Control Register (base + 04_{16})
-- Channels 0 through 15 Relay Control Register (base + 20_{16})
-- Channels 16 through 31 Relay Control Register (base + 22_{16})
-- Channels 32 through 47 Relay Control Register (base + 24_{16})
-- Channels 48 through 63 Relay Control Register (base + 26_{16})
-- Tree Relays 90 through 94 Control Register (base + 28_{16})

The ID Register

Reading the ID register returns $FFFF_{16}$ indicating the manufacturer is Hewlett-Packard and the module is an A16 register based device.

base + 00_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read	Manufacturer ID - returns $FFFF_{16}$ in Hewlett-Packard A16 only register based card															

The “Programming Examples” on page 112 shows how to read the ID Register.

The Device Type Register

Reading the Device Type Register returns 0218_{16} which identifies the device as the HP E1476A 64-Channel Multiplexer.

base + 02_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read	0218_{16}															

The “Programming Examples” on page 112 shows how to read the Device Type Register.

The Status/Control Register

Writes to the Status/Control Register (base + 04_{16}) which enables you to disable/enable the interrupt generated when channels are closed.

base + 04_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined									D	Undefined					R
Read	Unde-fined	M	Undefined						B	D	Undefined					

Status/Control register bits defined:

*WRITE BITS (Status/Control Register)		
bit 0	R	Writing a "1" to this bit resets the switch to the power-on state (all channels open). You must set bit 0 back to a logical "0" before resuming normal operations of the module such as closing and opening switches.
bit 6	D	Disable interrupt by writing a "1" to this bit (this is set back to "0" with a reset).

**READ BITS (Status/Control Register)		
bit 6	D	Interrupt Status; "1" = disabled, "0" = enabled.
bit 7	B	Busy Status; "1" = not busy, "0" = busy..
bit 14	M	MODID bit; if the bit is "0", module has been selected.

Disable/Enable Interrupts

To disable the interrupt generated when channels are opened or closed, write a “1” to bit 6 of the Status/Control Register (base + 04_{16}). Note: typically, interrupts are only disabled to “peek-poke” a module. Refer to your command module's operating manual before disabling the interrupt. Interrupts must be enabled in order to operate the “SWITCH” and “VOLTMTR” instrument drivers.

Reading the Status/Control Register Module Status

Each relay requires about 1msec execution time during which time the multiplexers are “busy”. Bit 7 of this register is used to inform the user of a busy condition. The interrupt generated after a channel has been closed can be disabled. Bit 6 of this register is used to inform the user of the interrupt status.

As an example, if the Status Register (base + 04_{16}) returns "BDFF (1011110111111111)" the multiplexer module is not busy (bit 7 set), and the module interrupts are disabled (bit 6 set).

Relay Control Registers

Writes to the Relay Control Registers (base + 20_{16} to 28_{16}) allows you to open or close any of the 64-channel relays or the five tree relays. Any number of relays per bank can be closed at a time.

For example, to connect both bank A and bank B to the analog bus, write a “1” to bits 0 and 1 of the Tree Relay Control Register (base + 28_{16}) to close

channel 90 (VSA) and channel 91 (VSB). All other bits must be set to “0”.

Bank A Channels 0 - 15 Relay Control Register (base + 20_{16})

base + 20_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	ch15	ch14	ch13	ch12	ch11	ch10	ch9	ch8	ch7	ch6	ch5	ch4	ch3	ch2	ch1	ch0
Read																

Bank A Channels 13 - 31 Relay Control Register (base + 22_{16})

base + 22_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	ch31	ch30	ch29	ch28	ch27	ch26	ch25	ch24	ch23	ch22	ch21	ch20	ch19	ch18	ch17	ch16
Read																

Bank B Channels 32 - 47 Relay Control Register (base + 24_{16})

base + 24_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	ch47	ch46	ch45	ch44	ch43	ch42	ch41	ch40	ch39	ch38	ch37	ch36	ch35	ch34	ch33	ch32
Read																

Bank B Channels 48 - 63 Relay Control Register (base + 26_{16})

base + 26_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	ch63	ch62	ch61	ch60	ch59	ch58	ch57	ch56	ch55	ch54	ch53	ch52	ch51	ch50	ch49	ch48
Read																

Tree Relay Control Register (relays 90 - 94) (base + 28_{16})

base + 28_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	undefined											RTB ch94	RTA ch93	CS ch92	VSB ch91	VSA ch90
Read	undefined															

*Write a “1” to close a channel; write a “0” to open a channel.
**Reading the channel bit indicates the state of the relay driver circuit only. It cannot detect a defective relay.

Tree relay control bits are defined:

bit 0	VSA (ch90)	Connects the Voltage Sense H-L-G terminals of the Analog Bus to Bank A.
bit 1	VSB (ch91)	Connects the Voltage Sense H-L-G terminals of the Analog Bus to Bank B.
bit 2	CS (ch92)	Connects the Current Source H-L-G terminals of the Analog Bus to Bank B.
bit 3	RTA (ch93)	Connects the Reference Thermistor to Bank A for voltage sense.
bit 4	RTB (ch94)	Connects the Reference Thermistor to Bank B for current source.

Resetting the Multiplexer

There are two ways to reset the multiplexer:

1. You can simply write a “0” to all bits in the Relay Control Registers.
2. You can use bit 0 (R) in the Status/Control Register. The R bit in the Status/Control Register must be set to “1” to reset the E1476A module and subsequently set to "0" to restore normal operation.

Note

You must wait at least 100msec after writing a “1” to the R bit of the Status/Control Register before you write a “0” to that bit to restore normal operation.

Reading the Relay Control Registers

Reading the Relay Control Registers returns a hexadecimal number which indicates a “1” for each bit representing a channel that is closed. A bit that is “0” indicates the channel is open.

Program Timing and Execution

This section contains generalized flowcharts and comments for performing these and other procedures. The flowcharts identify the registers used and the status bits monitored to ensure execution of the program.

Closing Channels

The following flowchart shows how to close (or open) a multiplexer channel and determine when it has finished closing (or opening).

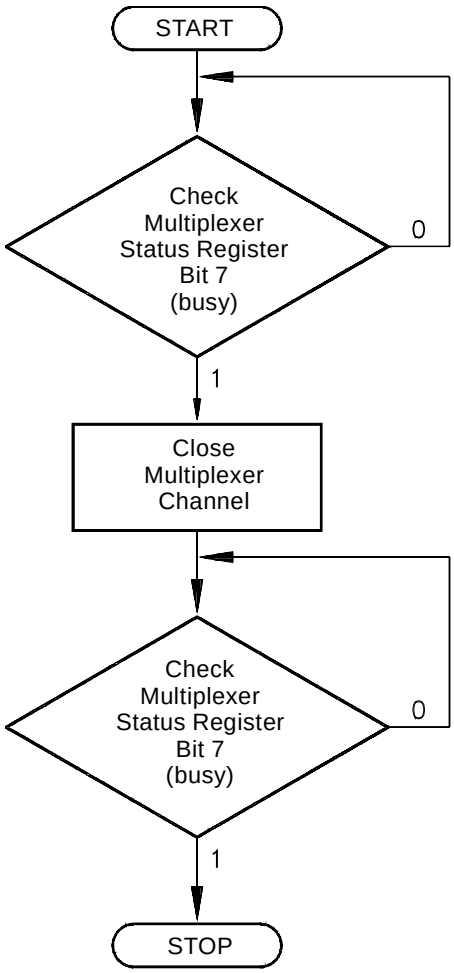


Figure B-3. Closing/Opening a Multiplexer Channel

Comments

- The address of the multiplexer Status Register is base + 04_{16}. The address of the channel is the base address plus the channel offset.
- Multiplexer Status Register bit 7 (the BUSY bit) is monitored to determine when a multiplexer channel can be closed (or opened), and when a channel has finished closing (or opening).

Using a Multimeter with the Multiplexer

This flowchart shows the timing sequence between closing an E1476A multiplexer channel and triggering an E1326/E1411 multimeter

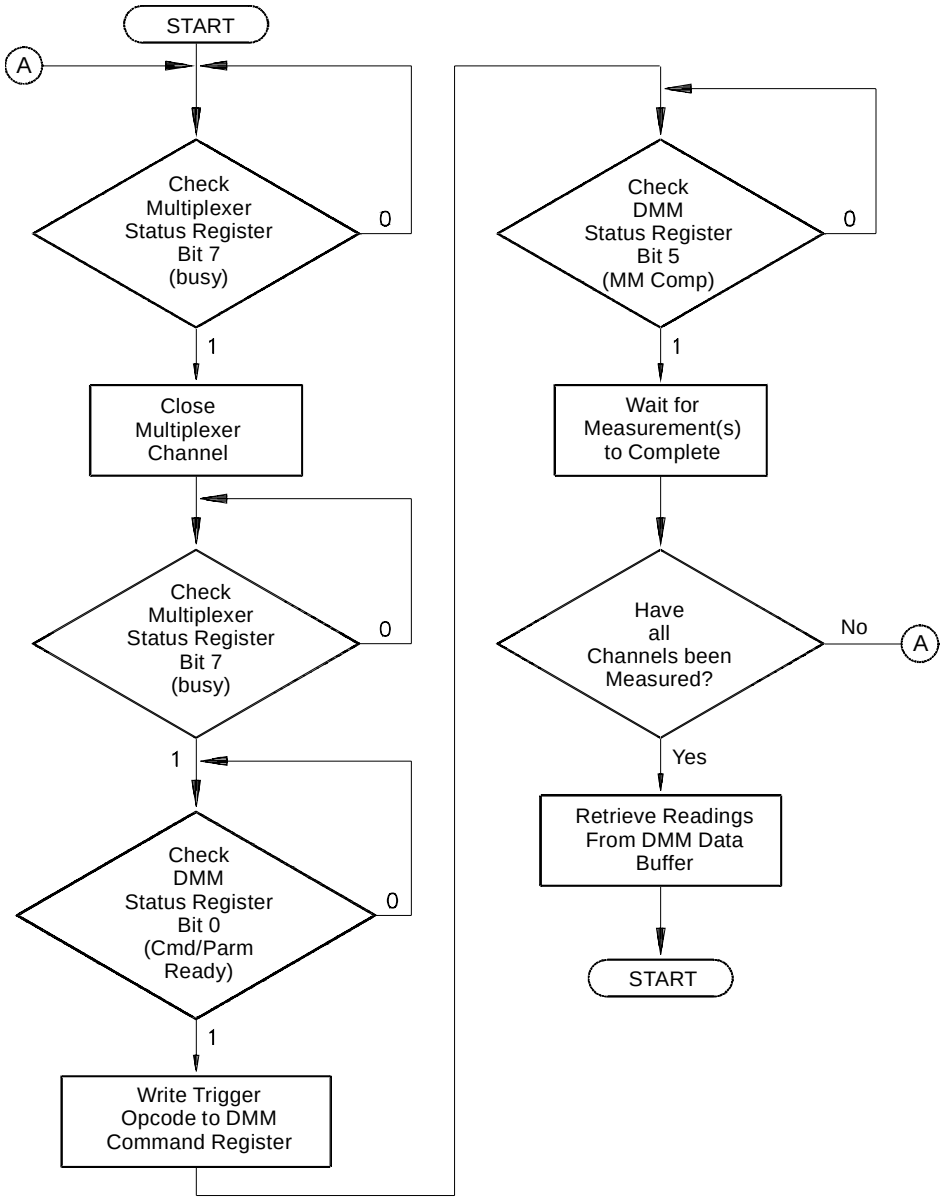


Figure B-4. Program Timing Between Multiplexer and Mutimeter

Comments

- The registers used are:
  - -- Multiplexer; Multiplexer Status Register (base + 04_{16})
  - -- Multimeter; Multimeter Status Register (base + 04_{16})
  - -- Multimeter; Multimeter Command Register (base + 08_{16})

- Multiplexer Status Register bit 7 (BUSY bit) is monitored to determine when a channel can be closed (or opened), and when a channel has finished closing (or opening).

- Multimeter status bit 0 (ready for command) is monitored to determine when a trigger opcode can be written to the Command Register (flowchart assumes the multimeter is already configured).

- Multimeter status bit 5 (multimeter complete) is monitored to determine when the analog-to-digital (A/D) conversion is in progress, and thus, when to advance the channel. This enables each channel to be measured before the readings are read from the buffer.

  The channel can also be advanced by monitoring bit 4 (Data Ready). However, before measuring the next channel, readings from the previous channel must be read from the buffer in order to clear the bit.

- Multimeter Autozero is often turned on in order to detect when bit 5 is active.

Programming Examples

The examples in this section demonstrate how to direct register program the multiplexer. The examples in this section include:

- Reading the ID, Device Type, and Status Registers
- Closing/Opening a channel, Stand-Alone Multiplexer Measurements
- Scanning through channels

System Configuration

The following C language example programs were developed on an HP RADI-EPC7 VXI embedded computer using Borland's Turbo C++® programming language[1] and using the SICL interface library. You can also use an HP Vectra (IBM PC compatible) computer connected via HP-IB to the HP E1406A slot 0 Command Module. The command module simply provides direct access to the VXI backplane.

If you use the HP E1406A with SCPI commands, you would use the HPE1476A SCPI driver which you installed in the HPE1406A firmware and register programming would not be necessary. Chapter 3 describes the SCPI commands for the switchbox driver.

Example Program

The following example program contains segments that:

1. Read the ID and Device Type Registers.
2. Read the Status Register.
3. Close a group of channels and the associated tree relay.
4. Resets the module to open all channels.
5. Scans through all the channels on the module.

1. Borland Intl., Inc.

Beginning of Program

```
/* This program resets the E1476A, reads the ID Register, reads the Device */
/* Type Register, closes tree relays and channels and reads the multiplexer's */
/* Relay Control Registers, opens channels and scans all 64 channels on the */
/* module.*/
/* (Borland Turbo C++ program using HP SICL I/O calls.) */
#include <sicl.h>
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include <dos.h>

/* function prototypes */
void reset_mux(char *base_addr);
void delay (unsigned milliseconds);
```

Program Main

```
void main(void)
{  double ldexp(double i, int exp);
   char *base_addr;
   int j, k;
   unsigned short chan_0_15_reg, chan_16_31_reg;/* Bank A channels */
   unsigned short chan_32_47_reg, chan_48_63_reg;/* Bank B channels */
   unsigned short chan_tree_reg;/* Tree relays */
   unsigned short id_reg, dt_reg;/* ID and Device Type */
   unsigned short stat_reg; /* Status Register */

   /* create and open a device session */
    INST e1476a; e1476a = iopen("vxi,112");

   /* map the E1476A registers into user memory space */
    base_addr = imap(e1476a, I_MAP_VXIDEV, 0, 1, NULL);

   /* clear the user screen */
    clrscr();

   /* reset the E1476A */
    reset_mux(base_addr);
```

Read ID and Device Type Registers

```
/********* read the multiplexer's ID and Device Type registers *********/

    id_reg = iwpeek((unsigned short *)(base_addr + 0x00));
    dt_reg = iwpeek((unsigned short *)(base_addr + 0x02));
    printf("ID register = 0x%4X\nDevice Type register = 0x%4X\n",
    id_reg, dt_reg);
```

Read Status Register

```
/**************** read the multiplexer's status register *************/

    stat_reg = iwpeek((unsigned short *)(base_addr + 0x04));
    printf("Status register = 0x%4X\n", stat_reg);
```

Close and Open Channels

```
/******************** close and open channels ******************/

 /* close channels 0-15 by setting all bits in register (base + 0x20) to 1 */
   iwpoke((unsigned short *)(base_addr + 0x20), 0xffff);

   /* write a 1 to the register for tree relay 90 (base + 0x28) */
   /* so channels 0-15 can be connected to the analog bus */
    iwpoke((unsigned short *)(base_addr + 0x28), 1);

   /* read the E1476A relay control registers and print their value */

    chan_0_15_reg = iwpeek((unsigned short *)(base_addr + 0x20));
    chan_16_31_reg = iwpeek((unsigned short *)(base_addr + 0x22));
    chan_32_47_reg = iwpeek((unsigned short *)(base_addr + 0x24));
    chan_48_63_reg = iwpeek((unsigned short *)(base_addr + 0x26));
    chan_tree_reg = iwpeek((unsigned short *)(base_addr + 0x28));

    printf("Channels 00-15 register = 0x%4X\n", chan_0_15_reg);
    printf("Channels 16-31 register = 0x%4X\n", chan_16_31_reg);
    printf("Channels 32-47 register = 0x%4X\n", chan_32_47_reg);
    printf("Channels 48-63 register = 0x%4X\n", chan_48_63_reg);
    printf("Channels 90-94 (tree) register = 0x%4X\n", chan_tree_reg);

    delay (2000); /* waits 2 seconds before resetting mux */

    /* reset the E1476A to open all closed channels */
    /* writing a 0 to the channels registers will also open channels */
    reset_mux(base_addr);
```

Scan Channels

```
/********************** scanning channels **********************/

   /* connect Bank A and Bank B to the analog bus by */
   /* closing the VSA and VSB tree relays (bits 0 and 1) */
    iwpoke ((unsigned short *)(base_addr + 0x28), 3);

   /* scan channels 0-15 in bank A (register offset 0x20) */
    for (k=0; k<=15; k++)
    {
    iwpoke ((unsigned short *)(base_addr + 0x20), ldexp(1,k));
    /* take measurement here after each iteration of the loop */
    }
    /* set all bits to 0 to open last closed channel */
    iwpoke ((unsigned short *)(base_addr + 0x20), 0);

   /* scan channels 16-31 in bank A (register offset 0x22) */
    for (k=0; k<=15; k++)
    {
    iwpoke ((unsigned short *)(base_addr + 0x22), ldexp(1,k));
    /* take measurement here after each iteration of the loop */
    }
    /* set all bits to 0 to open last closed channel */
    iwpoke ((unsigned short *)(base_addr + 0x22), 0);

   /* scan channels 32-47 in bank A (register offset 0x24) */
```

```
    for (k=0; k<=15; k++)
    {
    iwpoke ((unsigned short *)(base_addr + 0x24), ldexp(1,k));
    /* take measurement here after each iteration of the loop */
    }
    /* set all bits to 0 to open last closed channel */
    iwpoke ((unsigned short *)(base_addr + 0x24), 0);

   /* scan channels 48-63 in bank A (register offset 0x26) */
    for (k=0; k<=15; k++)
    {
    iwpoke ((unsigned short *)(base_addr + 0x26), ldexp(1,k));
    /* take measurement here after each iteration of the loop */
    }
    /* set all bits to 0 to open last closed channel */
    iwpoke ((unsigned short *)(base_addr + 0x26), 0);

   /* close HP SICL session */
    iclose(e1476a);
} /* end of main */
```

Reset Function

```
/*********************************************************/
void reset_mux(char *base_addr)
   /* reset the mux to open all relays (write a 1 to status bit 0)*/
   /* delay 100 ms for reset then set bit to 0 to allow closing*/
   /* switches        */
{
    /* this function resets the multiplexer */
    iwpoke((unsigned short *)(base_addr + 0x04), 1);
    delay (100);  /* must wait at least 100 usec before writing a "0" */
    iwpoke((unsigned short *)(base_addr + 0x04), 0); }}
```

Program Output

Printout from example program:

```
ID register = 0xFFFF
Device Type register = 0x 218
Status register = 0xFFBE
Channels 00-15 register = 0xFFFF
Channels 16-31 register = 0x 0
Channels 32-47 register = 0x 0
Channels 48-63 register = 0x 0
Channels 90-94 (tree) register = 0xFF01
```

Notes:

Appendix C
HP E1476A Multiplexer Error Messages

Error Types

Table C-2 lists the error messages generated by the E1476A Multiplexer module firmware when programmed by SCPI. Errors with negative values are governed by the SCPI standard and are categorized in Table C-1. Error numbers with positive values are not governed by the SCPI standard.

Table C-1. Error Types Described

Number Range	Error Types Description
-199 to -100	Command Errors (syntax and parameter errors). See the *HP E1405/E1406 Command Module User's Manual* for a description of these errors.
-299 to -200	Execution Errors (instrument driver detected errors). See the *HP E1405/E1406 Command Module User's Manual* for further details.
-399 to -300	Device Specific Errors (instrument driver errors that are not command nor execution errors). See the *HPE1405/E1406 Command Module User's Manual* for further details.
-499 to -400	Query Errors (problem in querying an instrument). See the *HP E1405/E1406 Command Module User's Manual* for description of these errors.

"Table C-2. Multiplexer Error Messages", appears in its entirety on the following page.

Table C-2. Multiplexer Error Messages

Code	Error Message	Potential Cause(s)
-211	Trigger ignored	Trigger received when scan not enabled. Trigger received after scan complete. Trigger too fast.
-213	Init Ignored	Attempting to execute an INIT command when a scan is already in progress.
-222	Data out of range	Parameter value is outside valid range.
-224	Illegal parameter value	Attempting to execute a command with a parameter not applicable to the command.
-240	Hardware error	Command failed due to a hardware problem.
-310	System error	Internal driver error. This error can result if an excessively long parameter list is entered.
1500	External trigger source already allocated	Assigning an external trigger source to a switchbox when the trigger source has already been assigned to another switchbox.
1510	Trigger source non-existent	Selected trigger source is not available on this platform (e.g. some triggers are not available on the E1300/E1301 VXI B-size mainframes).
2000	Invalid card number	Addressing a module (card) in a switchbox that is not part of the switchbox.
2001	Invalid channel number	Attempting to address a channel of a module in a switchbox that is not supported by the module (e.g., channel 99 of a multiplexer module).
2006	Command not supported on this card	Sending a command to a module (card) in a switchbox that is unsupported by the module.
2008	Scan list not initialized	Executing a scan without the INIT command.
2009	Too many channels in channel list	Attempting to address more channels than available in the switchbox.
2010	Scan mode not allowed on this card	The selected scanning mode is not allowed with this module or you have misspelled the mode parameter (see SCAN:MODE command).
2011	Empty channel list	No valid channels are specified in the channel_list.
2012	Invalid Channel Range	Invalid channel(s) specified in SCAN <*channel_list*> command. Attempting to begin scanning when no valid channel list is defined.
2017	Config error 17, Slot 0 functions disabled	Attempt to run a downloaded scan list with ARM:COUNt set to a value other than 1. Applies to HP FET switches only.
2600	Function not supported on this card	Sending a command to a module (card) in a switchbox that is not supported by the module or switchbox.
2601	Channel list required	Sending a command requiring a *channel_list* without the *channel_list*.

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